4.2.2 Surface Water Monitoring

The second type of monitoring is surface water flow measurements at all existing sites where flow can be measured. **Table 5** lists existing flow measurement sites, and locations are shown on **Figure 4**.

Table 5: Existing Flow Measuring Flumes to Continue Monitoring

Number	Location
1	Lizard Tail Seep
2	Dead Hawk
3	Black Sand
4	Horse Pasture 3" Flume
5	Horse Pasture 2" Flume
6	Keeler Flowing Well
7	Bonsai Mound
8	Sulfate Flowing Well
9	Carbide Dump
10	Mill Site Flowing Well
11	Swedes Pasture
12	Mambo
13	Indian Creek
14	L9 Ditch
15	Truck Sticker
16	Tubman Channel
17	Cement Pond
18	Whiskey Springs
19	Wahoo
20	Georgia O'Keefe
21	Kaiser Permanente
22	Cottonwood Spring (W3)
23	PPG Flowing well (W4)
24	Bartlett Flowing well (W5)
25	Northwest Spring
26	Rio Tinto

Flow measurements will continue throughout the operational test. Current flow measurement frequency is on an hourly basis, which is recorded using data loggers. LADWP will download flow measurement data from these sites approximately 10 days prior to the start of the operational test to ensure monitoring is continuing. Data downloaded from the flumes during the operational test will be according to the schedule shown in **Table 2**.

All other existing surface water flow measuring flumes throughout the Owens Lake area will continue to be monitored during the operational test of TW-E.

4.2.3 Meteorological Monitoring

Meteorological parameters will be monitored at seven (7) existing LADWP and GBUAPCD weather sites during the operational test as shown on **Figure 4**. The meteorological parameters to be recorded at the stations are listed in **Table 6**.

Table 6: Parameters to be Monitored at Meteorological Sites at Owens Lakes

Station Name	Relative Humidity	Barometric Pressure	Temperature	Precipitation	Evaporation
A-Tower	**Yes**	No	**Yes**	**Yes**	No
1552	No	No	No	**Yes**	No
OL North	**Yes**	No	**Yes**	**Yes**	**Yes**
Cottonwood	No	No	**Yes**	**Yes**	No
Mill	**Yes**	No	**Yes**	**Yes**	No
Olancha	**Yes**	**Yes**	**Yes**	No	No
T7	**Yes**	**Yes**	**Yes**	No	No

4.2.4 Ground Elevation Monitoring

Land subsidence occurs when a large volume of groundwater is pumped for a long period of time from a groundwater aquifer. As observed earlier in testing of the Mill and River sites, the proposed 6-month operational test is not expected to be long enough or pumping at a high enough rate to cause subsidence. In addition, the recovery cycle after the 6-month test allows for recovery of groundwater levels. However, ground surface elevation will be monitored as part of the monitoring program before, during, and after the operational test of TW-E.

Table 7 lists existing LADWP ground surface monitoring locations on Owens Lake; locations are shown on **Figure 7.** Five (5) sites are selected to be the ground elevation monitoring locations owing to their close proximity to TW-E (i.e., 7012) and to assess potential subsidence impacts on the east side of the Owens River Fault (i.e., 6527 and 6532) and the west side of the Owens Valley Fault Zone (OVFZ - i.e., 6371 and 6372).

Ground elevation will be monitored:

- one (1) time within one (1) month prior to commencement of the 6-month operational test,
- three (3) months after commencement of the operational test, and
- at the end of the operational test (6 months).

Ground elevation surveys will be completed using a Trimble RTK system consisting of a Trimble R8 global positioning system (GPS) receiver for a base unit, and a Trimble R10 GPS receiver for the rover unit. The base unit sets on a control point and broadcasts the correction to the receiver using an ultra-high frequency radio transmitter which is received by the R10 rover unit. The data is processed and gathered using a Trimble TSC3 control unit.

Real-time kinematic positioning (RTK) is a satellite navigation technique used to enhance the precision of the position data from the satellite-based positioning system. It uses measurements of the phase of the signal's carrier wave in addition to the information content of the signal and relies on a single reference station to provide real-time corrections, providing up to centimeter-level accuracy.

As previously noted, no change in ground elevation is expected; however, if it does occur, it will provide valuable knowledge of the relationship between pumping deeper aquifers and effects at the surface and the potential for elastic rebound of the aquifers. This knowledge will greatly enhance development of future pumping plans and the adaptive management process.

Table 7: Existing LADWP Ground Elevation Monitoring Locations, Method, and Frequency

Subsidence Monitoring Location ID*	General Location	Measurement Method	Frequency (prior to, during and after long-term operational test)
6371	Within the OVFZ	Survey	Within 1 month prior, at 3 and 6 months during, and at 3 and 6 months after, the latter, if warranted
6372	Within the OVFZ	Survey	
6527	East of Owens River Fault	Survey	
6532	East of Owens River Fault	Survey	
7012	Southwest of TW-E	Survey	

Note: * Locations shown on **Figure 7**.



Figure 7: Locations of Ground Elevation Monitoring Sites during Operational Test of TW-E

4.2.5 Vegetation Monitoring

Vegetation monitoring will be conducted during the operational test to 1) document any potential changes in vegetation activity as a result of the operational test and 2) inform future development of monitoring protocols. Vegetation monitoring will occur before and after the operational test because the operational test is anticipated to occur during the winter months when vegetation is dormant. Vegetation monitoring is focused on two specific resource areas: springs and associated alkali meadow and VDAs. Each is described below.

- **Springs and Associated Alkali Meadows.** From 2014 through 2018, LADWP worked with the Habitat Work Group (HWG) and the Groundwater Work Group (GWG) to develop the "*Resource Protection Protocol for Springs and Associated Alkali Meadows at and around Owens Lake (RPP)*" (Owens Lake Habitat Work Group, 2018). The RPP identifies criteria, protocols, and management actions to prevent significant impacts to springs and associated alkali meadow resources due to groundwater pumping. Appendix A of the RPP (Technical Approach) details the rational, methods, and data analysis techniques used to monitor and identify changes in vegetation productivity (i.e., Leaf Area Index or LAI) and acreage. Identified changes are then statistically compared to the historical range of variability (HRV) and used to trigger tiered management actions. Vegetation monitoring during the operational test will be consistent with the methods outlined in Appendix A of the RPP.
- **Vegetated Dune Areas.** LADWP, in collaboration with the HWG and the GWG, is currently developing an RPP to protect VDAs from potential impacts due to groundwater pumping. In February 2020, a Workplan was developed for VDA RPP that describes data collection and analysis methods to 1) quantify baseline conditions to inform development of Resource Protection Criteria (RPC), 2) identify monitoring protocols to achieve the RPC, and 3) develop triggers for further resource evaluation or management actions. Given the complex nature of the vegetated dune system around the playa, the VDA RPP Workplan is being implemented in a phased approach.
    - Phase 1 includes historical baseline data analysis of vegetative cover, evapotranspiration (ETa), and LAI on all VDAs, as well as detailed data collection, characterization, and monitoring on four VDAs. Additional characterization will be conducted on three VDAs on the southeast shore of Owens Lake playa. These datasets will be used to develop a generalized conceptual model, identifying (to the extent possible) the major drivers influencing changes in vegetative cover within the VDAs. This includes vulnerability to changes in groundwater levels that could occur as a result of groundwater pumping.
    - Phase 2 will use the information from Phase 1 to develop appropriate RPCs and monitoring protocols, which will then be scaled to all VDAs.

Implementation of the VDA RPP Workplan is anticipated to be complete prior to the operational test. Vegetation monitoring is anticipated to include remote sensing-based methods for estimating leaf area index (LAI) and actual evapotranspiration (ETa). Monitoring methods may be further refined based on results of workplan implementation.

4.3 Reporting Interval

All of the data collected during the proposed operational test of TW-E will be made available to any interested stakeholder in a timely manner. Measurement data may be revised after quality assurance/quality control (QA/QC) of collected data. The following a description of data reporting for different types of data collected.

Groundwater level data collected from monitoring locations list in **Table 3B**, surface water data listed in Table 5 and meteorological data listed in **Table 7** are generally downloaded once every two months and after QA/QC will be available to stakeholders.

Data collected from monitoring wells list in **Table 3A** will be downloaded at 1, 3, 5, 8, 11, 14, 17, 20, 23, and 26 weeks after start of the pumping phase of the test. All data will undergo a QA/QC process.

Once the operational test is started, measurements collected from data loggers at trigger wells will be downloaded, and data from manual measurements will be compiled 24 hours, 72 hours, and then weekly thereafter during the pumping phase. After completion of the QA/QC process, data will be made available to any interested stakeholder. Trigger locations are discussed in more detail in Section 6. Within 10 business days of data downloading, data will be made available to interested parties by either email or the OLGDP web page (www.ladwp.com/olg). Measurement data may be revised after further QA/QC of collected data. Adverse trends which appear to be leading toward a trigger value within the 6-month period will be reported when they are observed. If these adverse trends are noted in any trigger well, groundwater levels for that well will be downloaded every weekday and made available to any interested stakeholder. Management actions based on adverse trends will include increasing the monitoring frequency, and/or decreasing the pumping rate at TW-E.

4.4 Groundwater Quality Sampling and Monitoring

The purpose of the planned groundwater quality sampling and analysis is to document any potential change in groundwater quality as a result of the operational test. The groundwater quality testing is focused on LADWP monitoring wells located near non-LADWP wells, spring and seep locations, and VDA locations. Groundwater quality samples from select monitoring wells will be collected once just prior to the start of the operational test and once prior to the conclusion of the test. In addition to field parameters (temperature, pH, dissolved oxygen, and specific conductance), samples will be collected for laboratory analysis of major ions, indicator constituents, stable

isotopes, and nutrients (for VDA samples) as listed in **Table 8**. Indicator constituents are those constituents that have been shown in previous sampling to be close to, or above the Maximum Contaminant Level (MCL) as noted during baseline sampling (LADWP, 2020). Water quality samples will be collected:

- one week prior to start of pumping, and
- one week prior to the end of pumping (or when pumping stops, if test is stopped before 6 months of pumping).

4.4.1 Groundwater Quality Sampling Constituents

As part of water quality monitoring, groundwater quality will be sampled and analyzed for the constituents noted in **Table 8**.

Table 8: Groundwater Quality Sampling Constituents

Category		Constituent
Field		Temperature (T)
		pH
		Specific Conductance (SC)
		Dissolved Oxygen (DO)
Laboratory	Major Cations	Calcium (Ca)
		Magnesium (Mg)
		Sodium (Na)
		Potassium (K)
	Major Anions	Bicarbonate (HCO_3)
		Chloride (Cl)
		Sulfate (SO_4)
		Nitrate (NO_3)
		Carbonate (CO_3)
	Indicator Constituents	Arsenic (As)
		Boron (B)
		Fluoride (F)
		Total Uranium (U)
		Total Dissolved Solids (TDS)
	Stable Isotopes	Deuterium (^2H)
		Oxygen 18 (^{18}O)
	Nutrients*	Nitrate Nitrogen (NO_3-N)
		Phosphate-P (PO_4-P)

Note: *VDA locations only

4.4.2 Groundwater Sampling Locations

Groundwater sampling will be performed at specific resource areas using monitoring wells as shown in **Table 9**.

Table 9: Groundwater Quality Sampling Locations

Type of Resource	Resource	Location of Resource	Monitoring Well to Be Sampled
Non-LADWP Well	Boulder Creek RV Park, O'Dell Well, and Nearby Domestic Supply Wells	west of Owens River Fault and 4.5 miles NE of TW-E	T931
	FW Aggregates Supply Well	east of the Owens River Fault and 4.5 miles E-NE of TW-E	T929
	Mortensen Domestic Well	west of Owens Valley Fault, 3 miles west of TW-E	T920
	Mt. View Trailer Park	4 miles NW of TW-E	T858
	Fault Test Well (FTW)	2.7 miles east of TW-E	FTW
	Keeler CSD	northeast of Keeler across Hwy 136	P8 (30)
Vegetated Dune Areas	VDA-1	3 miles NW of TW-E	VDA-1
	VDA-2	3 miles NE of TW-E	VDA-2-1
	VDA-3	3 miles NE of TW-E	VDA-3b
	VDA-5	3 miles NE of TW-E	VDA-5
	VDA-6	3 miles E of TW-E	Staging Area Monitoring Well
	VDA-7	3 miles E of TW-E	P8 (30)
	VDA-8	3 miles E of TW-E	VDA-8-2
Spring	Northwest Spring	2.9 miles NW of TW-E	P1(5)
	Horse Pasture	4.7 miles E-SE of TW-E	P8(5)

5.0 ASSOCIATED FIELD ACTIVITIES

This section describes planned downhole flow measurements during pumping of TW-E called "spinner logging". Spinner logging consists of lowering a device for measuring the in-situ velocity of fluid flow in a production well based on the speed of rotation of an impeller, or "spinner". A spinner log allows for measurement of flow from the aquifers to various sections of the well screen and provides valuable information about the relative permeability of various aquifers outside the screened portion of the well.

This section also describes the disposal of the water produced during testing of TW-E.

5.1 Spinner Logging

Spinner logging will be performed, if possible, depending on the available annular space around the pump column. The goal of spinner logging is to calculate the percentage of the pumped water that is extracted from each of the aquifers that contribute to pumping in TW-E. Spinner logging involves lowering a tool consisting of a small impeller at the end of a rod into the well, moving vertically at a constant rate. The impeller rotation measures fluid velocity from which aquifer properties (hydraulic conductivity), interflow between different aquifers, and contribution of each aquifer to the total well production can be calculated.

The continuous TW-E screen is 870 feet long, penetrating a generally silty sand formation with varying silt proportion and occasional thin clay/clayey intervals. Therefore, it cannot be determined with certainty whether the aquifer TW-E is extracting from is a continuous confined aquifer or multiple confined aquifers contributing in varying proportions to the total well production.

A spinner log was performed on TW-E after well construction under non-pumping conditions. Results from the initial log showed over 50% of the artesian flow is from the upper portion of the screen (around 700 feet bgs). Depths beyond 900 feet bgs provided negligible flow.

A spinner log will be performed (if possible, based on pump design) during the proposed operational test via a 2-inch polyvinyl chloride (PVC) pipe extending below the pump intake (but above the well screen) to determine the source of groundwater during testing and further characterize the pumped aquifer(s). The measurements from the spinner log will determine the percentage of the pumped water that is extracted each of the aquifers. The rate of extracted water from the individual aquifers will be utilized when aquifer parameters are being estimated using the specialized aquifer test solver (AQTESOLV) software. This approach should significantly improve the estimate of hydrologic parameters for each of the aquifers in the vicinity of TW-E, and it will also provide important information to improve the OLGM.

5.2 Discharge of Pumped Water

TW-E is located in the center of the dust control area T-36. **Figure 8** shows a map of the area in the vicinity of TW-E. The ponds around TW-E are interconnected and the slope of the area is generally from north to south toward the Brine Pool. Water will be discharged to T36-1W and/or T36-1E and then can flow to other adjacent ponds. The current water supply to the ponds is primarily water diverted from the LAA or the Lower Owens River Project (LORP) Pump Back Station at the southern end of LORP. Pumped water from TW-E during the operational test will be discharged into the dust mitigation ponds surrounding the well and will supplement the flow from the LAA.

While the water diverted from the LAA to Owens Lake for dust mitigation is of high quality, the quality degrades considerably once discharged into the ponds due to evaporation and the high concentration of undesirable constituents in the soil floor of the ponds. To evaluate compatibility of the pumped water from TW-E with water in these ponds, LADWP collected and analyzed water quality samples from TW-E and surrounding ponds in March 2020, then compared the results with samples taken between 2010 and 2019. **Table 10** shows the results of sampling collected in March 2020 from all seven (7) points.

The purpose of this sampling is to demonstrate that disposal of pumped groundwater from TW-E will not degrade surface waters in the ponds. This data indicates there will be no adverse effects of disposal of groundwater from TW-E on water quality of the designated ponds.

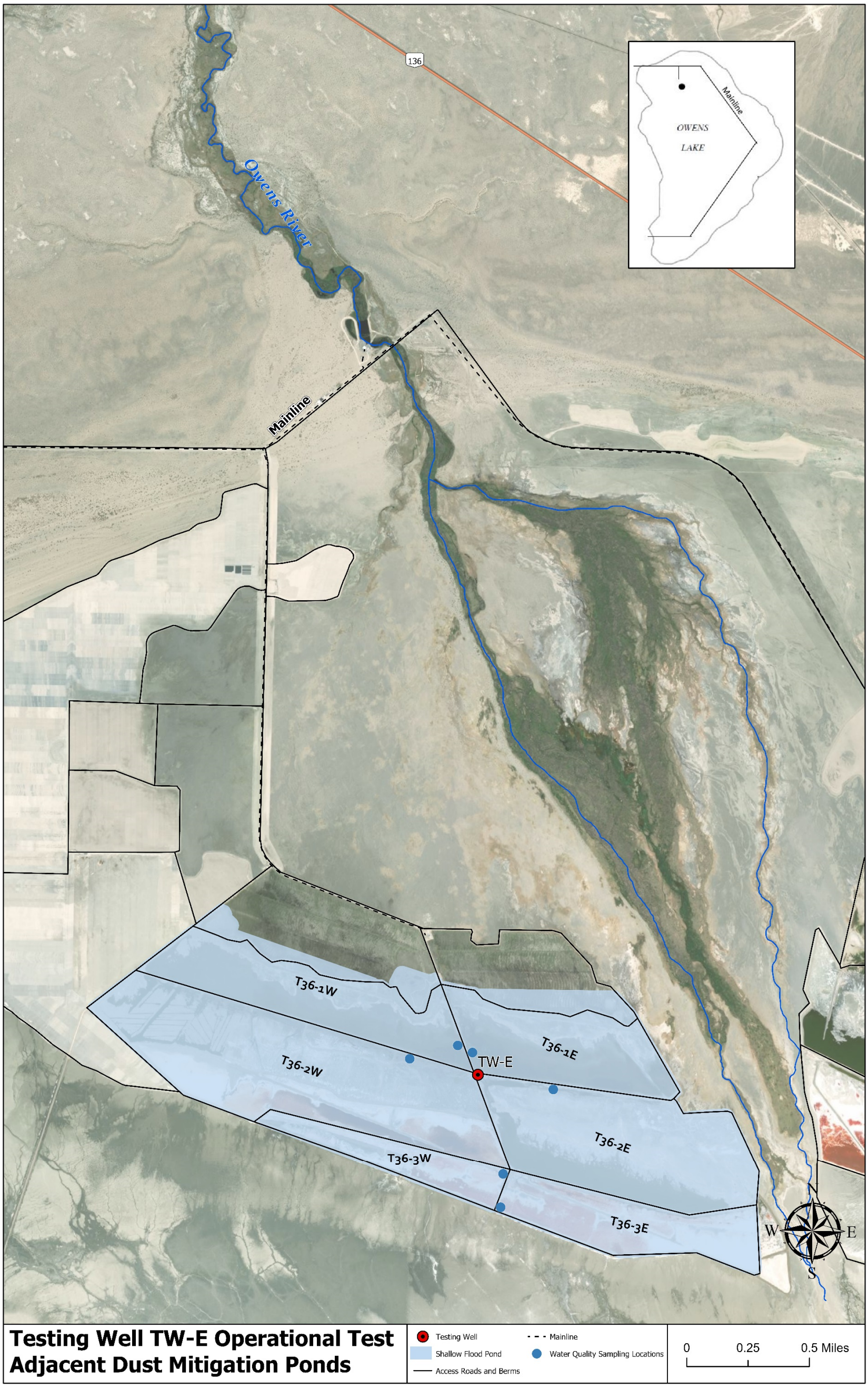


Figure 8: Location of Discharge Ponds Adjacent to TW-E

Table 10: Water Quality Testing Results (March 2020)

Constituent	T36-3W	T36-1W	T36-2W	TW-E	T36-2E	T36-1E	T36-3E
Temperature (°C)	17.4	38.1	26.7	21.3	34.4	36.5	25.4
Specific Conductivity (µs/cm)	164,100	18,11	14,930	2.7	15,020	1,770	166,700
pH	9.6	8.8	10	7.9	10	8.9	9.8
Turbidity	78	66	43	6.6	60	70	80
Dissolved Oxygen[1] (mg/L)	1.77	13.87	16.2	5.6	25.52	17.7	5.37
Total Dissolved Solids (mg/L)	346,400	2,200	9,600	1,920	11,200	2,100	338,700
Aluminum[1] (mg/L)	N/A	ND	1.54	0.57	1.54	ND	N/A
Arsenic (mg/L)	74.3	0.16	1.78	0.0516	1.73	0.16	75
Barium (mg/L)	0.23	0.027	0.056	0.475	0.051	0.026	0.228
Boron (mg/L)	N/A	11.3	1.1	8.19	1.1	11.3	N/A
Lead (mg/L)	0.042	0.0059	0.014	0.013	0.014	0.0073	0.033

Notes: ND – Non-detect; N/A – Not tested; mg/L – milligrams per liter

[1] Values reported for Dissolved Oxygen and Aluminum are from 2018 sampling.

