Appendix G2

Technical Memorandum: Groundwater

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THE METROPOLITAN WATER DISTRICT
OF SOUTHERN CALIFORNIA

Pure Water Southern California

Technical Memorandum: Groundwater

September 5, 2024

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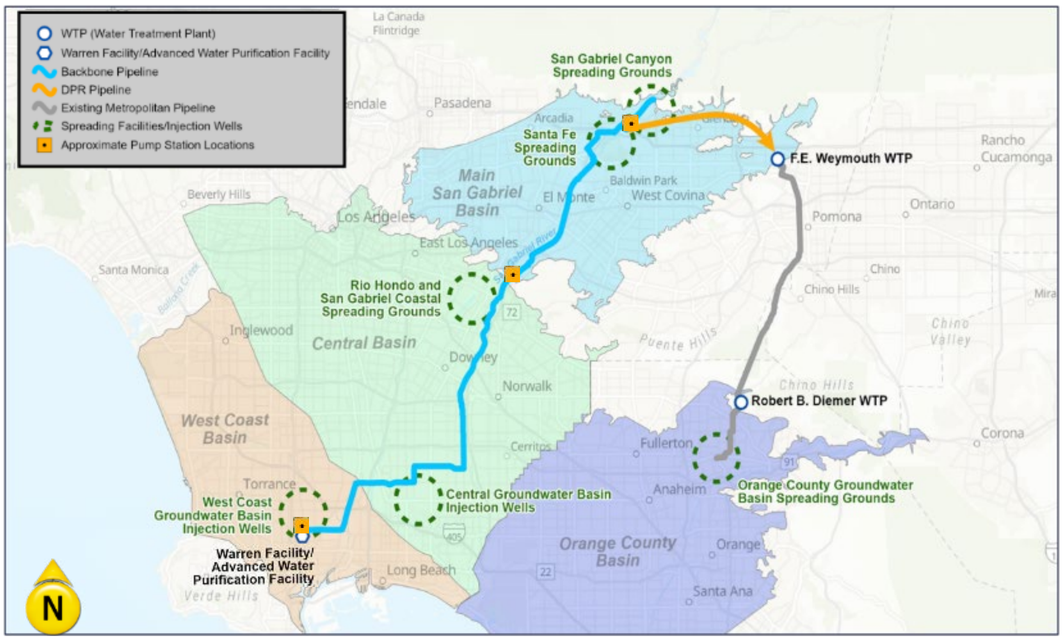
Introduction

This Technical Memorandum (Groundwater Tech Memo) provides an overview of the hydrogeologic conditions, groundwater recharge facilities, and modeling performed for the groundwater basins that would be served by Pure Water Southern California (Pure Water or Program), as shown in **Figure 1**. Pure Water is a proposed partnership between The Metropolitan Water District of Southern California (Metropolitan) and the Los Angeles County Sanitation Districts (Sanitation Districts) to beneficially reuse cleaned wastewater that currently is being discharged to the Pacific Ocean from the Sanitation Districts' A.K Warren Water Resource Facility (Warren Facility) in the city of Carson. The cleaned wastewater would be purified through a new Advanced Water Purification (AWP) facility constructed to produce approximately 150 million gallons per day (mgd) of purified water (up to 155,000 acre-feet per year or AFY) that is conveyed via new conveyance facilities to four groundwater basins (**Figure 2**) for groundwater replenishment and to existing water treatment plants for raw water augmentation.