6.0 PROTECTION OF GROUNDWATER-DEPENDENT RESOURCES

As used in this document, the term "groundwater-dependent resources" has a relatively broad meaning to describe things that depend on, or are influenced by groundwater, including the land surface (which depends in part on groundwater pore pressure), non-LADWP wells (which depend on the groundwater level), springs (which depend on upwelling groundwater to the surface), and vegetated dune areas (which may depend to some degree on the depth to groundwater). The term "groundwater-dependent ecosystems" refers to a subset of groundwater-dependent resources that includes ecosystems at springs that depend on groundwater. Although the vegetation on dunes could be considered a groundwater-dependent ecosystem, the protection mechanism is slightly different because the vegetation on the dunes is dependent to some degree on the depth to groundwater, as opposed to the springs in which groundwater is essentially at the surface, and it is the upwelling groundwater which supports the ecosystem.

The only mechanism by which the pumping of TW-E can potentially affect nearby groundwater-dependent resources is if the pumping lowers the groundwater level directly beneath the resource or reduces overland flow to the resource. This in turn could potentially change the water quality in the shallow aquifer near the resources. Because of a relatively thick clay layer between the surficial aquifer and the aquifer where TW-E is screened, no significant impact is expected from the 6-month operational test of TW-E. This has been further confirmed by groundwater modeling.

An easily measurable method to protect groundwater-dependent resources is to set limits ("triggers") on groundwater level beneath the resources and/or the gradient toward the resources. At the suggestion of reviewers on the initial version of the testing plan for the 6-month operational test of TW-E, a specific trigger mechanism will be utilized to manage the pumping phase of the proposed 6-month operational test of TW-E. Setting triggers will be out of an abundance of caution to provide an additional layer of protection from potential impacts of pumping on nearby groundwater-dependent resources, including groundwater-dependent ecosystems and/or nearby non-LADWP wells.

Triggers (such as the depth to water under VDAs) utilized in this operational test are anticipated to be much more conservative than those ultimately utilized during operational pumping and may not be realistic for long-term operation. This test is expected to provide valuable information regarding how conservative the trigger levels identified in this document are, and based on that, more realistic triggers for the long-term operation can be developed.

If a trigger level in any monitoring well is reached anytime and for any reason during the test, then LADWP will cease the pumping of TW-E for the test, start recovery data collection, and report to parties within 24 hours of such determination and action. The same is true of the trigger gradients toward springs.

6.1 Hydrogeologic Setting

Conducting a 6-month operational test of TW-E is important to collect necessary data to further understand the hydrogeology of Owens Lake. The test is designed to collect the necessary data but ensuring that groundwater-dependent resources will not be impacted.

Generally, groundwater-dependent resources of concern at Owens Lake utilize water from the shallow surficial aquifer. The surficial aquifer is separated from the confined aquifers underneath by a thick layer of clay (aquitard) varying from approximately 100 feet to 200 feet as shown in schematically on **Figure 9**. Multiple aquitards underlie TW-E. Aquitards have very low hydraulic conductivity and act as a relatively low-permeability barrier between aquifers. Therefore, there is minimal to no direct connection of the near surface resources to the deeper aquifers proposed to be pumped. Additionally, most of the groundwater-dependent resources are located to the east of Owens River Fault or to the west of Owens Valley Fault. Previous studies have shown these faults most probably act as lateral groundwater barriers; therefore, the resources are protected to some degree by the faults from the effect of pumping in-between these faults (MWH, 2012, 2016). More recent groundwater level and water quality data from wells located across faults confirm this finding.

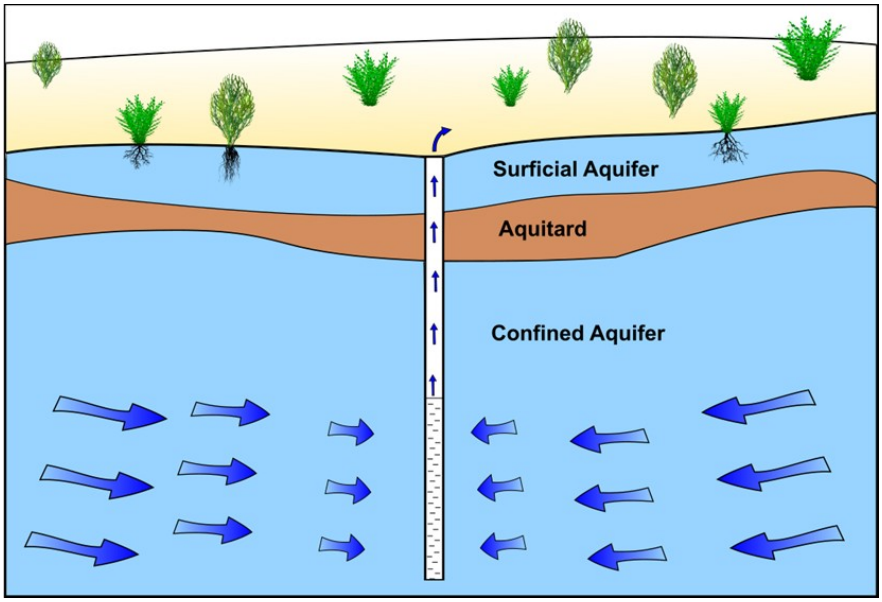


Figure 9: Schematic Showing General Cross Section Near Owens Lake Surface

The construction of TW-E consists of solid casing from ground surface to 620 feet depth and screen from 620 feet to 1,490 feet bgs (**Figure 2**). Due to the depth interval of the screen, TW-E extracts water from the deeper confined aquifers and not from the shallow surficial aquifer.

The groundwater gradient, also referred to as hydraulic gradient, is the slope of the water table or potentiometric surface, that is, the change in water level per unit of distance along the direction of groundwater flow. It is determined by measuring the water level in two or more wells. The water level in a well is usually expressed as feet above sea level. The groundwater (or hydraulic) gradient is the driving force that causes groundwater to move in the direction from high elevation to low elevation, much like surface water. Gradient is generally expressed in consistent units, such as feet per foot. For example, if the difference in water level in two wells 1,000 feet apart is 2 feet, then the gradient is 2/1,000 or 0.002.

In the unique case of routine or periodic monitoring of the gradient using the exact same two monitoring locations over time, the change in gradient can be simplified. This is because the distance between the two wells does not change; only the groundwater elevation in one or both of the wells may change. In these cases, the relative gradient can be expressed as a length, that is, the elevation difference between the two wells.

In the example above, the relative change in gradient could be expressed as the change in the 2 feet difference. If the difference at a later date is 1 foot, the gradient has been reduced by 50 percent. At Owens Lake, the pre-pumping gradient (expressed as a length) can be compared to concurrent pumping or post-pumping gradient and is expressed as a change in either feet or percent, as in the example above.

This testing plan calls for two types of gradient monitoring using well pairs: horizontal gradients and vertical gradients.

- **Horizontal gradients** refer to monitoring of the gradient between a monitoring well located upgradient of Owens Lake (generally on the adjacent alluvial fans) and a paired shallow piezometer or monitoring well near the margins of the lakebed. This is an indirect measurement of groundwater flow toward the springs at the margin of the lake. This groundwater flow supports habitat surrounding the lake.
- **Vertical gradients** are measured between two piezometers (which are essentially shallow monitoring wells with short screens) located in the same borehole or next to each other but screened at different depths. The LADWP has installed several monitoring sites surrounding Owens Lake in which there is a deeper piezometer (generally 30 feet deep), and a co-located shallow piezometer (generally 5 feet deep), termed a piezometer cluster. These are designated as "P" sites (as listed on **Table 4** and shown on **Figure 6**). There is also typically a 10-foot piezometer at the same location (which is not used in the gradient calculation). Groundwater level measurements at these piezometers at different depths are used to

calculate the vertical gradient (upward or downward). Similar to the horizontal gradients described above, monitoring change in vertical gradients can be simplified by monitoring the change in the difference between the groundwater levels in a deep and shallow piezometer at the same location. The shallow piezometers and alluvial monitoring wells are illustrated schematically in **Figure 10**. Both the vertical and horizontal gradients have remained relatively constant since monitoring has begun, so a single "pre-pumping" gradient can be expressed in units of feet as listed on the hydrographs in **Appendix A**.

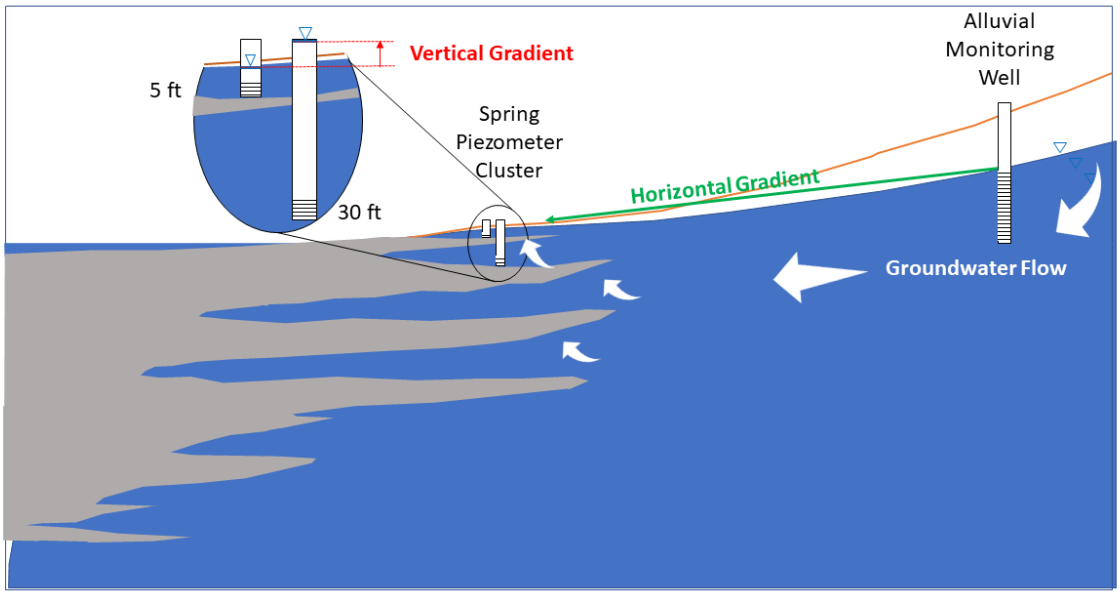


Figure 10: Illustration of Vertical and Horizontal Groundwater Gradients

6.2 Resources to be Protected, Methods, and Rationale for Triggers

As shown on **Figure 11**, key resources to be protected during the proposed operational test utilizing conservative triggers include:

- Groundwater-dependent ecosystems (GDEs), including:
  - Habitat at springs around Owens Lake
  - Vegetated dune areas (VDAs)
- Production capability of non-LADWP wells (generally private wells)

Along with identification of these resources to be protected, methods to monitor each of these resources have been developed, as described below.



Figure 11: Location of Resources and Associated Trigger Wells for the 6-month Operational Test of TW-E

6.2.1 Methods of Monitoring Groundwater-Dependent Resources

Each type of groundwater-dependent resource has a specific monitoring method designed to protect that resource, as described below.

Groundwater-Dependent Ecosystems primarily consist of springs and associated alkali meadows that surround the lake. These areas are supported by horizontal and vertical groundwater flow that seeps in wide areas around the lakeshore and flows toward the brine pool as described in the previous section. VDAs could also be considered GDEs but are handled separately because they are not dependent on upwelling groundwater, but instead potentially shallow groundwater as discussed below.

Due to the dispersed nature of upwelling groundwater, flow in many of the springs cannot be measured accurately with typical surface water monitoring techniques such as flumes or weirs. However, groundwater modeling of the Owens Lake area has shown that flows at the springs correlate to the vertical and horizontal groundwater gradient toward the springs (MWH, 2012). For this reason, LADWP has installed monitoring wells and piezometers specifically to monitor the flow toward springs as a surrogate for direct measurement of spring flow. These include the monitoring wells located on the alluvial fans upgradient of the springs, as well as multi-depth piezometers located at the springs. Measurement of the gradient has been conducted beginning at various locations during the 2013 to 2015 period. Hydrographs of these monitoring locations are included in **Appendix A**.

In addition to monitoring groundwater levels and gradients around springs, an entirely independent method of monitoring the GDEs has been developed utilizing remote sensing of vegetation productivity, cover, and extent of alkali meadow vegetation. The historical range of variation of these areas was calculated based on data gathered from over 30 years.

Production Capability of non-LADWP wells is monitored using the static groundwater elevation in the wells relative to the top of the screen in the non-LADWP well. Although it would be preferable to monitor pumping water level in the well, this data is generally not available due to access constraints for non-LADWP wells. In cases where the water level in the non-LADWP well cannot be measured directly, a nearby LADWP monitoring well is utilized.

Vegetated Dune Areas are monitored by the shallow groundwater elevation under, or close to the dune areas. While some dune areas may be technically considered GDEs, the approach to monitoring differs from the spring and seep areas because although the VDAs may be sensitive to groundwater depth, they are not fed by groundwater upwelling to the surface and flowing overland.

6.2.2 Rationale for Triggers

A "trigger" level for each resource listed above is designed to provide early warning of a potential adverse condition during the operational test, so that the test can be

stopped before an adverse condition for that particular resource arises. There are two important aspects of triggers (as used in this plan) that are particularly important:

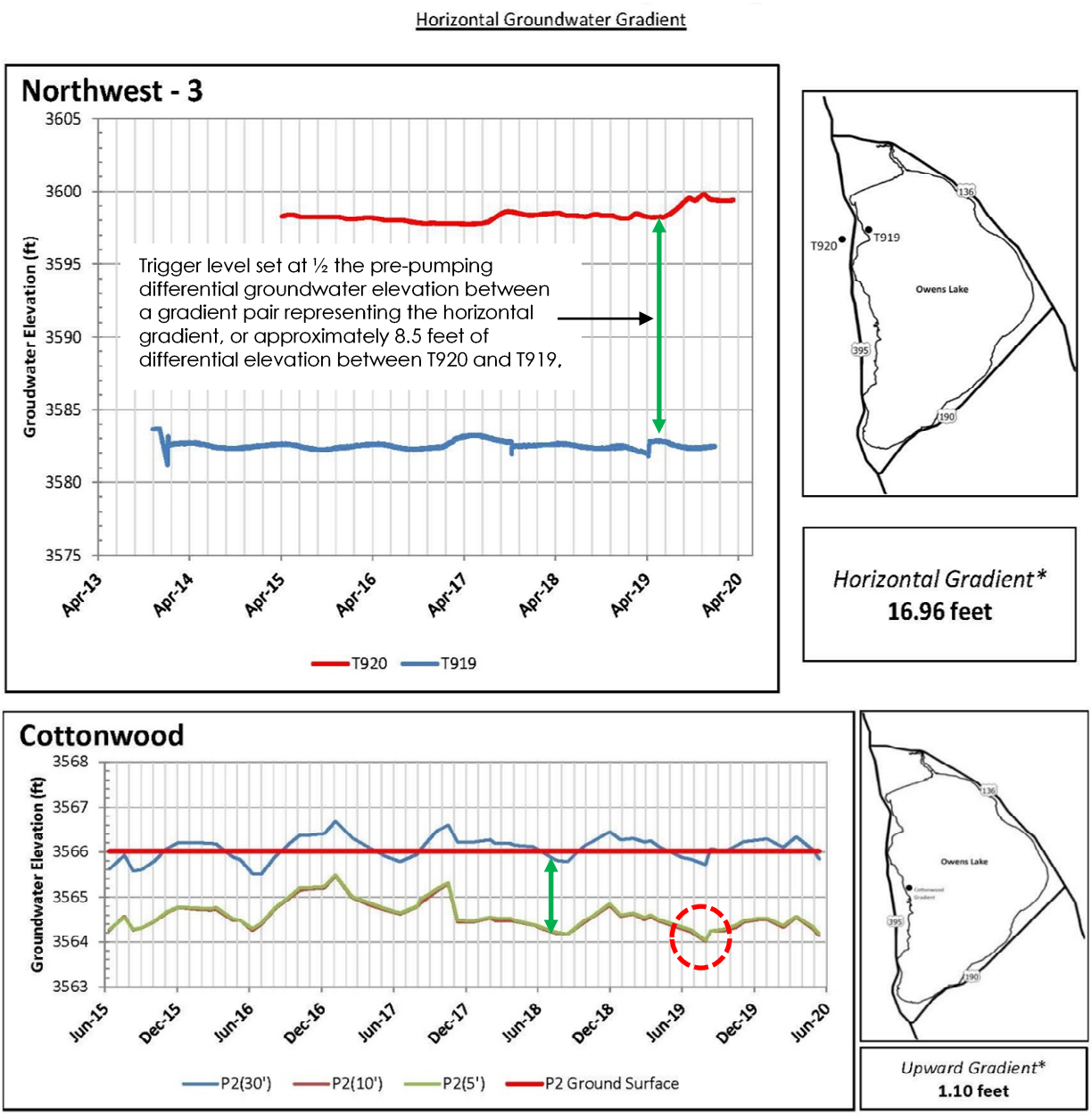
- Triggers are not transferrable from one type of resource to another. As an example, triggers to protect production capability in non-LADWP wells are not appropriate (or designed) to protect GDEs or VDAs. This is because GDEs and VDAs may be much more sensitive to groundwater level changes than a production well.
- All trigger levels work independently, such that reaching any one of the trigger levels will result in the termination of the pumping to protect the given resource.

The rationale for triggers is summarized in **Table 11** and described in more detail below.

The **rationale for trigger levels for GDEs** is based both on monitoring of horizontal and vertical gradients, as well as an absolute value for drawdown in the vicinity of springs. The rationale for the trigger level for horizontal and vertical gradients is to ensure that positive gradients are maintained, and flow continues to the springs. The proposed trigger level for horizontal and vertical gradients is to maintain at least 50 percent of the pre-pumping flow to the springs. This ensures that water is available to the root zones of the vegetation at the springs. Gradient monitoring locations surrounding the lake are summarized in **Table 4**. The locations with triggers are limited to the northern portion of the lake. Trigger values are specific to each gradient pair, as illustrated in an example at the northwest portion off the lake (**Figure 12**) and compiled for other locations in **Appendix A.**

Table 11: Summary of Rationale for Triggers

Resource	Rationale for Triggers
GDEs	The rationale for protection of GDEs is monitoring of flow toward the springs as represented by groundwater gradients with the understanding that some reduction in flow is permissible, as long as a positive gradient toward ground surface is maintained. An absolute value of depth to groundwater at the shallowest piezometer near the springs is also utilized at the request of reviewers. This absolute value will be set at the seasonally adjusted historical range of variation. In addition, the seasonally adjusted LAI and size of transmontane alkali meadow (TAM) area will be documented before and after the test utilizing remote sensing techniques.
Production Capability at non-LADWP Wells	The rationale for protection of production capability at non-LADWP wells is based on the depth of the top of the screen in all non-LADWP wells in the northern portion of the lake relative to the static water level. With the recognition that a certain amount of drawdown will not affect production capability, as long is the pumping water level is above the well screen. The trigger for all non-LADWP wells is based on the shallowest, or most sensitive non-LADWP well in the northern portion of the lake (i.e. where the distance between the static water level and the top of the well screen is the shortest).
VDAs	The trigger level for VDAs is based on the review of literature observations that the type of vegetation on the dunes is capable of sustaining certain level of groundwater elevation decline temporarily without adverse effects (see following text and **Appendix B**).



Trigger level set at ½ the pre-pumping differential groundwater elevation between a gradient pair representing the vertical gradient, or approximately 0.5 feet of differential elevation between P2(30') and P2(5') (green arrow). In addition, a groundwater elevation trigger in the P2(5') equal to the historical recorded low will also act as a trigger (red dashed circle).

Figure 12: Example of Horizontal (Top) and Vertical (Bottom) Gradient Triggers

The rationale for trigger levels for non-LADWP wells is based on maintaining an adequate water column above the top of the well screen in non-LADWP wells. To develop a threshold level for non-LADWP wells in the northern portion of the lake, a review of the length of the water column above the well screen in the shallowest non-LADWP wells within a cluster of adjacent wells was performed, as summarized in **Table 12**.

Table 12: Non-LADWP Wells to be Protected

Well Name	Top of Screen (depth-ft)	Static Water Level (depth-ft)	Water Column Above Top of Screen (ft)	Threshold Level Based on Each Well (drawdown, ft)[1]
Jean Crispin #2	60	12	48	24
Don Odell	145	37	108	54
Don Echelberger	100	50	50	25
Stradling	43	0	43	21
Mortensen	300	275 (estimated)[2]	25	12
Keeler CSD	51	41	10	5

Notes:
[1] The well-specific threshold is a measure of drawdown, which is set at ½ the distance between the static water level and the top of the well screen for the most sensitive well in a cluster of non-LADWP wells (i.e., Keeler CSD above).
[2] The water level in the Mortensen well cannot be measured due to obstructions by pumping equipment. Therefore, the static water level was estimated based on nearby wells.

The non-LADWP wells around Owens Lake are located either west of the Owens Valley Fault or east of the Owens River Fault and are protected by the barrier effect of the faults. Water level in non-LADWP wells cannot be measured directly because of access limitations. Instead, trigger wells are selected at a location between the TW-E and each non-LADWP well or group of wells. **Figure 13** shows the general spatial relationship between the TW-E, trigger wells, and the non-LADWP wells. For the protection of non-LADWP wells, a drawdown of five (5) feet from the pre-pumping groundwater level in the trigger wells corresponds to a much smaller drawdown at non-LADWP wells and therefore is considered very conservative. The rationale for the five (5) feet of drawdown is based on the most sensitive non-LADWP well in the northern portion of the lake (Keeler CSD Well) but has been applied to all non-LADWP monitoring locations to apply a conservative level of protection and for simplicity.

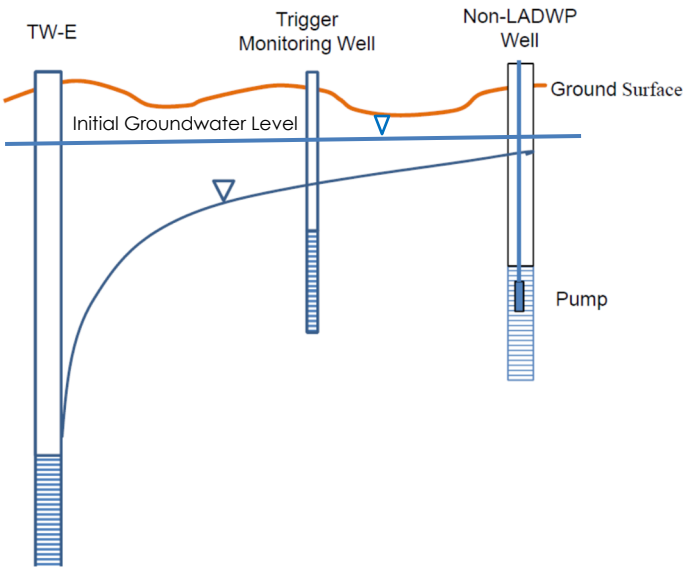


Figure 13: Spatial Relationship of Groundwater Levels in TW-E, Trigger Monitoring Wells, and Non-LADWP Wells

The rationale for **trigger levels for VDAs** is based on a literature review of *Sarcobatus* response to variations in groundwater depth. The literature review to support the conservative nature of these trigger levels is briefly summarized in the bullets below and in **Appendix B**:

- **Daily Oscillations in Depth to Water**. A number of detailed studies of *Sarcobatus* have documented daily oscillations of 1-5 cm in the depth to water with minima in late afternoon/evening and overnight recovery during the growing season (See **Appendix B**: Robinson, 1970; Devitt et al., 2011; Devitt and Bird, 2016; T931 hydrograph data). The oscillations are not present after leaf senescence (Devitt and Bird, 2016). These oscillations are direct evidence of groundwater use and their magnitude is related to transpiration, leaf area index, atmospheric demand, root depth distribution, and specific yield of the aquifer (Steinwand et al., 2006; Devitt and Bird, 2016). The magnitude of these oscillations, or even their presence, however, can be affected by the texture and specific yield of the aquifer being tapped by *Sarcobatus* roots. In the Devitt and Bird (2016) study, oscillations that were initially present, disappeared for 2,225 days while groundwater declined from 9.33 m to 10.71 m below ground surface, but reappeared coincident with the level crossing a textural boundary at 10.67 m.

  At Owens Lake, similar daily oscillations of groundwater depth have been documented at well T931 where there is dense shrub vegetation with *Sarcobatus* and other species. At the end of April 2019, daily oscillations of up to 4.3 cm (0.14 ft) were observed when groundwater was at 3.58 m (11.76 ft) depth. Together, these results show that *Sarcobatus* can adjust to changes in groundwater depth

of up to 1.38 m (4.5 ft) over several years (average 0.75 ft / yr) and continue to utilize groundwater to depths of at least 10.71 m (35 ft).

- **Seasonal Fluctuation in Depth to Water.** Another line of evidence that *Sarcobatus* root systems can adjust to changes in groundwater depth with no adverse impacts on cover or vigor comes from assessment of seasonal variation in depth and historical variation in cover. *Sarcobatus* naturally experiences and tolerates these seasonal variations with no detectable effect on the health of the plant community, which remains essentially stable through these variations (Great Basin Report, 2019; Pilot Study Results, 2019). Decrease in groundwater level under *Sarcobatus* communities during the growing season has a surprisingly small range considering the diversity of sites studied and the range of years covered (**Appendix B**). Based on the data summarized in **Appendix B**, the typical growing season decline in groundwater depth ranges from 20.0 – 35.1 cm (0.66 – 1.15 ft) (Robinson, 1970; Nichols, 1994; Devitt et al., 2011; Devitt and Bird, 2016; Steinwand et al., 2006; T931 hydrograph data; Keeler Landfill Monitoring Well hydrograph data). In addition to these typical values over different years and study locations, single year maximal declines of 64 cm (2.10 ft), 55.2 cm (1.81 ft) (Keeler Landfill Monitoring Well near VDA08 in 2005, 2017) and 54.9 cm (1.80 ft) (T931 well near VDA01 in 2017) have been observed. These seasonal fluctuations have occurred during the period where our historical analyses of cover (Pilot Study Results 2019) shows fluctuations but no trend in cover change (i.e. stable cover). The flexibility of *Sarcobatus* root systems is such that it can tolerate changes up to these magnitudes without any detrimental effect on the vegetation community.

  Furthermore, measurements of plant stress as xylem water potential show no end of season differences for *Sarcobatus* following wet and dry precipitation years with a one-year decline in groundwater up to 1.3 m (Trent et al., 1987). Devitt et al. (2011) also found that differences in groundwater depth from 4.6-9.3 m among sites did not cause differences in *Sarcobatus* stress levels. Its root system was able to adjust to these differences and access capillary fringe water resources.

  Setting a target trigger within the range of these seasonal fluctuations or year-year declines for cessation of groundwater pumping is conservative in the sense that these are the normal variations experienced and tolerated by *Sarcobatus*. Even seasonal declines of up to 2.1 ft are not unusual in the long history of these communities, and yearly declines of approximately one meter are not more stressful than usual for *Sarcobatus*.

- **Multiple Year Responses to Groundwater Decline**. Based on Fig 7b of Elmore et al. (2003), a decline of 1.1 m in groundwater level over multiple years would be required to produce a detectable change in the live cover of *Sarcobatus* communities. Smaller changes in groundwater depth, even over multiple years, are unlikely to cause any detectible change in cover of groundwater dependent shrubs. The plasticity of *Sarcobatus* root systems to access different water sources was demonstrated by Wagner et al. (2018) and supports the

conclusion from Devitt and Bird (2016) that the root zone of greasewood is very deep (up to 10.75 m depth) and the "findings, including the groundwater oscillations, deep unsaturated zone extraction and shifts in soil water in storage based on precipitation support a very flexible and dynamic utilization of multiple water sources by greasewood." In a rabbitbrush and *Sarcobatus* community on dunes at Mono Lake, growth reduction and mortality were not initiated until much more than 1 m of groundwater decline over multiple years (Toft, 1995). Large plants of rabbitbrush were largely unaffected by a 2.1 m decline in groundwater level over multiple years and recovered to initial size after long-term drought (Toft and Frazier, 2003). There was no mortality among the large rabbitbrush plants in this community and they flowered every year of the 17-year study. Although *Sarcobatus* was not studied in this location because of the difficulty of determining genetic individuals, large established *Sarcobatus* survived and recovered after the long-term drought and groundwater decline (Toft, pers. comm.).

All of these studies and data from hydrographs at Owens Lake (**Appendix B**), support the conclusion that *Sarcobatus* can easily withstand seasonal or multiple year declines in groundwater of up to approximately one meter because of their flexible, extensive root systems that can adjust to changes in groundwater depth and also access multiple water sources (vadose zone soil moisture, perched saturated zones and capillary fringe water). The 1-foot trigger is a conservative threshold for this operational test.

6.3 Simulation of the 6-Month Operational Test

As noted in Section 3.0, the current version of the OLGM (Stantec, 2020) was utilized to evaluate the potential shallow groundwater elevation decline (drawdown) due to pumping TW-E at 3 cfs for 6 months so that key locations can be identified as trigger locations to protect groundwater-dependent resources. Due to sequences of silt and clay aquitards, the drawdown caused by pumping of TW-E will be greatest in the deeper aquifers, but muted in shallow surficial aquifers that support groundwater-dependent resources and non-LADWP wells. Simulated drawdown at specific trigger locations is described in the following section.

6.3.1 Simulated Area of Influence

The largest simulated drawdown occurring at any non-LADWP well is 0.53 feet at the O'Dell well northwest of TW-E. The highest simulated drawdown in any of the shallow piezometers surrounding the lake is 0.04 feet at P1 located west of TW-E, while the highest simulated drawdown at any VDAs site is 0.03 feet at VDA05, located east of TW-E. These simulated drawdown values are shown in **Figure 14,** which has been utilized to focus trigger locations where deep pumping may affect shallow groundwater levels and groundwater-dependent resources. Note that simulated drawdown due to the proposed pumping is limited to the northern portion of Owens Lake and the area immediately north of Owens Lake.



Figure 14: Simulated Shallow Aquifer Drawdown (ft) at Groundwater-Dependent Resources due to Operational Test of TW-E

6.3.2 Use of the Model to Determine Trigger Levels

The OLGM was utilized in preparing the proposed monitoring plan for the 6-month testing two ways:

1) To provide an initial estimate of the expected drawdown in the shallow aquifer in the vicinity of groundwater-dependent resources to provide confidence that the proposed testing of TW-E will not cause significant impact to groundwater-dependent resources.
2) To evaluate the geographic extent of area of potential drawdown from pumping of TW-E.

The level of expected drawdown in the shallow aquifer (where measurable based on the groundwater model) is described in Section 6.3.1. The modeling results indicate that drawdown in the shallow aquifer is very minor, and in many cases may not be measurable. It also indicates that drawdown near groundwater-dependent resources is limited to the northern portion of Owens Lake, which is why monitoring is focused (but not exclusive) to the northern portion of the lake.

The modeling results may raise the question: "*Why not set trigger values at or near the simulated model results?*" The answer to this question is that the trigger values are designed to be conservative protective values for the specific resource to be protected, *and not* the modeling results. If the model results are used as trigger values, then the test will be terminated unreasonably early, partially negating the purpose of the test, which is to evaluate the impact of pumping at groundwater-dependent resources. This concept is illustrated schematically in **Figure 15**, whereby the trigger level is set conservatively to protect the resource, and not on modeling results.

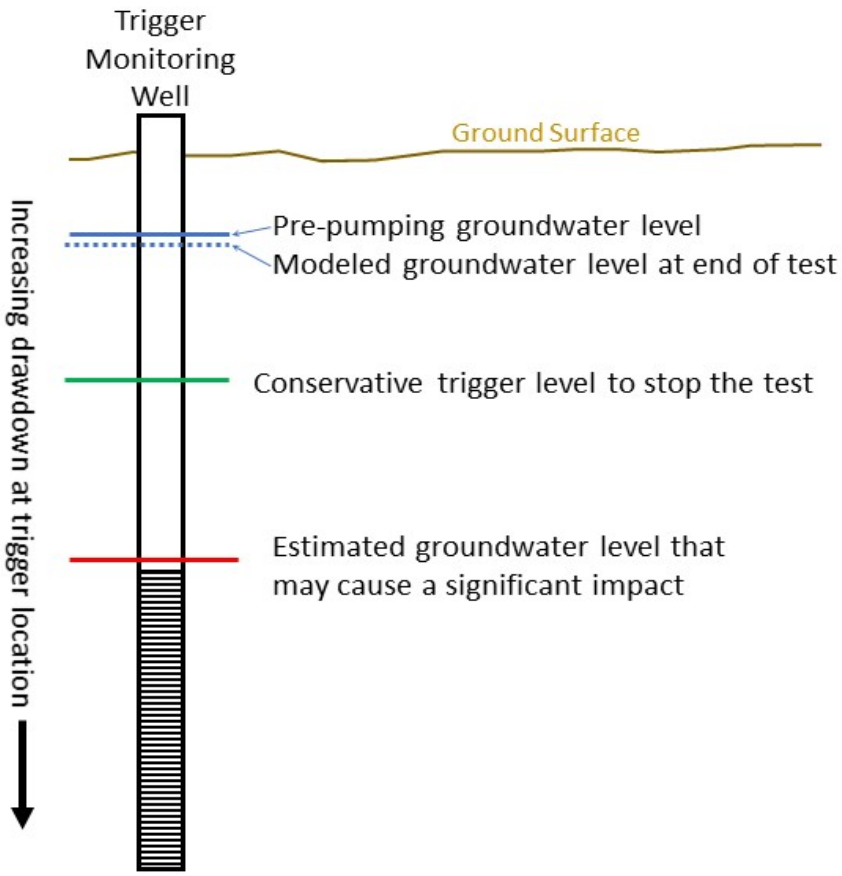


Figure 15: Schematic Relationship between Model Scenarios and Trigger Levels

An associated question may also be: "*If the modeled changes in groundwater levels are so minor, then why not run the test at a much higher pumping rate, or a longer duration so that a reaction at monitoring locations is assured?*" This is a reasonable conclusion based on the modeling results, but it is not in keeping with the overall philosophy of groundwater development at Owens Lake, which is adaptive management - start very slowly and conservatively, using only one testing well. It is also true that a negative result (no impact) is partially instructive in increasing the knowledge of how the groundwater regime reacts to pumping at various rates.

And finally, another reasonable question may be: "*What if the groundwater model simulations are grossly wrong?*" Because of the years of work in building an accurate conceptual and calibrated numerical model which has been vetted by independent experts (**Table 1**), this outcome is considered unlikely. However, if it does occur, it can be considered a positive outcome, in that the model can be updated and calibrated based on the field results, and ultimately become a much more robust tool in protection of resources and the adaptive management process. The trigger levels are

set independently of the model results to protect resources, and not by outcomes predicted by groundwater model results. Therefore, in the unlikely event that modeled predictions are grossly wrong, groundwater dependent resources will still be protected.

6.4 Proposed Trigger Locations and Preliminary Trigger Values

Trigger values are proposed not only for groundwater elevations, but also for groundwater gradients toward groundwater-dependent resources within the estimated area of influence of pumping at TW-E, as described below.

6.4.1 Groundwater Elevation Monitoring

Specific groundwater-dependent resources and their associated trigger wells are shown on **Figure 11** and listed in **Tables 13** through **16**. These trigger wells are located either at the resources themselves or between TW-E and the resource to be protected. If during the pumping phase of the test, groundwater levels below a trigger value are detected in any of the trigger wells, pumping from TW-E will stop within 24 hours. In this situation, recovery data collection will start, and parties will be notified of the situation and the action taken. Trigger levels are described in terms of drawdown, or the change in groundwater elevation measured prior to initiation of testing compared to the groundwater elevation during testing.

6.4.2 Groundwater Gradient Monitoring

Triggers associated with calculated groundwater gradients toward springs are listed in **Table 15.** This table lists both the horizontal gradient toward and vertical gradient at five (5) groundwater dependent resources that could be affected by the 6-month operational test of TW-E, generally located in the northern half of Owens Lake.

To address reviewers' requests for absolute drawdown triggers at spring sites, a drawdown trigger of 2.3 and 3.2 feet at the shallowest piezometer near Northwest and Horse Pasture springs would also be used respectively and listed in **Table 16**.

Table 13: Non-LADWP Wells and Associated Trigger Wells

Resource	Location	Trigger Well	Simulated Drawdown After Testing for 6 Months at 3 cfs (feet)	Proposed Trigger Drawdown (feet)	Trigger DTW from RP (feet)
Boulder Creek RV Park, O'Dell Well, and Nearby Domestic Supply Wells	west of Owens River Fault and 4.5 miles NE of TW-E	T931 T902a	0.24 0.73	5 5	TBD
FW Aggregates Supply Well	east of the Owens River Fault and 4.5 miles E-NE of TW-E	T929	0.20	5	TBD
Mortensen Domestic Well	west of Owens Valley Fault, 3 miles west of TW-E	T920	0.0	5	TBD
Mt. View Trailer Park	4 miles NW of TW-E	T858	0.06	5	TBD
Keeler CSD	northeast of Keeler across Hwy 136	P8 (30)	0.0	5	TBD

Note: A trigger level of 5 feet in the trigger well corresponds to less than 5 feet in the non-LADWP well (**Figures 13 and 15**).
DTW = Depth to Groundwater RP = Reference Point
The Trigger DTW from RP will be set prior to the start of the test based on the latest field measurements

Table 14: VDA Wells and Associated Groundwater Drawdown Triggers

Resource	Location	Trigger Well	Simulated Drawdown After Testing for 6 Months at 3 cfs (feet)	Proposed Trigger Drawdown (feet)	Trigger DTW from RP (feet)
VDA-1	3 miles NW of TW-E	Delta W(1)	0.0	1	TBD
VDA-2	3 miles NE of TW-E	VDA-2-1	0.0	1	TBD
VDA-3	3 miles NE of TW-E, just SE of VDA-2	VDA-3b	0.0	1	TBD
VDA-4	3 miles NE of TW-E, just SE of VDA-3	VDA-5	0.01	1	TBD
VDA-5	3 miles NE of TW-E, just SE of VDA-4	VDA-5	0.03	1	TBD
VDA-6	3 miles E of TW-E, just S of VDA-5	Staging Area Monitoring Well	0.01	1	TBD
VDA-7	3 miles E of TW-E, just S of VDA-6	P8 (30)	0.0	1	TBD
VDA-8	3 miles E of TW-E, just E of VDA-7	VDA-8-2	0.0	1	TBD

Note: The Trigger DTW from RP will be set prior to the start of the test based on the latest field measurements.
DTW = Depth to Groundwater RP= Reference Point

Table 15: Trigger Wells Associated with Groundwater Gradient[1] toward Springs around Owens Lake

Gradient Type	Up-Gradient Location	Down-Gradient Location	Location Notes	Pre-Pumping Gradient (feet)[2]	Simulated[3] Gradient After 6-month Testing at 3 cfs (feet)	Trigger Gradient (feet)[4]
Vertical	P1 (30)	P1 (5)	Northwest (Northwest Spring)	0.5	0.5	N/A[5]
	P8 (30)	P8 (5)	Northeast (Horse Pasture)	4.6	4.6	2.3
Horizontal	MW-3	T918	Northwest	174.3	173.8	87.1
	MW-2	P1(5)	Northwest	81.0	80.9	40.5
	T920	T919	Northwest	17.0	17.0	8.5
	T929	Lizard Tail	Northeast	33.0	32.8	16.5

Notes:
[1] See Section 6.0 for explanation of how gradients are recorded.
[2] Pre-pumping gradients are shown in **Appendix A** hydrographs.
[3] Simulated gradients after pumping are very close, or the same as pre-pumping conditions (i.e. little effect is predicted by the numerical groundwater model).
[4] Trigger levels will also be set for a specific depth to groundwater at each 5-foot piezometer based on the seasonally adjusted historic range of variation (**Figure 12**).
[5] Water levels in the shallowest piezometer at this site has been unreliable. An absolute value in the 5-foot piezometer based on the historical range of variation will be used as a trigger (**Table 16**).

Table 16: Groundwater Trigger Drawdown for the Shallow Aquifer at Springs

Location	Trigger Well	Trigger Drawdown (feet)[1]	Trigger DTW from RP (feet)[2]
Northwest (Northwest Spring)	P1 (5)	2.3	TBD[3]
Northeast (Horse Pasture)	P8 (5)	3.2	TBD

Notes:
[1] Based on the historical range of variation (**Figure 12 and Appendix A**)
[2] DTW=Depth to Water RP=Reference Point
[3]Trigger DTW from RP will be set prior to the start of the test based on the latest field measurements.

Groundwater-dependent resources and their trigger mechanisms are grouped and discussed below:

- **Supply well for Boulder Creek RV Park located northeast of Highway 395 and Lubken Mainline Road and several nearby domestic wells** – All of these wells are located west of Owens Valley Fault and approximately 4.5 miles northwest of TW-E (MWH, 2016). Comparison of groundwater measurement from these wells and the monitoring wells located east of Owens Valley Fault show the clear effect of the fault zone, which would protect these wells from potential effect pumping TW-E. As an additional protection measure, T902a will be utilized as the trigger well (**Table 13**).
- **Domestic well at Mortenson Property**– Located three (3) miles directly west of TW-E, and west of Owens Valley Fault, this well is protected by the Owens Valley Fault Zone, which may be a barrier to groundwater flow. As an additional protection of this resource, T920 will be used as a trigger well (**Table 13**).
- **Supply wells for the FW Aggregates Mining Operation located east of Highway 136** - These wells are located on the east side of Owens River Fault and approximately 4.5 mile east and northeast of TW-E. As a result of the barrier effect of the Owens River Fault, these well would be protected from the effect of pumping TW-E. Monitoring well T929 will be utilized as the trigger well for these domestic wells (**Table 13**).
- **Springs located West of Owens Lake** - This specific spring area includes Northwest Spring and associated vegetated area. This area is approximately 2.5 miles west of TW-E. Similar to the domestic wells to the north, these areas are protected from any effect of pumping TW-E by the barrier effect Owens Valley Fault. The trigger wells assigned for the additional protection of these areas are P1(5'), and P1(30') for calculating groundwater gradient (**Table 15**), as well as an absolute value for the 5 feet deep monitoring well (**Table 16**).

- **Vegetated Dune Areas** – Based on groundwater modeling using the OLGM, the VDAs that are located north and northeast of Owens Lake are those that could potentially be affected by the proposed 6-month operational test of TW-E (VDA-1through VDA-8). It is assumed that the vegetation on VDAs that keep these dunes stable is partially dependent on surficial aquifers under the dunes. The surficial aquifer is separated from the deeper groundwater aquifers beneath Owens Lake. However, to ensure no significant impacts would occur to these vegetated dunes, groundwater levels under or adjacent to each dune will be monitored during the 6-month operational test of TW-E (**Table 14**).
- **Vertical and Horizontal Gradients** – The springs on both east and west sides of Owens Lake are fed by groundwater flowing lakeward both horizontally and vertically upward. Because flow emanating from springs cannot be measured directly, measurement of groundwater gradients toward the springs serve as a mechanism to monitor flow from these areas (**Table 15**).

6.5 Finalization of Triggers Levels Prior to Commencement of Testing

LADWP and responsible agencies will meet and review the most recent hydrographs for the trigger wells (**Appendix A**) about three (3) weeks prior to the start of the operational test to verify pre-pumping groundwater levels for the trigger wells (**Tables 13 through 16**). LADWP will prepare a memo to document the pre-pumping trigger levels. Triggers will be identified in terms of depth to groundwater (DTW) from the reference point (RP) of trigger monitoring wells. The reference point is a location on the well casing that has been surveyed and is used each time to measure the depth to water by LADWP hydrographers. The memo will be provided to the parties for review and comment before being finalized.

It is understood that numerous factors affect groundwater levels in each trigger well, including flows in the nearby surface water features, surface water applied to the nearby area, precipitation, evapotranspiration, change in barometric pressure, and pumping from other nearby wells. Some or all of these factors contribute to a variable, non-periodic historic hydrograph in most monitoring wells in the area, and a "typical" seasonal background water table trend cannot be readily identified. Therefore, the final trigger level in each trigger well will be set considering:

1) groundwater levels prior to the start of operational test,
2) historic hydrograph for each trigger well, where available, and
3) typical plant seasonal water demand by GDEs.

During the proposed operational test, LADWP will attempt to minimize fluctuations in groundwater levels due to controllable factors by providing consistent operational management. For example, during the test, LADWP will attempt to keep flows in the Lower Owens River and discharge to Owens River delta relatively constant and not

change operation of any nearby pumps. In addition to the trigger wells listed in **Tables 13, 14, and 16,** the groundwater gradient will also be monitored (**Table 15**) with associated trigger gradients to ensure the groundwater- dependent springs located on the margins of the lake are not impacted by the test.

7.0 DATA ANALYSIS

Data analysis will include graphical analysis, calculation of aquifer parameters, and model calibration as described below. This data analysis will follow the test, not to be confused with routine reporting during the test itself.

Graphical Analysis - Groundwater levels and surface water flow measurements will continue to be collected from monitoring wells, flow measuring flumes, and meteorological stations described in Section 4 for the duration the proposed operational test of TW-E. The planned graphical analysis includes preparation of hydrographs using data from all monitoring locations. Additionally, changes in groundwater level from the pre-pumping condition in every monitoring well will be calculated, and hydrographs will be prepared. Using the calculated drawdowns, contour maps of drawdown will be prepared to visually present the spatial effect of the operational test, as well as the effects in various aquifers to the extent that available data allows. This type of graphical analysis will help identify areas that can potentially be affected by pumping TW-E on a longer-term basis and help identify sources pumped water. Of particular interest will be the groundwater level changes across the Owens Valley and Owens River fault zones to determine the effect of fault zones on groundwater movements.

Aquifer Parameters Calculations - Groundwater level and discharge rate data collected at testing well TW-E and groundwater level data collected at monitoring wells will be analyzed using AQTESOLV, a specialized software developed by HydroSOLVE, Inc. of Reston, Virginia, to calculate specific aquifer hydraulic parameters, such as transmissivity, storativity, and hydraulic conductivity at testing well TW-E and the wells monitored during the 6-month operational test, to the extent possible. Based on the spinner log results, pumped water can be proportioned to specific aquifers allowing for more accurate calculation of aquifer characteristics, and as a result improved model calibration.

Model Calibration - Using the data collected during the operational test from monitoring locations throughout the Owens Lake area, hydrogeologic parameters of various aquifers in between and across fault zones will be adjusted in the Owens Lake groundwater flow model to achieve model calibration, which will improve the estimated hydraulic characteristics of the Owens Valley and Owens River fault zones. Similarly, aquifer parameters in the vicinity of TW-E will be adjusted to achieve optimal model calibration for the area. These model improvements will result in increased model reliability and accuracy in forecasting the effect of various potential future groundwater management scenarios.

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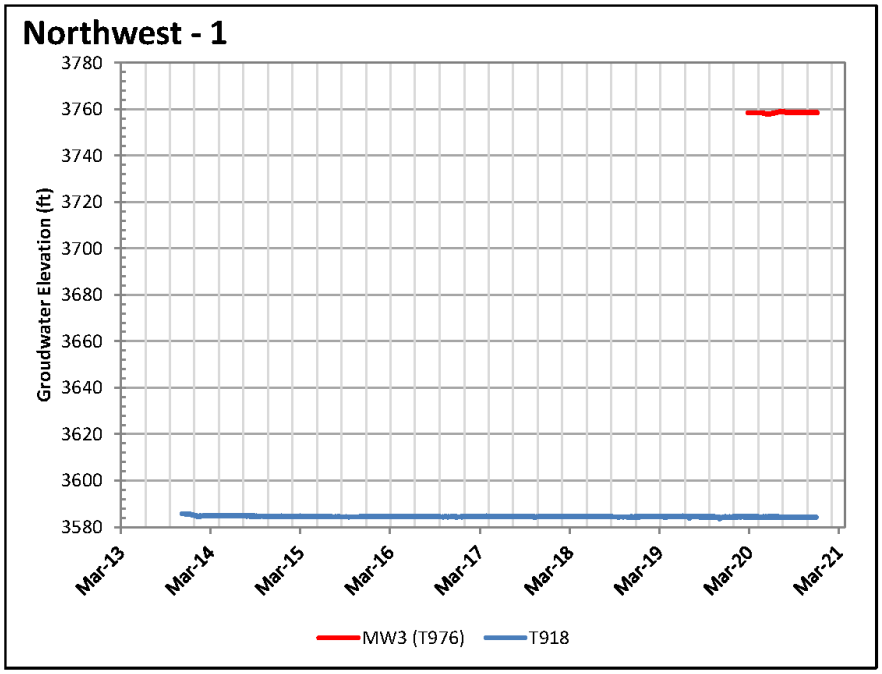
APPENDIX A

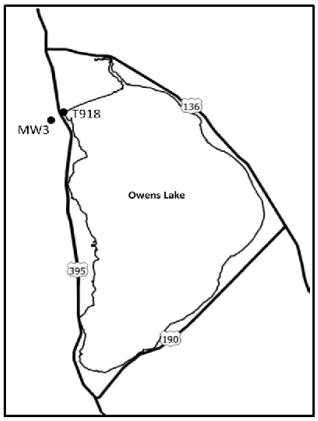
HYDROGRAPHS AND GROUNDWATER GRADIENTS (HORIZONTAL AND VERTICAL FOR KEY MONITORING WELLS

Appendix A: Horizontal Gradients

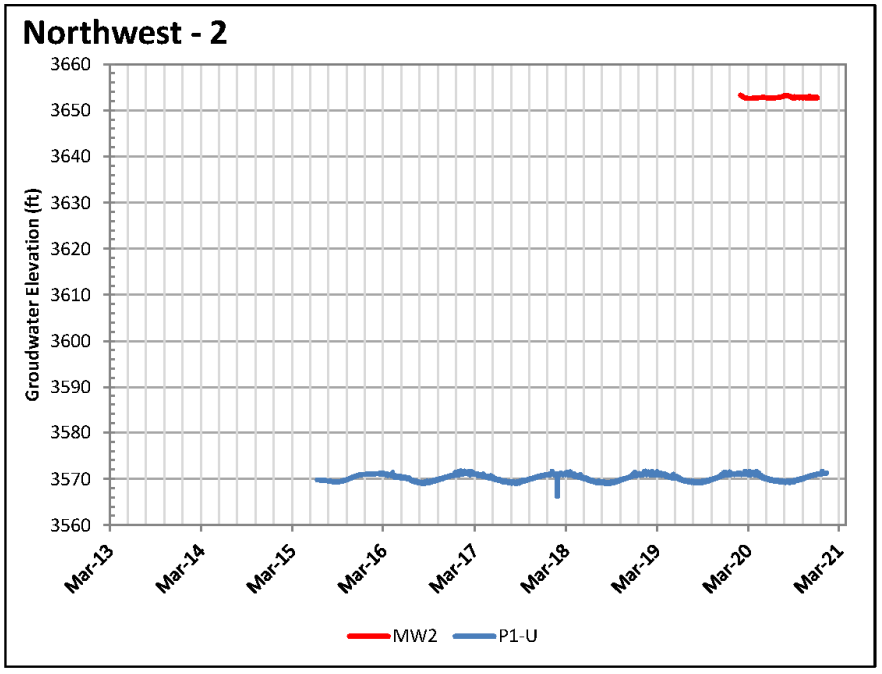
Owens Lake Groundwater Development Program

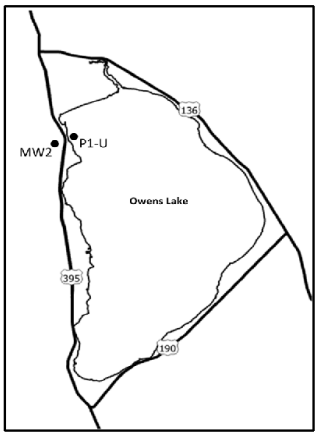
Horizontal Groundwater Gradient





*Horizontal Gradient**
174.3 feet



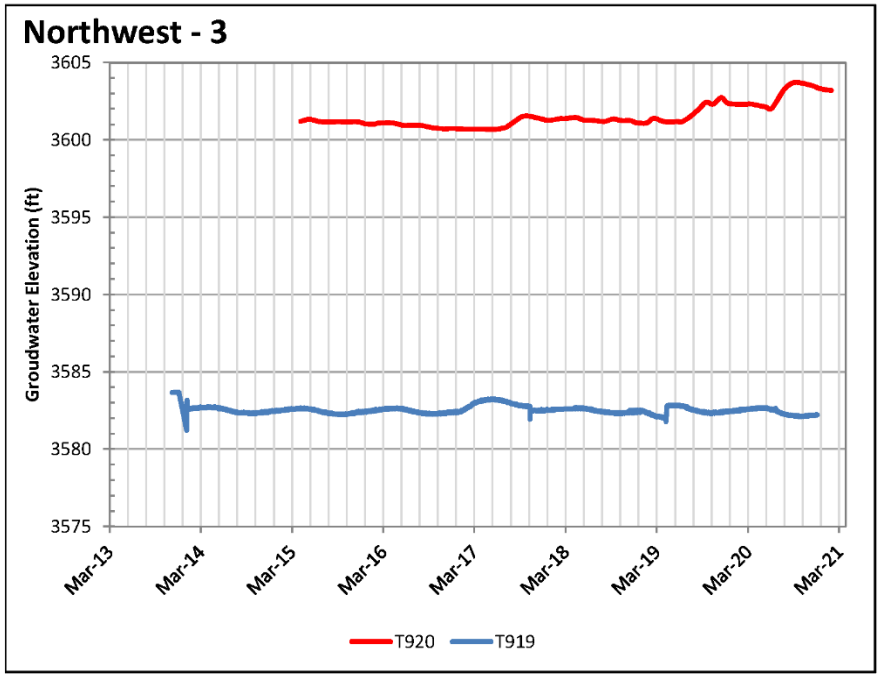


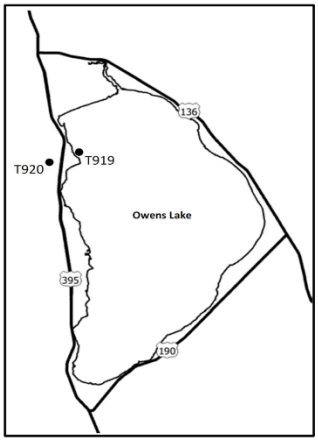
*Horizontal Gradient**
81.1 feet

*Horizontal Groundwater Gradient is the difference in groundwater level in the alluvial fan monitoring well and the corresponding monitoring well at Owens Lake margin.

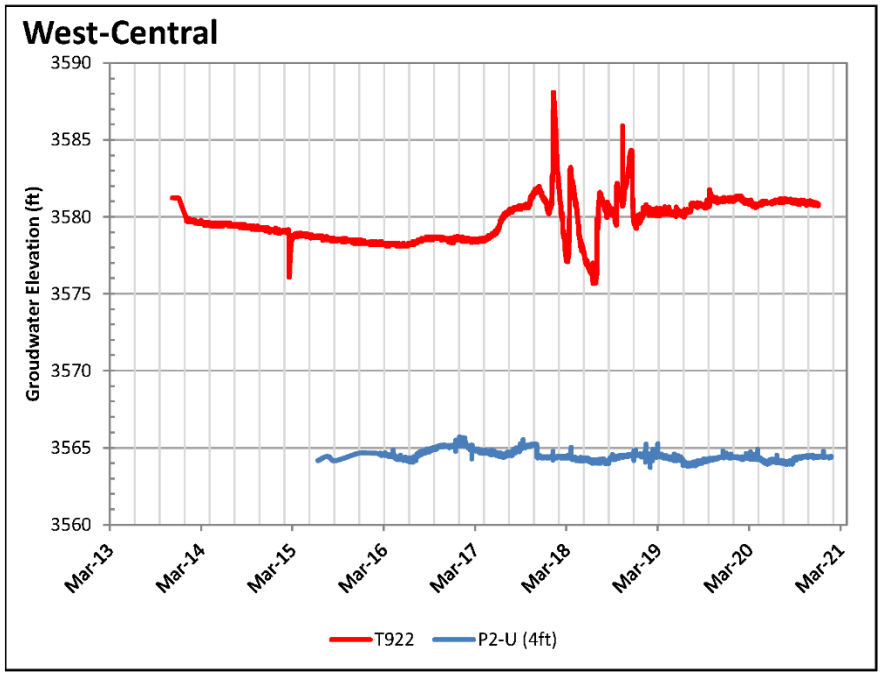
Owens Lake Groundwater Development Program

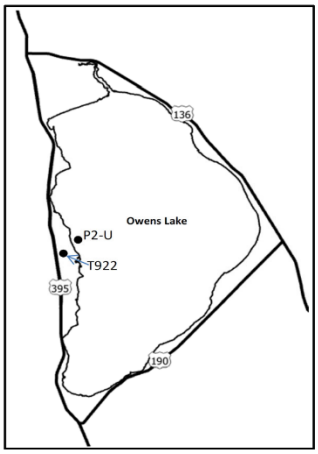
Horizontal Groundwater Gradient





*Horizontal Gradient**
16.9 feet



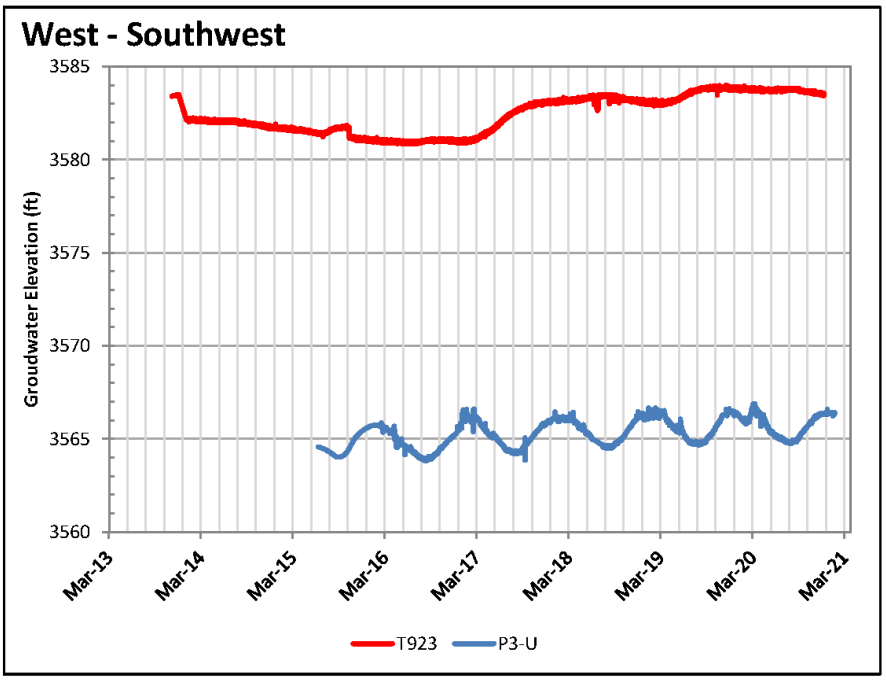


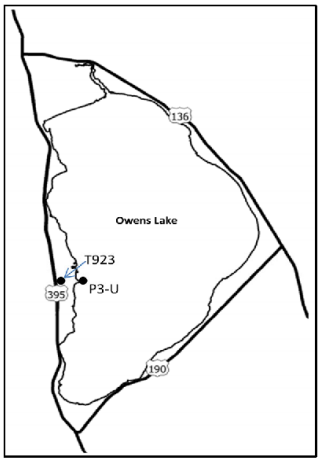
*Horizontal Gradient**
13.8 feet

*Horizontal Groundwater Gradient is the difference in groundwater level in the alluvial fan monitoring well and the corresponding monitoring well at Owens Lake margin.

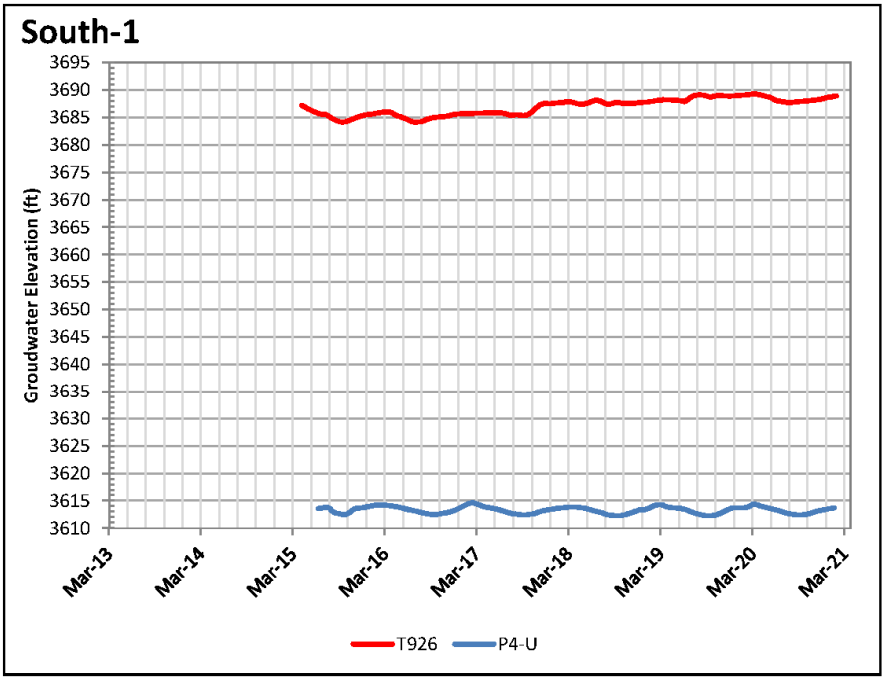
Owens Lake Groundwater Development Program

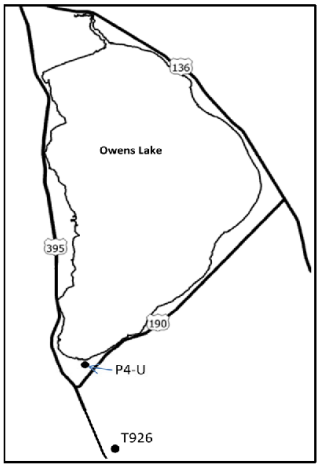
Horizontal Groundwater Gradient





*Horizontal Gradient**
17.9 feet



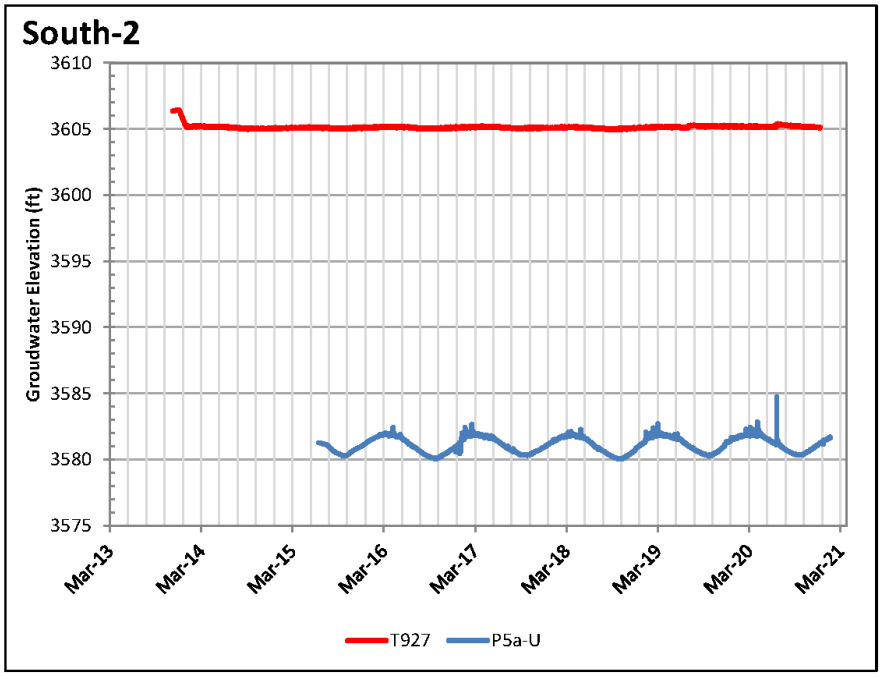


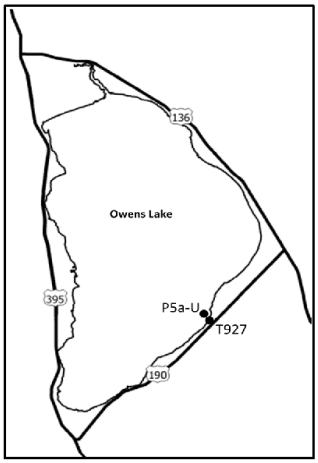
*Horizontal Gradient**
74.8 feet

*Horizontal Groundwater Gradient is the difference in groundwater level in the alluvial fan monitoring well and the corresponding monitoring well at Owens Lake margin.

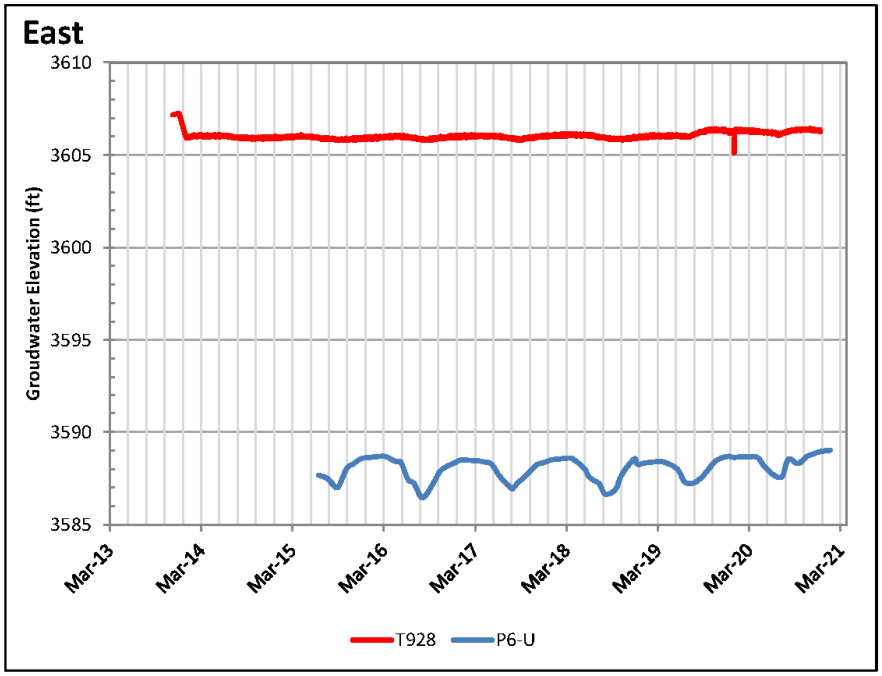
Owens Lake Groundwater Development Program

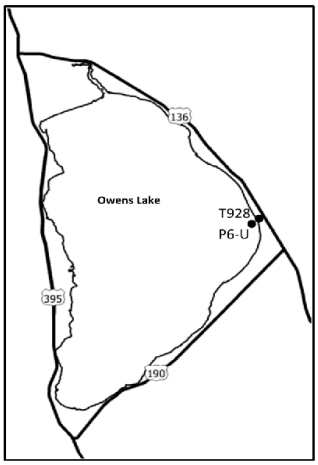
Horizontal Groundwater Gradient





*Horizontal Gradient**
20.3 feet



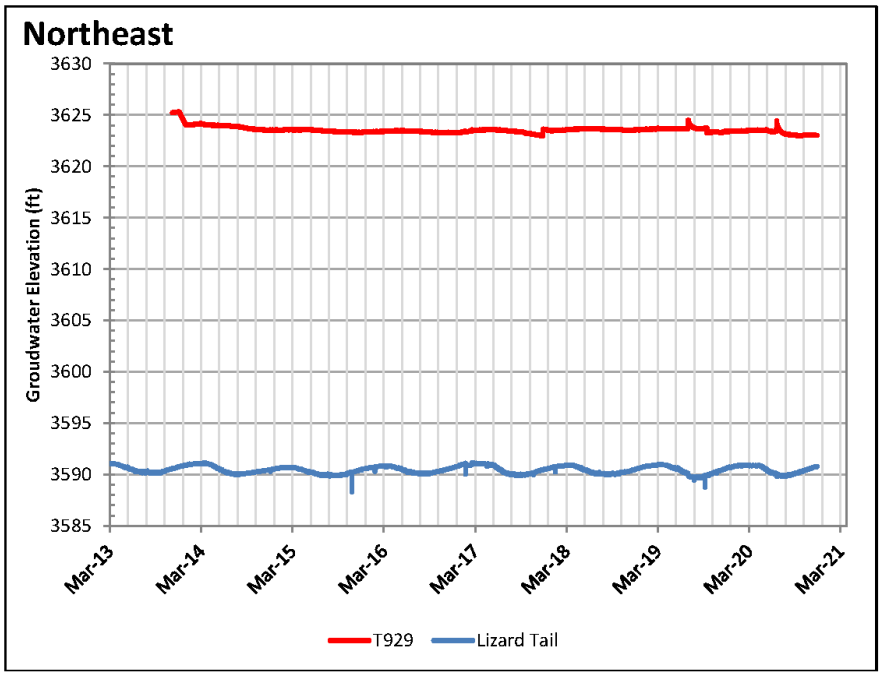


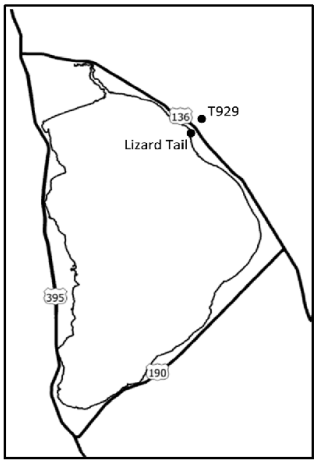
*Horizontal Gradient**
17.3 feet

*Horizontal Groundwater Gradient is the difference in groundwater level in the alluvial fan monitoring well and the corresponding monitoring well at Owens Lake margin.

Owens Lake Groundwater Development Program

Horizontal Groundwater Gradient





*Horizontal Gradient**

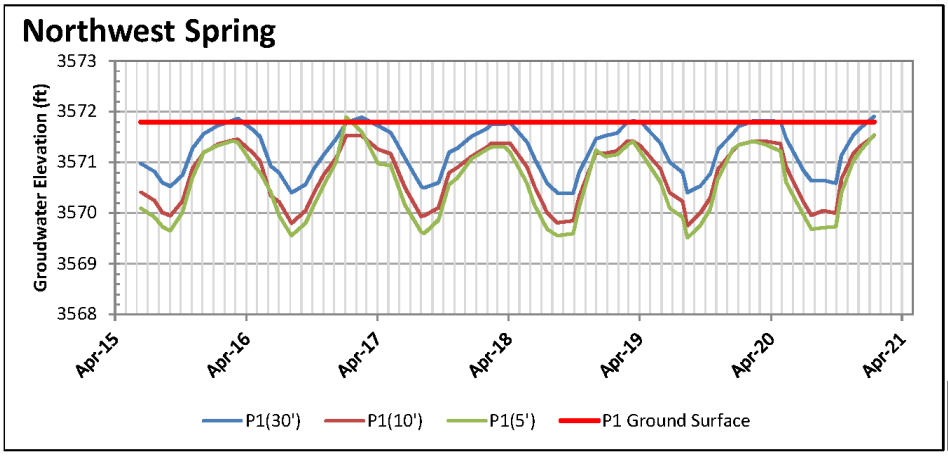
33.0 feet

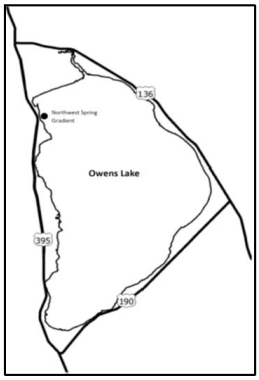
*Horizontal Groundwater Gradient is the difference in groundwater level in the alluvial fan monitoring well and the corresponding monitoring well at Owens Lake margin.

Appendix A: Vertical Gradients

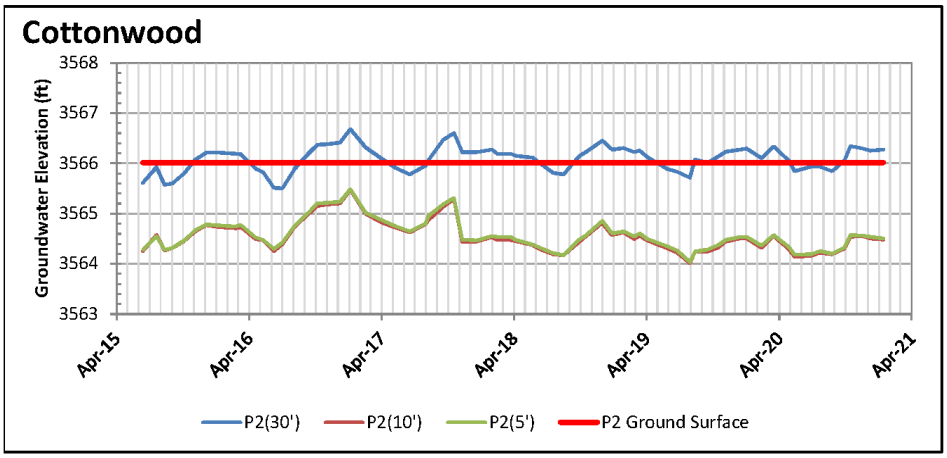
Owens Lake Groundwater Development Program

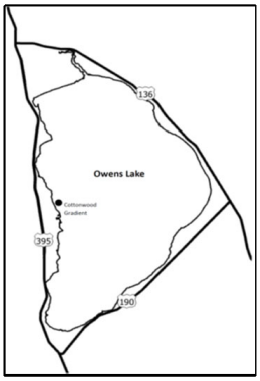
Vertical Groundwater Gradient



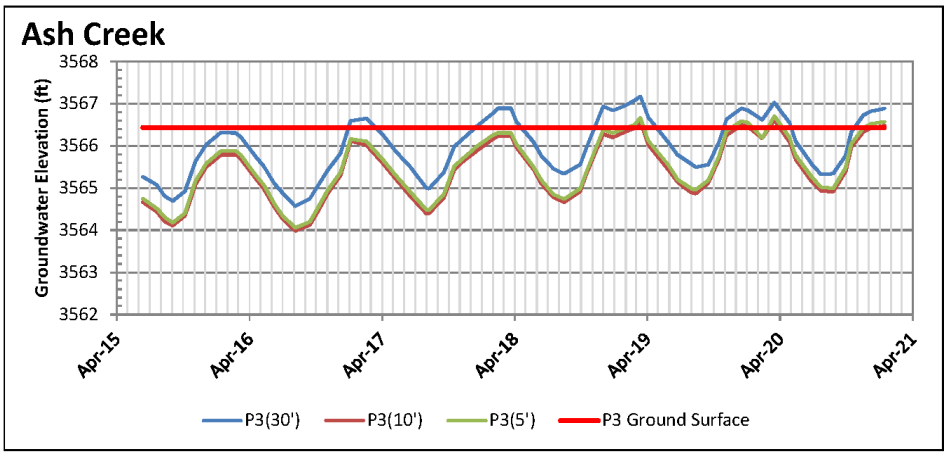


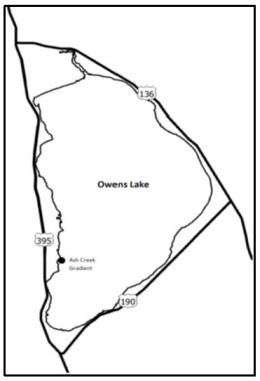
*Upward Gradient**
0.5 feet





*Upward Gradient**
1.1 feet





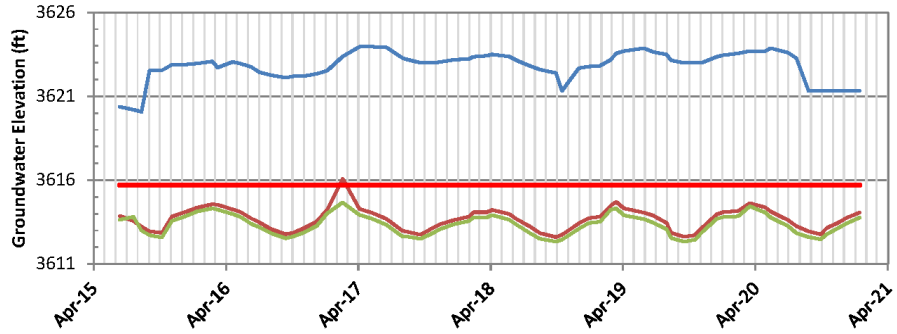
*Upward Gradient**
0.5 feet

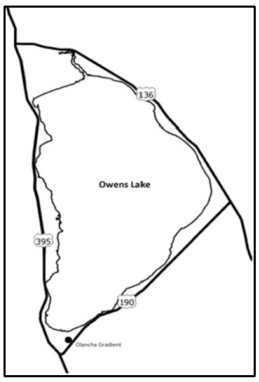
*Vertical Groundwater Gradient is the difference in groundwater level in the 30-foot deep monitoring well and 5-foot deep monitoring well at each site.

Owens Lake Groundwater Development Program

Vertical Groundwater Gradient

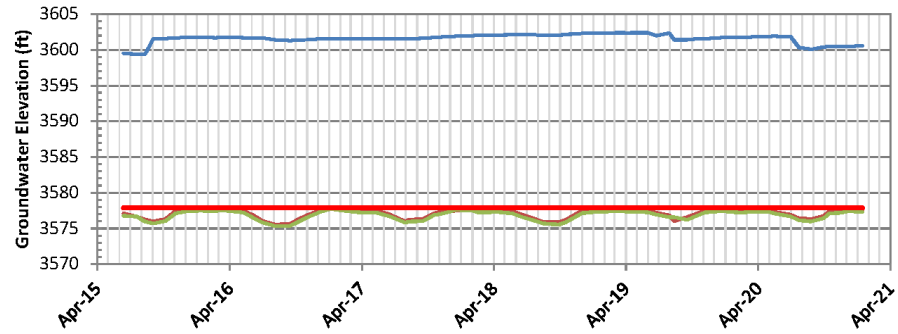
Olancha

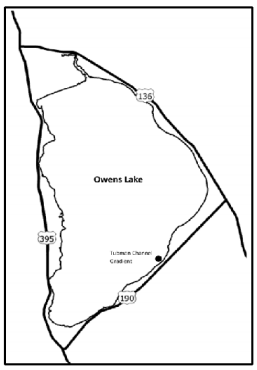




*Upward Gradient**
9.2 feet

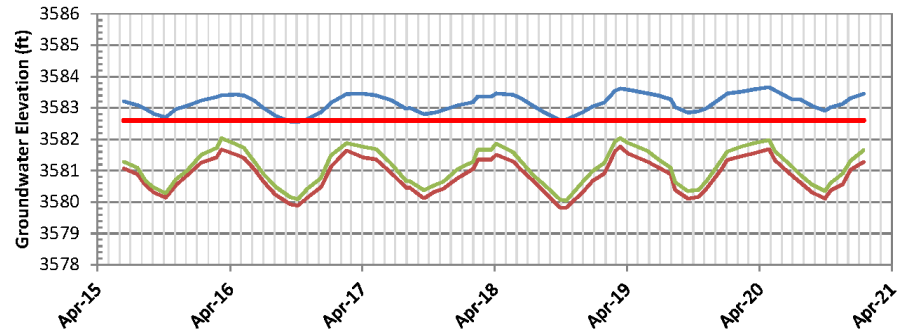
Tubman Channel





*Upward Gradient**
24.1 feet

Truckstricker



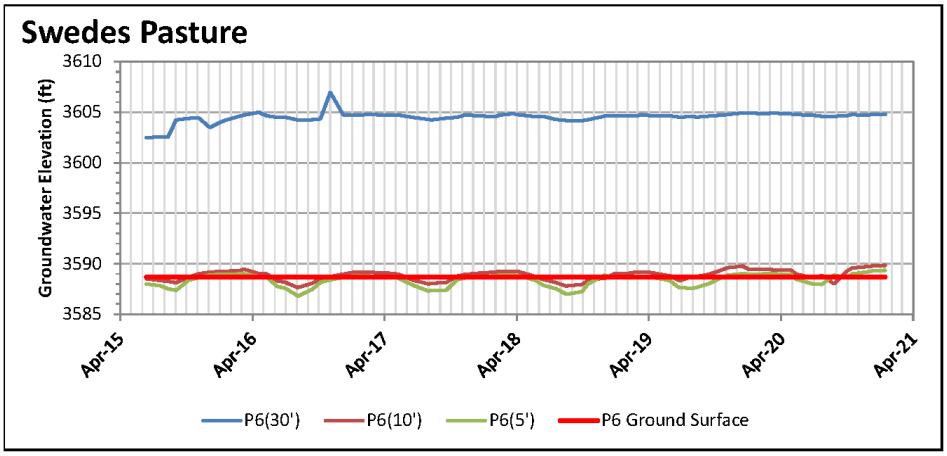


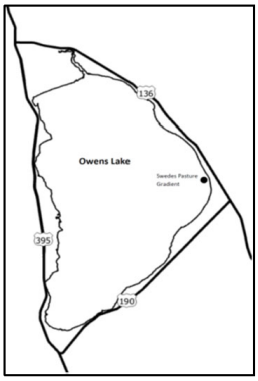
*Upward Gradient**
1.6 feet

*Vertical Groundwater Gradient is the difference in groundwater level in the 30-foot deep monitoring well and 5-foot deep monitoring well at each site.

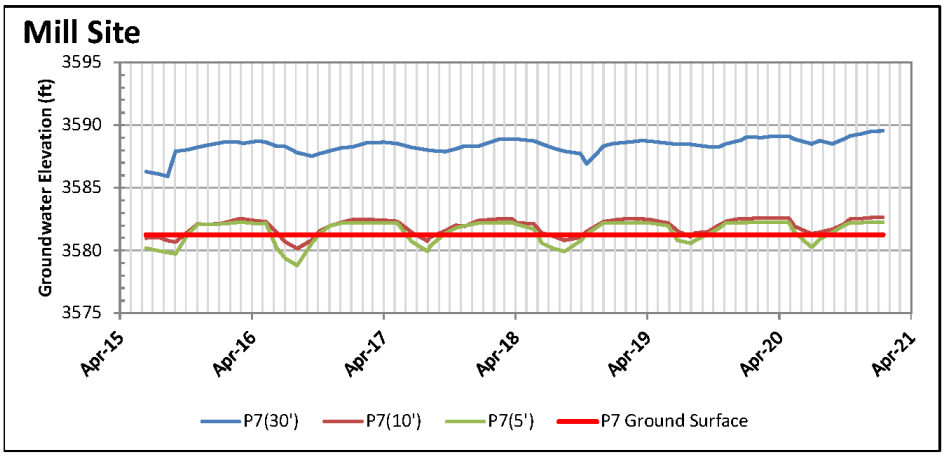
Owens Lake Groundwater Development Program

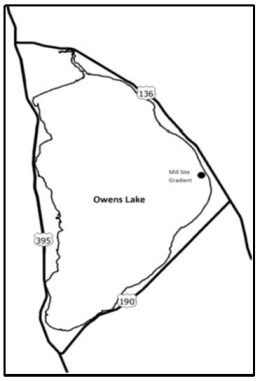
Vertical Groundwater Gradient



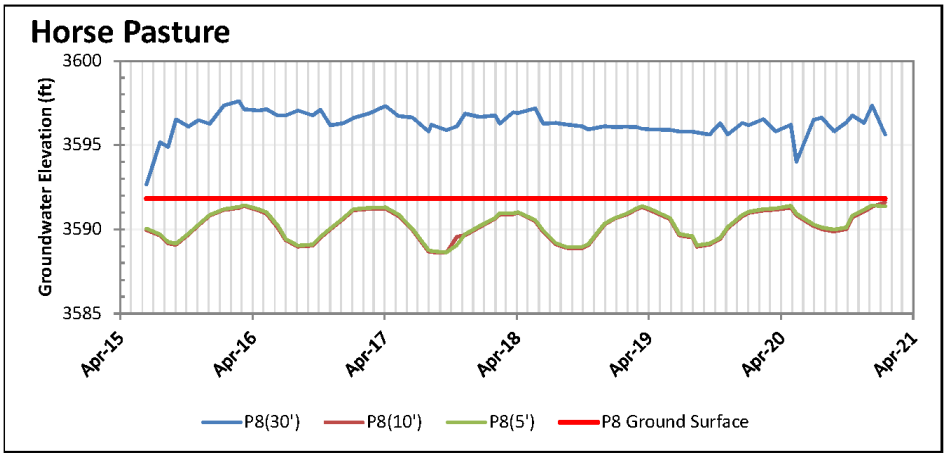


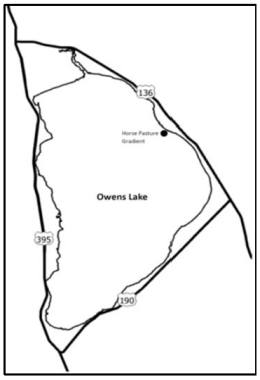
*Upward Gradient**
16.3 feet





*Upward Gradient**
6.1 feet





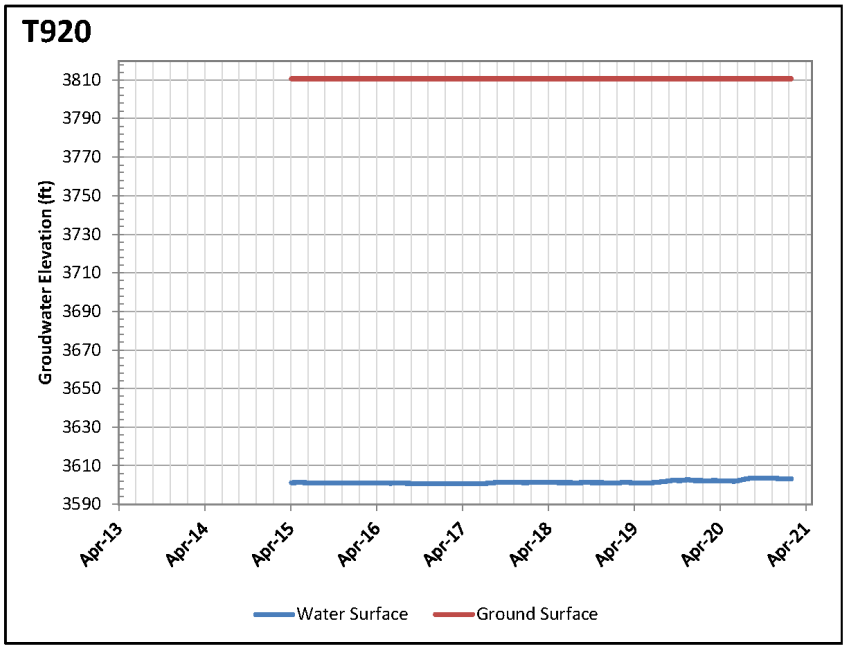
*Upward Gradient**
4.6 feet

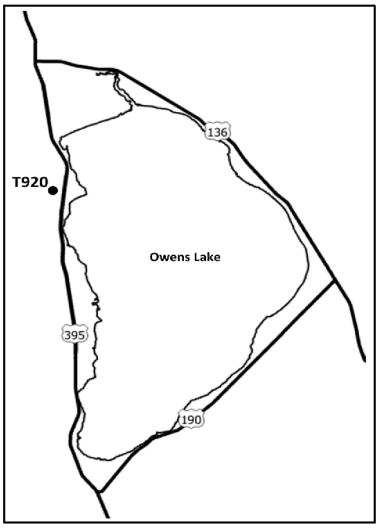
*Vertical Groundwater Gradient is the difference in groundwater level in the 30-foot deep monitoring well and 5-foot deep monitoring well at each site.

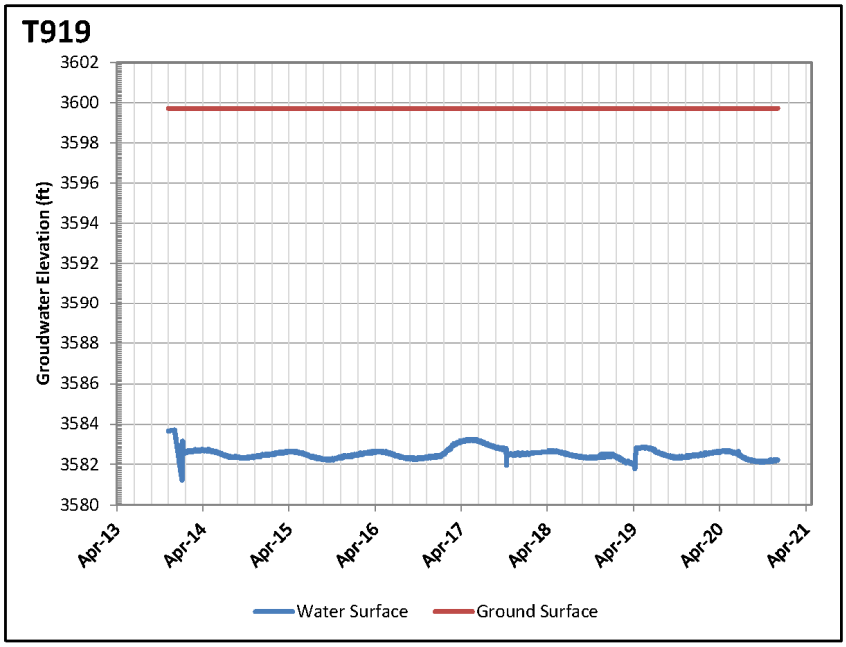
Appendix A: Trigger Wells

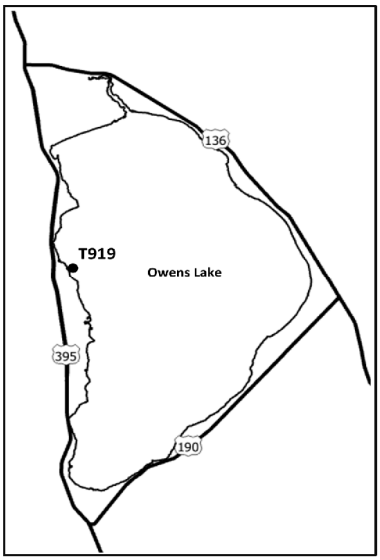
Owens Lake Groundwater Development Program

Trigger Wells



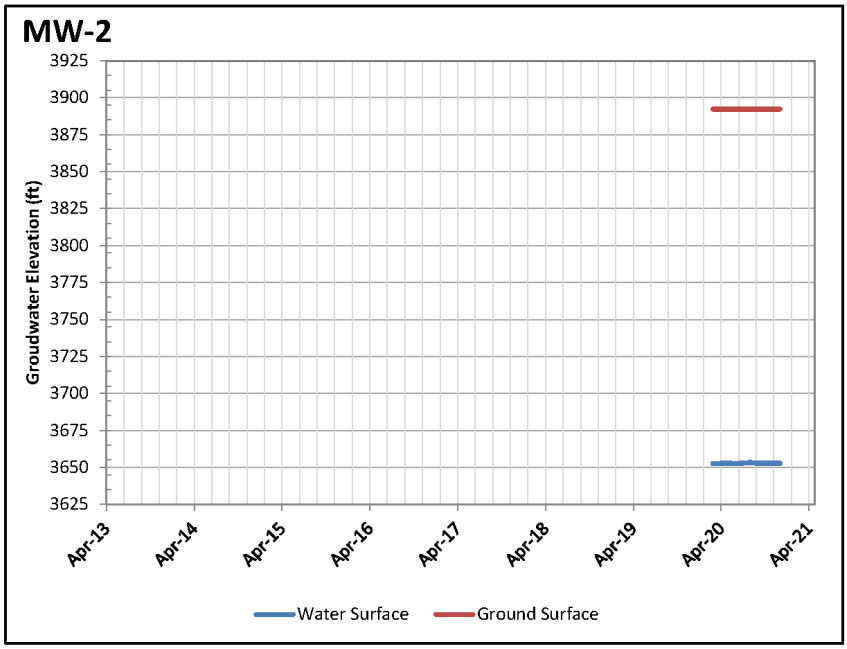


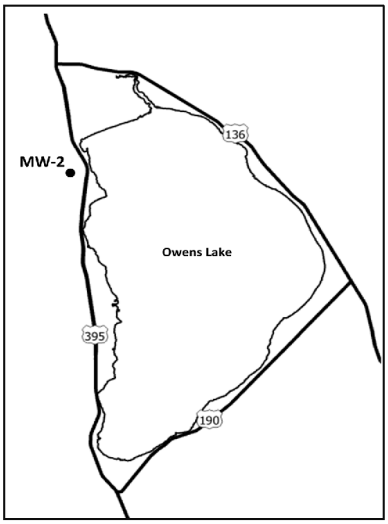


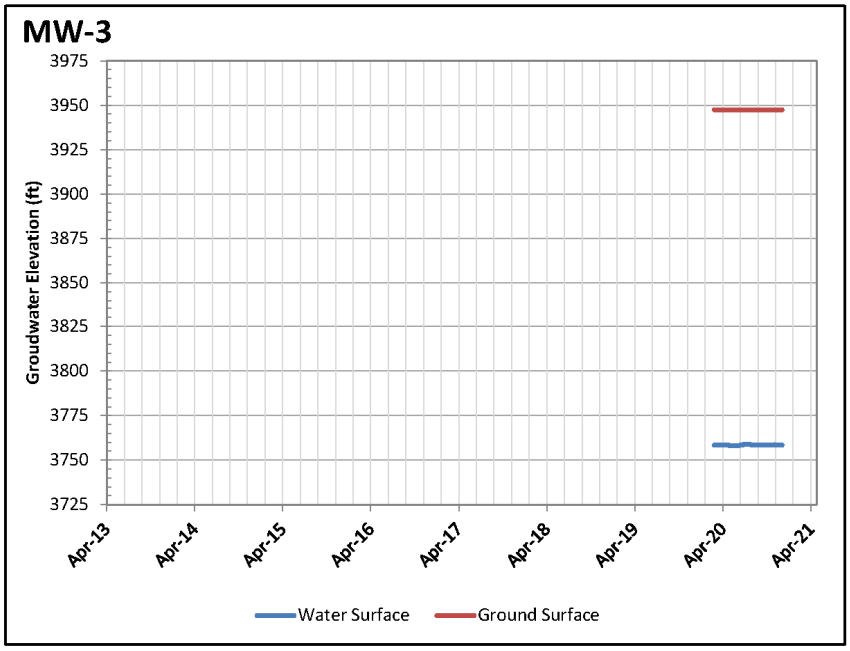


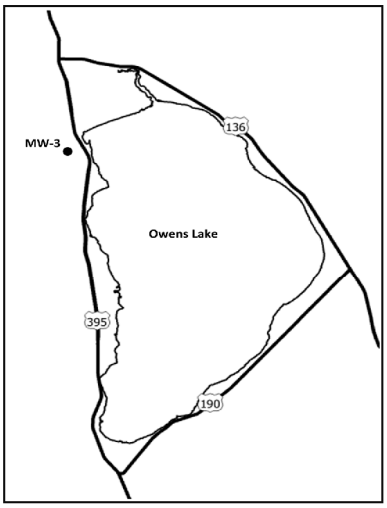
Owens Lake Groundwater Development Program

Trigger Wells



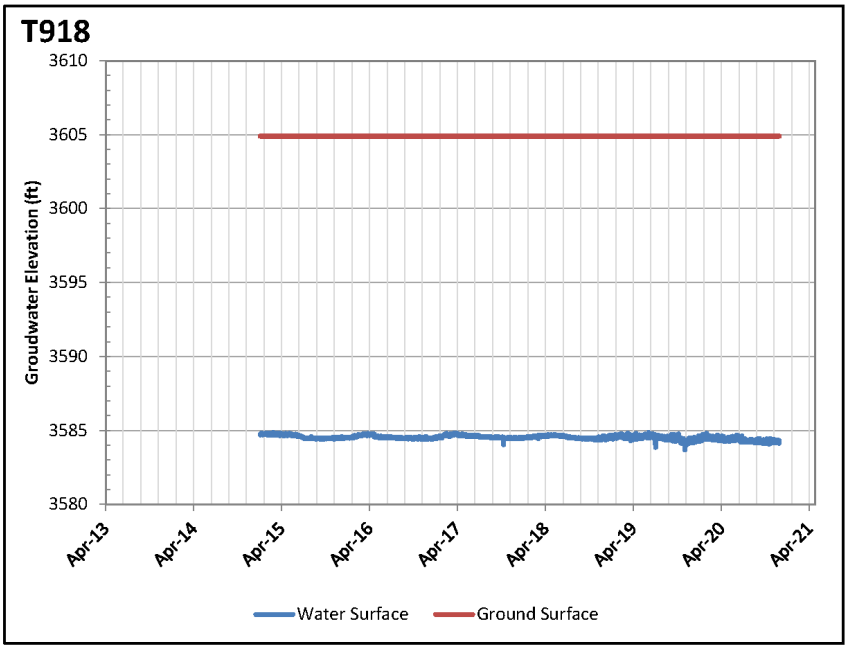


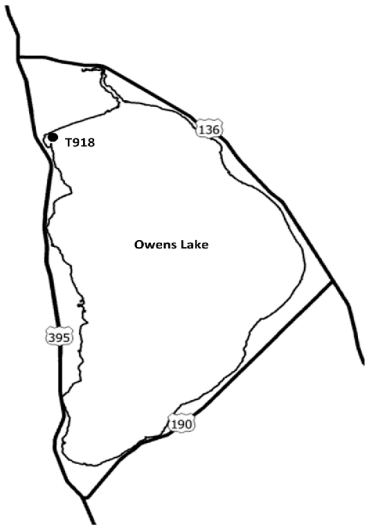


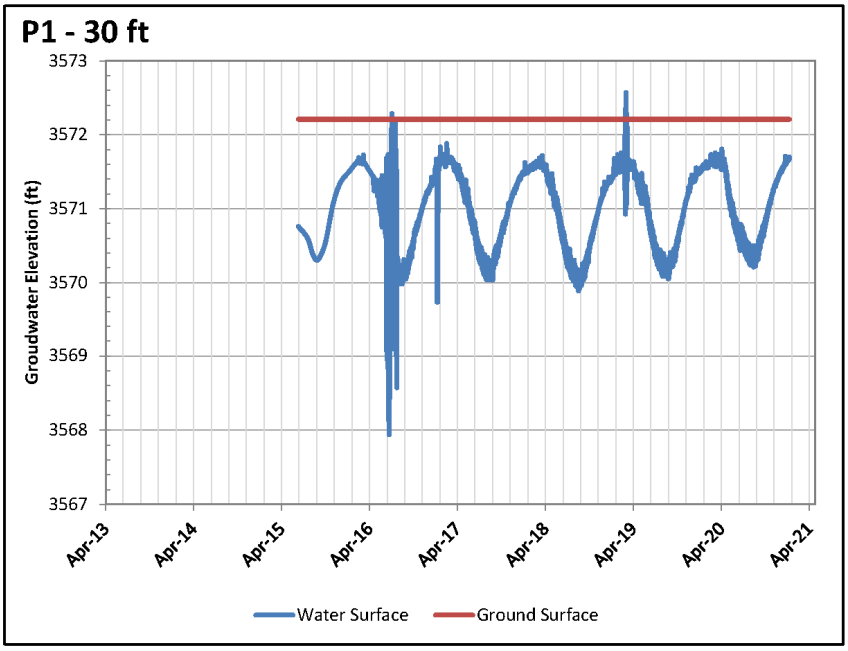


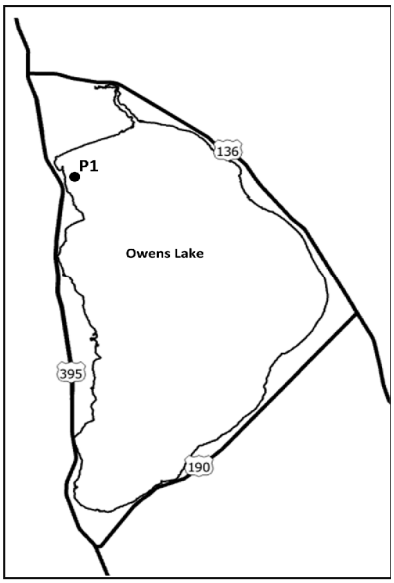
Owens Lake Groundwater Development Program

Trigger Wells



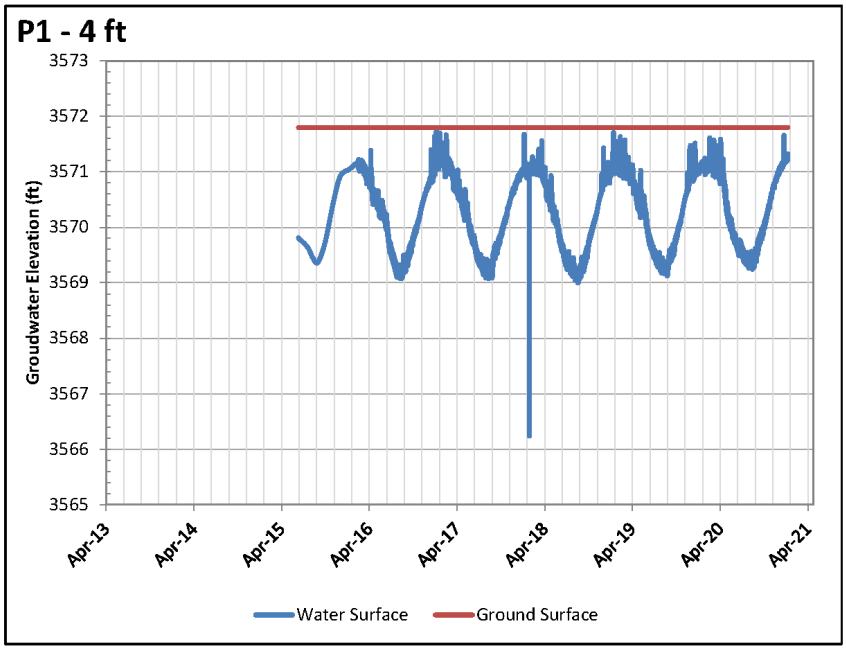


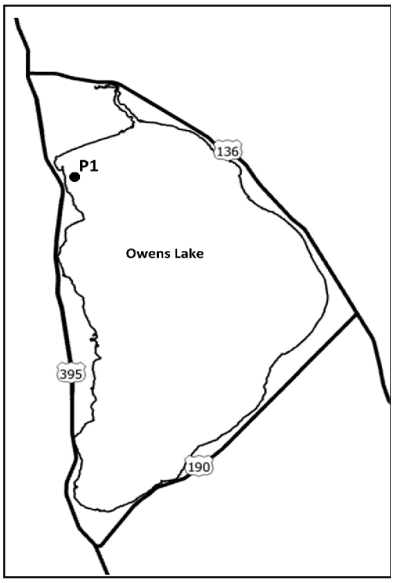


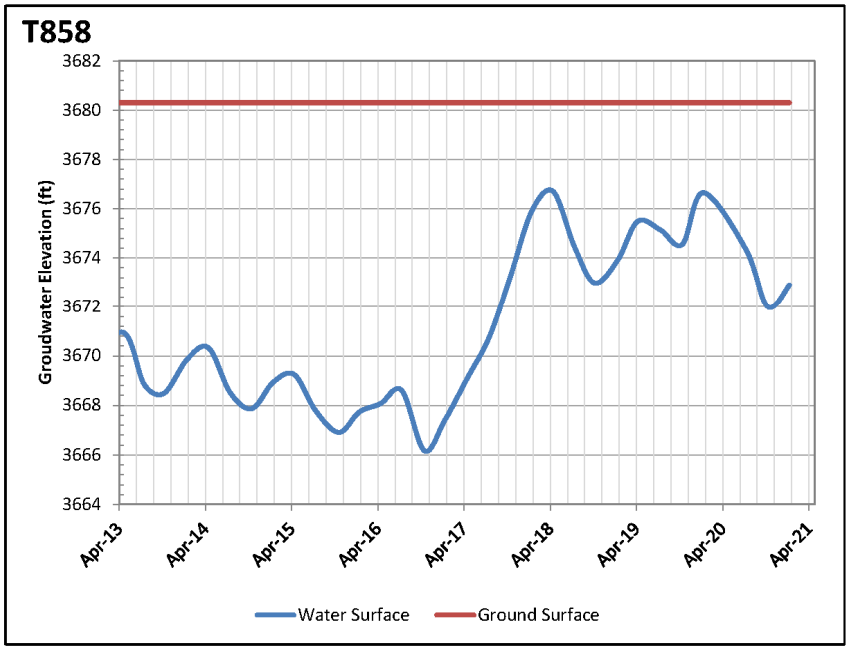


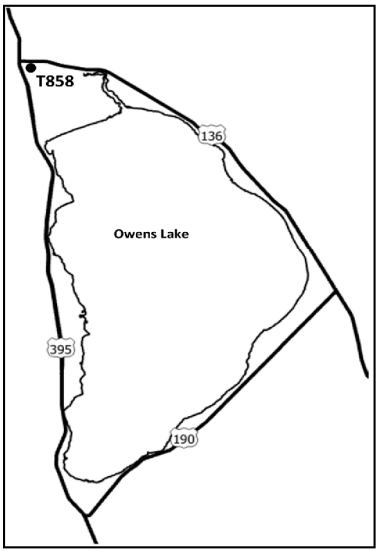
Owens Lake Groundwater Development Program

Trigger Wells



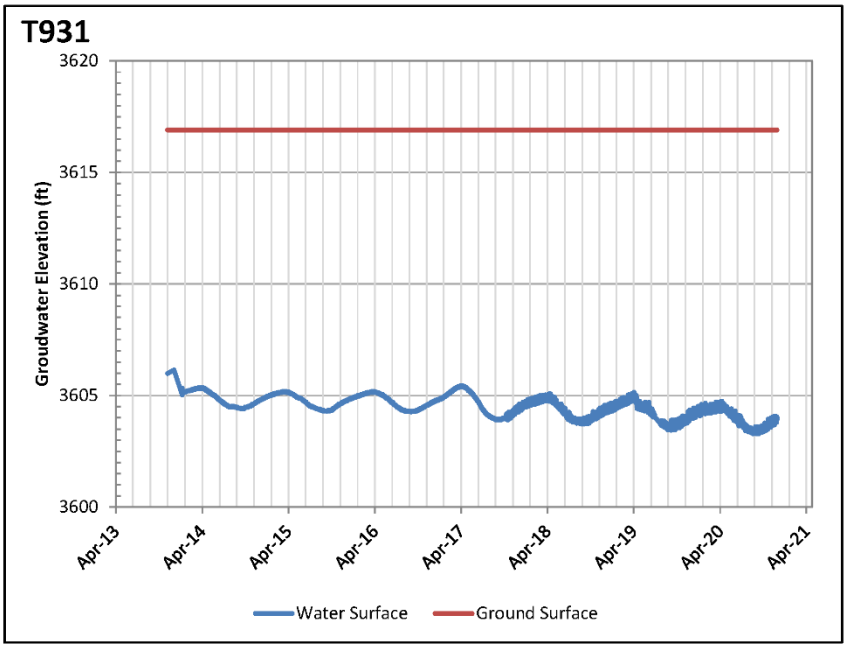


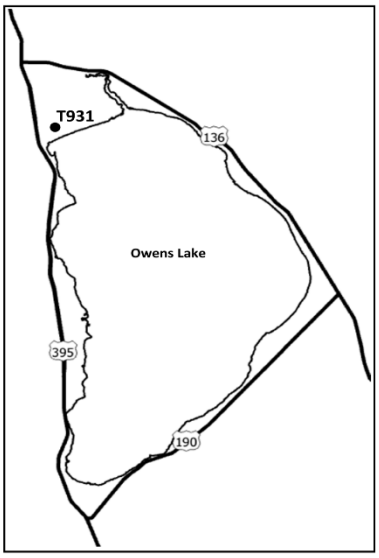


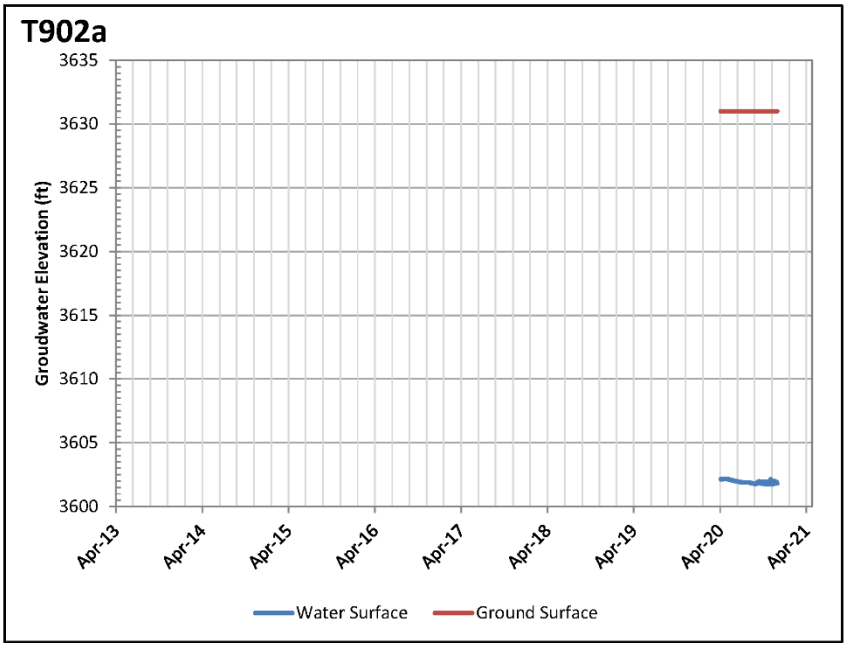


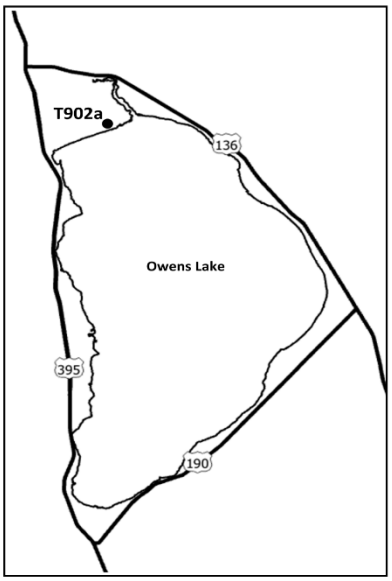
Owens Lake Groundwater Development Program

Trigger Wells



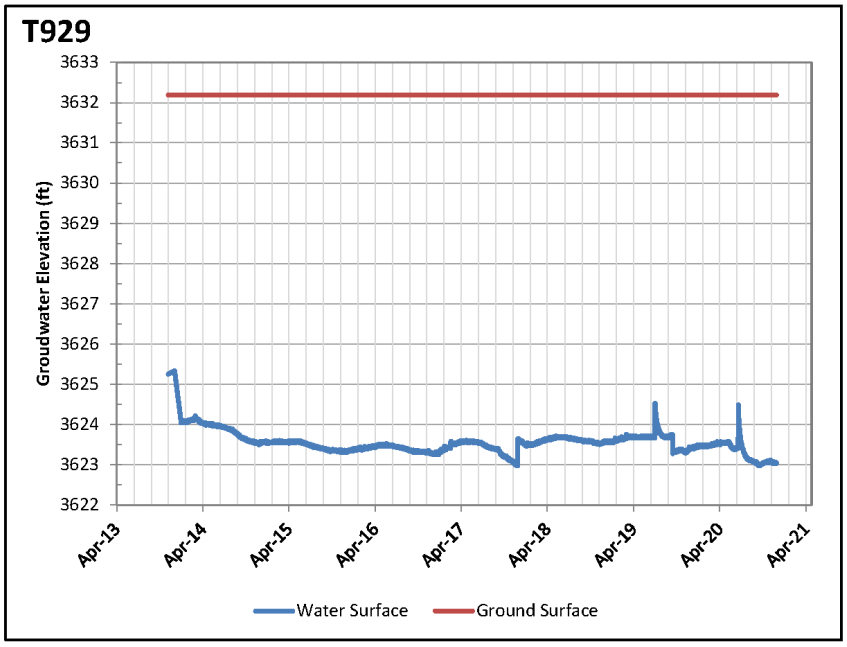


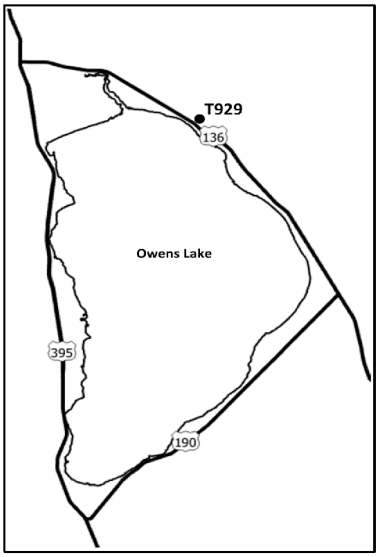


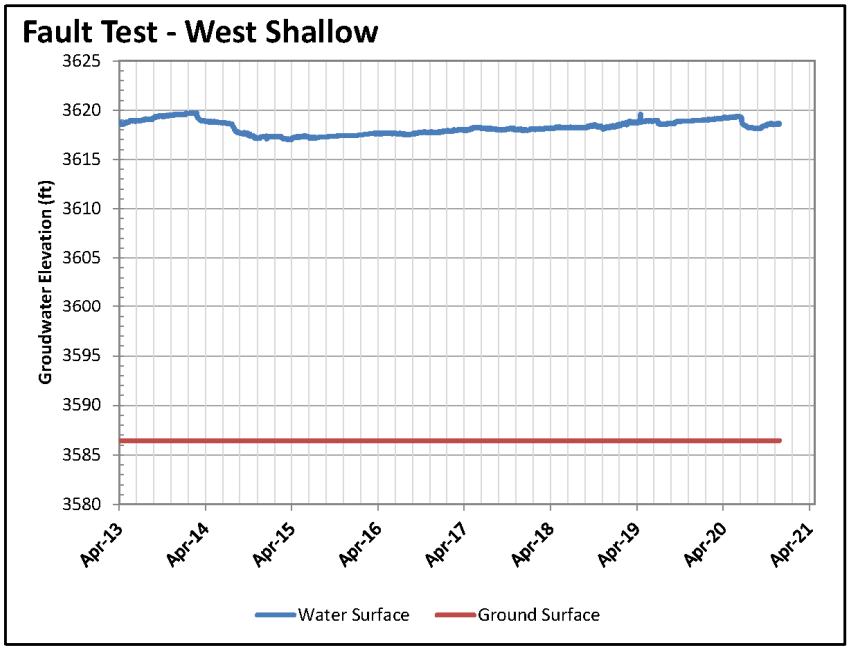


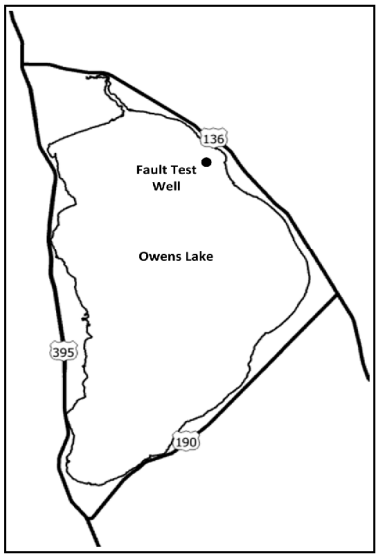
Owens Lake Groundwater Development Program

Trigger Wells



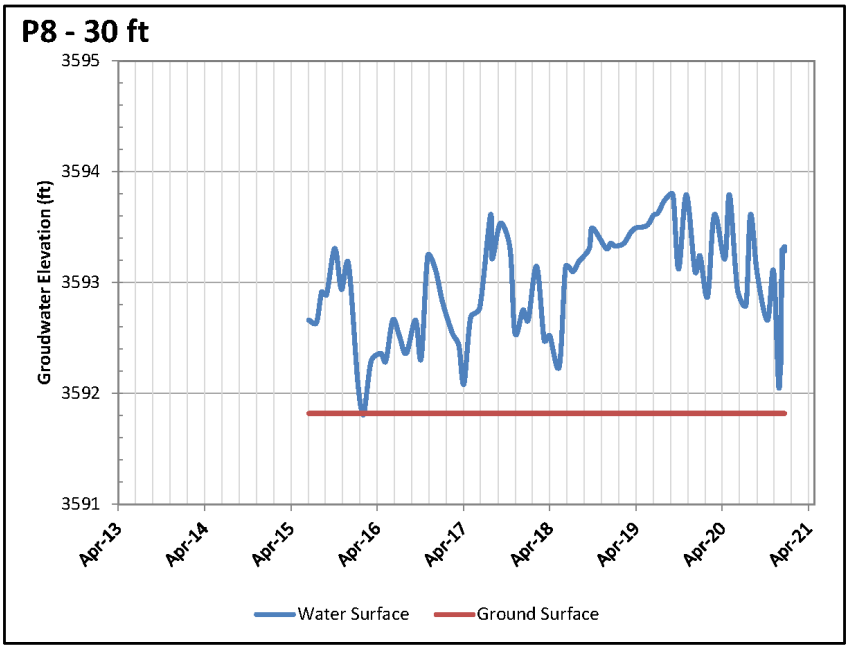


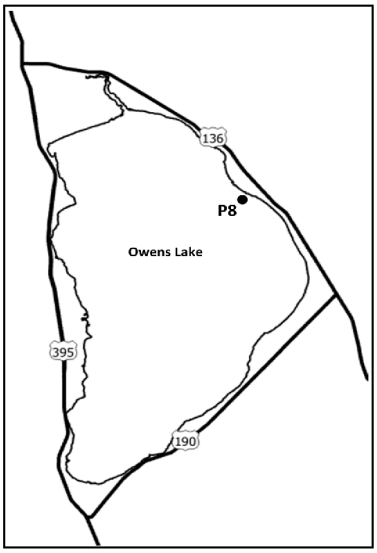


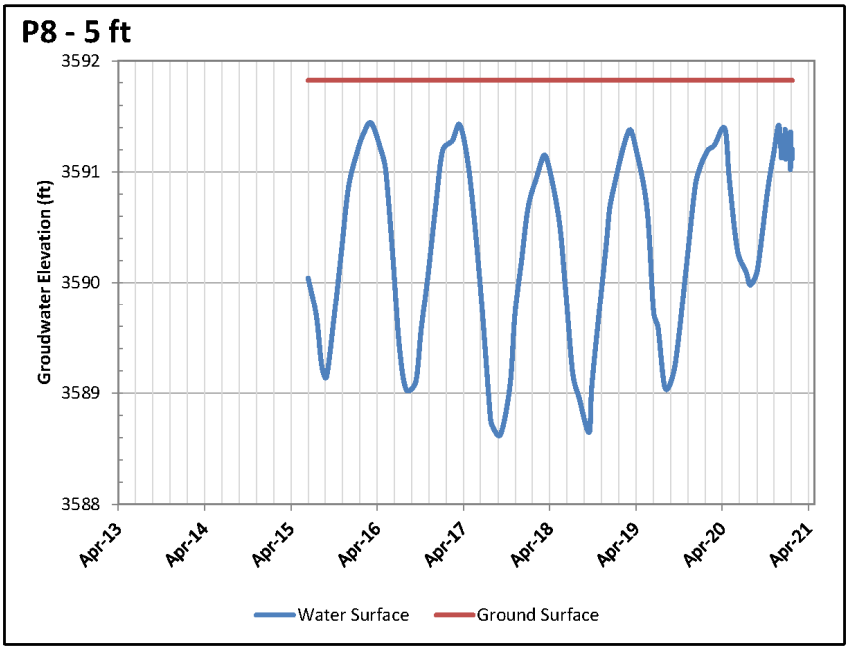


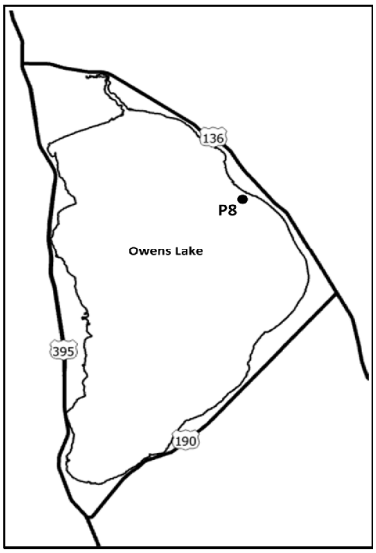
Owens Lake Groundwater Development Program

Trigger Wells









APPENDIX B

Groundwater Access and Use by *Sarcobatus* from Published Papers and Two Monitoring Wells at Owens Lake

Note:

The following table is designed to be printed on a 11X17 inch page.

Reference	Study Area	Period	Groundwater Depth	Avg. ETa (cm)	Avg Precip (cm)	Avg. ETa-Precip (cm)	Daily Water Table Oscillations	Groundwater Change Over Period	Groundwater Seasonal Change	Relationship to Plant Cover/Health/Stress	Rootzone	Conclusions
Robinson 1970	Tank expts near Winnemucca, NV	1963-1967					Observed and used to calculate GW seasonal change		*Sarcobatus* transpires 0.18-0.24 m / yr of GW			Seasonal GW use up to 24 cm
Nichols 1994	Six Great Basin sites in Nevada with 95% *Sarcobatus* vegetation (plus 1 site with sagebrush/rabbitbrush); 1192-1845 m elev	1989-1992	1.7-6.4 m; one site had GW depth of 5.8 m but perched saturated zone at 2.7 m					End of season GW depth was measured and ranged from 1.7-6.4 m	With GW at 1.8 to 12.2 m depth and equivalent plant density of 0.25 estimated GW use for 100 d period from late June-early Sept was 30.8 to 2.4 cm, respectively.	Greater cover increased GW use	Rooting depths constrained by GW but up to a maximum of 18 m	Seasonal GW use during summer depends on depth to GW and plant density. Up to 30.8 cm use reported for 100 day period with GW at 1.8 m depth.
Devitt et al. 2011	Snake Valley, Spring Valley, White River Valley, NV; 1564-1762 m elev range; 13-62% total cover (12-100 % *Sarcobatus* ; other species included rabbitbrush, sagebrush, shadscale, saltgrass); Note that one irrigated pasture (SV2b) is not included in this summary	2005-2007	12.2 -24.4 m wells; screened 3 m at first encountered GW	14.9 (growing season)	2.1 (growing season)	10.7 (does not include vadose zone stored water from non-growing season precip)	3 cm daily in some growing season months and sites	4.64-9.31 average depth across sites for 2006-2007 period; net change not reported)	Decline during growing season from late May-early September averaged 6 cm/mo. At Snake Valley sites 18 cm decline was found from late June-early Sept (2.25 mo; Fig 4)	"ET rates in 2007 were highly correlated with the percentage cover of greasewood (R^2 = 0.96), regardless of the depth to groundwater." Comparing a high precip (2005) versus low precip (2007) year at the Spring Valley site showed similar end of season stress levels of ~-4.4 MPa in August but much lower stress in the wet year in May (Fig 5). Differences in GW depth among sites did not show up as large differences in stress levels	Despite variation in GW depth from 4.6-9.3 m across sites all had ET in late summer related to *Sarcobatus* cover. This, plus observations of daily oscillations and *Sarcobatus* stress levels, suggests that this species was effective at rooting to capillary fringe at all sites, up to 9.3 m or more (see Devitt and Bird 2016 for data to 10.75 m).	Midday leaf water potential declined seasonally showing "that whatever groundwater extraction was occurring, it was not adequate to offset stress during the later periods of summer." ET was highly correlated to *Sarcobatus* cover, regardless of depth to GW. Seasonal variation of up to 30 cm possible during growing season GW decline (6 cm/mo x 5 mo) or 18 cm in 2.25 mo.
Devitt and Bird, 2016	Snake Valley NV; 1564 m elev; 13% cover (100% *Sarcobatus*)	2007-2013	12.2 m well; screen 6.2-12.2 m	22.34 (annual total; eddy co-variance)	14.57 (annual)	7.77; greater GW extraction in low precip years (range of seasonal ET provided by GW ranged from 12-55%)	Observed Sept 2007 (7 days) and Oct-Nov 2013 (32 days); range 1-5 cm/day; daily oscillations ceased with leaf senescence in early Nov 2013; observation of oscillations depended on texture i.e. sandier aquifer with higher specific yield prevented observation of oscillations for 2225 days between 2007 and 2013. Oscillations re-appeared when GW surface crossed a textural boundary into less sandy aquifer with lower specific yield.	9.2-10.7 m depth (1.5 m decline based on Fig. 1, but 1.3 m based on text statements); decline due to GW pumping for alfalfa irrigation 2.36 km away; Precip actually increased during this period	Average decline was 22.2 cm/yr over 6.2 yr period	"Observations of plant cover/health indicated no negative changes during the late summer periods of 2007–2012" despite a 1.3 m decline in GW	"Rootzone for greasewood at our site extended to at least a depth of 10·75m. All of our findings, including the groundwater oscillations, deep unsaturated zone extraction and shifts in soil water in storage based on precipitation support a very flexible and dynamic utilization of multiple water sources by greasewood."	"Our results indicate that a decline in the groundwater level of 130 cm over 6.2 years did not exceed the ability of greasewood root systems to adjust and that a depth of 10·7 m did not represent a physiological maximum for rooting depth at our site"
Wagner et al. 2018	Spring Valley, NV; 1756 m elev; total cover 45% of which 19% was *Sarcobatus* and 71% sagebrush	mid-June-mid-Oct; year not given	5.5-6.0 m below surface from mid-June to mid-Oct	22.63 (April-Sept)	8.92 (April-Sept)	13.71 (April-Sept)		0.5 m decline from mid-June to mid-Oct partly due to GW pumping for alfalfa irrigation but also due to GW use by plants	0.5 m decline from mid-June to mid-Oct partly due to GW pumping for alfalfa irrigation but also due to GW use by plants	Isotope analyses of precip, vadose zone water, groundwater, and shrub stem water showed that *Sarcobatus* shifted from 30 % GW use in July to 2 % in Sept suggesting at this site that it was not acting as a phreatophyte in late summer; Conversely, *Sarcobatus* shifted from using deep, vadose zone water (90-180 cm depth) at 38% in July to 97% in Sept. This saline soil moisture could be used by *Sarcobatus* because of its salt tolerance but was not extracted by the less salt-tolerant sagebrush and rabbitbrush. Leaves of *Sarcobatus* had midday water potentials as low as ~ -5 MPa by July and remained at this level through end of September.	To 6 m for *Sarcobatus* ; other shrubs more restricted to vadose zone above high salinity layer at 140-180 cm depth	*Sarcobatus* decreased GW use in late summer and increased uptake from a saline, vadose zone layer at intermediate depth (90-180 cm). "Greasewood demonstrated plasticity in accessing different water sources" over time.
Elmore et al. 2003	Owens Valley	1984-1998	171 monitoring wells		13			variable from none to more than -7 m		For shrub communities the relationship in Fig 7b shows a possible loss of 25.5 % cover with a 7 m decline in GW level from 1986-1992 during an extended precipitation drought period	Variable among communities and locations.	Based on Fig 7b, a decline of 1.1 m in GW level from 1986-1992 would be needed to produce a detectible change in live cover (given the error reported of +/- 3.8 %). Smaller changes in GW level (over multiple years) are unlikely to cause any detectible change in cover of GW dependent shrub communities
Steinwand et al. 2006	Owens Valley; sites used for this summary are shrub dominated sites, especially desert shrub sink (DSS communities dominated by *Sarcobatus* and rabbitbrush or saltbush dominated communities)	2000-2003	Access tubes installed in spring and nearby piezometers for determination of fluctuations	Growing season (26 Mar-15 Oct) ET for DSS sites were 108 and 205 mm for 2002 and 2003 (wetter preceding winter), respectively	10-15	For shrub dominated sites GW supply to growing season ET was 21-33% or 11-51 mm; For 4 shrub dominated communities growing season GW use per unit spring maximum LAI ranged from 40-140 mm	Yes, but not reported for DSS communities	3.9-4.1 m for scrub sites with connection to GW; Similar spring GW depth at the beginning of each year	Seasonal decline from spring to fall; in low cover scrub communities up to 20 cm seasonal change was observed	Fig. 7 shows GW use (annual ET - precip) increasing from 50 - 840 mm as cover increased from 10 -70% and decreasing from 840 - 50 mm as depth to water increased from 0 - 5 m.	GW use per unit spring maximum LAI varied 10 fold from ~40 to 400 mm as GW depth varied from > 5 to 1.3 m across sites, respectively (Fig 6)	Growing season daily fluctuations could be an indicator of GW use (but see Devitt and Bird 2016 who suggest this is influenced by aquifer texture and specific yield). Estimates of annual ET minus precipitation (i.e. GW use), as shown "in Fig. 7 could substitute for poorly defined or arbitrary functions in models for regions dominated by these plant communities.
Trent et al. 1997	Eagle Valley, NV. 1234 m elev	1991-1992	Eight 3-m- deep, perforated access tubes were monitored monthly		11.5 cm (1991 =14.6 cm and 1992 = 9.6 cm)		Not determined (monthly observations only)	1991 May -Oct GW declined from 1.7-2.5 m; By 1992 Jun GW was > 3 m	0.8 m decline during first season;	*Allenrolfea* and *Sarcobatus* maintain similar leaf xylem potentials from a low-precipitation year with a water table depth remaining above 3 m to a dry year when the water table drops below 3 m.	Most roots in 30-60 cm deep soils but some to 150 cm. GW EC ranged from 18-25 dS/m, well within tolerance of both shrub species.	"Years of high soil moisture result in low water- use efficiencies [for both shrub species]. In contrast to this, plants have the ability to reduce leaf conductance and increase water-use efficiencies in low-precipitation years. This allows the plants to maintain predawn and afternoon water potentials, which vary little from high- to low-precipitation years in these saline environments."
Toft 1995	Mono Lake, CA; 1966 m elev.; *Chrysothamnus nauseosus* ssp. *consimilis* was monitored in an area co-dominated with *Sarcobatus* ; *Sarcobatus* not censused because of difficulty in determining genetic individuals.	1983-1992	Clover test hole 2 (LADWP well 55) and the Dreiss test hole 5A and Mono Lake elevation		16.0 cm		Not determined (monthly or less frequent observations only)	1983-1985 declined ~ 1 m; 1986-1992 during major drought period GW declined another 1.4-1.7 m (Fig 3 D & E)		1983-1985 with GW decline of 1 m resulted in no mortality and no decrease in canopy size; 1986-1992 with further GW decline some mortality and reduced growth began in 1987 but reached maximum only after several years of GW decline (Fig 3 A & B). Smaller shrubs and shrubs growing higher on dunes (farther from GW level) had greater risk of reduced growth or mortality.	Rooting depth up to 6 m, estimated.	"Thus, the larger the shrub, the less the risk it had of dying during the study. To a lesser degree, the higher the elevation (i.e., the farther from ground water) the greater the risk of dying, although this effect was much weaker than that of size and only marginally significant." "The years of drought (1987-1990) were characterized by higher mortality of individuals in this population and by no known replacement of those individuals." Growth reduction and mortality was not initiated until more than 1 m of GW drawdown over multiple years.

Reference	Study Area	Period	Groundwater Depth	Avg. ETa (cm)	Avg Precip (cm)	Avg. ETa-Precip (cm)	Daily Water Table Oscillations	Groundwater Change Over Period	Groundwater Seasonal Change	Relationship to Plant Cover/Health/Stress	Rootzone	Conclusions
Toft and Frazier 2003	Mono Lake, CA; 1966 m elev.; *Chrysothamnus nauseosus* ssp. *consimilis* was monitored in an area co-dominated with *Sarcobatus* ; *Sarcobatus* not censused because of difficulty in determining genetic individuals.	1983-2001	Clover test hole 2 (LADWP well 55) and perforated access tubes at lagoon and dune sites.		16.0 cm		Not determined (monthly or less frequent observations only)	1984 3.7 m depth at beginning of drought period. Minimum was 5.8 m depth in 1992 with recovery to 4.1 m in 1998.		Mortality and growth decline occurred through the drought period, especially for smaller plants (see Toft 1995). Larger plants (>70 cm diameter), however, were essentially 'immortal' with no detectable mortality and they flowered every year of the 17 year study that included a major, multi-year drought. The canopy size of these plants did decline slightly during the drought but recovered as GW levels rose after the drought. (Fig 2)	Rooting depth up to 6 m, estimated.	"The minimum size of shrub able to access deep soil moisture reliably was apparently ~25–30 cm of canopy diameter (Fig. 4), which was also the threshold size of flowering." Shrubs larger than 70 cm diameter were able to tolerate the 2.1 m variation in GW depth observed during this 17 yr study. These long established, large adult shrubs adjusted to a 2.1 m decline in GW level during multi-year drought with small declines in canopy size and recovered to initial sizes afterward. They showed no mortality and flowered every year. This range of variability in GW level (up to 2.1 m) can be tolerated by these phreatophytic dune species with no impact on the plant community resource.
T931 hydrograph	Owens Lake, CA, near VDA01; 3617 ft (1102.4 m) elev; dense, high cover shrub vegetation of *Sarcobatus* and several other species in vicinity of the well.	Nov 2013-Apr 2019	62 ft deep well with perforation from 27-57 ft.				Yes, in 2019 when monitored hourly; late April 2019 showed daily oscillations of up to 0.14 ft.	Average GW depth for the period was 12.09 ft below ground surface. Depth increased from 13.93 ft in Dec 2013 to the maximum depth of 16.17 ft near the end of the drought period in Sept 2017 with recovery to a minimum of 11.76 ft in early April 2019.	Seasonal decline from March to September was 0.91, 0.84, 0.81, 1.38 ft for 2014, 2015, 2016, 2017, respectively. In 2017 the minimum spring depth was later, in May, making the seasonal decline 1.80 ft from May to September.			Daily fluctuations of up to 0.14 ft observed. Seasonal decline of 0.81-1.80 ft observed during the growing season.
Keeler Landfill Monitoring Piezometer	Owens Lake, CA, near VDA08; 3606 ft (1099.1 m) elev; dense, high cover shrub vegetation of *Suaeda* and *Sarcobatus* in vicinity of the well.	Mar 1999-Nov 2017	25 ft deep well with perforation from 20-25 ft.				Not determined (spring and fall observations only)	Average GW depth for the period was 8.14 ft below ground surface. Lowest levels were 9.76 ft in Dec 2000 and 9.37 ft in September 2017. Shallowest depth was 6.98 ft in May 2005.	Seasonal decline was observed from spring (generally Mar-May) until fall (Sept-Nov) in all 18 years, although the dates of monitoring were not completely consistent. Average growing seasonal decline was 1.15 ft (35.1 cm). Minimum decline was 0.11 ft (in 2008 and the highest declines were seen in 2003 (2.10 ft) and 2017 (1.81 ft).			Seasonal decline of 0.11-2.10 ft observed during the growing season (18 of 18 years of record).