Figure 1: Pure Water Project Area

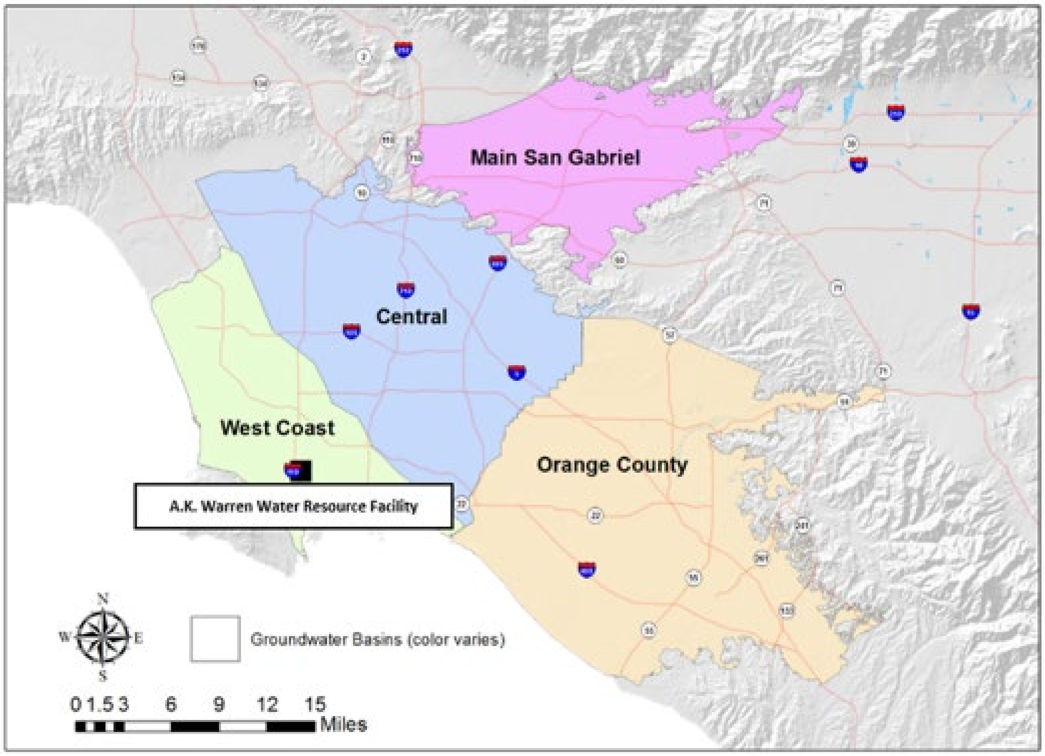


The purpose of this Groundwater Tech memo is to:

- Provide an overview of basin governance for each of the four groundwater basins,
- Discuss the hydrogeologic setting for each of the four groundwater basins,
- Describe the water quality constraints of each basin,
- Summarize groundwater modeling that has been performed to date, and
- Evaluate the impacts to the four groundwater basins of the Program.

The technical analyses herein do not include groundwater quality impacts of introducing Pure Water into groundwater basins. Detailed water quality studies will be performed as part of the tracer study analysis and are therefore not included in the document. General water quality information regarding current conditions is provided. Technical references for this technical memorandum are provided in Appendix A.

Figure 2: Groundwater Basins to be Served by Pure Water



Main San Gabriel Basin

Basin Governance

The Main San Gabriel Basin, shown in **Figure 2**, is an adjudicated basin. The Main San Gabriel Basin Judgment was recorded in January 1973. The Judgment adjudicated water rights; developed the concept of operating safe yield; established assessments to pay for administration, replenishment, and management programs; and created the Main San Gabriel Basin Watermaster.

The Watermaster is a nine-person board appointed by the Los Angeles County Superior Court that administers and enforces the provisions of the Main San Gabriel Basin Judgment, which established water rights and responsibility for efficient management of the quantity and quality of the Basin's groundwater. The Watermaster manages and controls the withdrawal of groundwater/surface water and replenishment of imported water supplies in the basin and determines the amount that can be safely extracted. The Watermaster manages imported water deliveries and recharge and coordinates local involvement in efforts to preserve and restore the quality of groundwater in the basin. The Watermaster assists and encourages regulatory agencies to enforce water quality regulations affecting the basin; collects production, water quality, and other relevant data from producers; prepares an annual report of pumping and diversions; and prepares a Five-Year Plan to address water quality management.

Any entity, public or private, desiring to spread and store supplemental water within the basin for subsequent recovery and use for Watermaster credit must have a cyclic storage agreement pursuant to Watermaster's Rules and Regulations. Cyclic storage agreements are for a term of five years and may extend for additional terms, not to exceed five years. The cyclic storage agreement notes the maximum amount of supplemental water that may be stored at any point in time by a particular storing entity.

Hydrogeologic Setting

The Main San Gabriel Basin is bounded by the San Gabriel Mountains to the north, San Jose Hills to the east, Puente Hills to the south, and by a series of hills and the Raymond Fault to the west. The watershed is drained by the San Gabriel River and Rio Hondo, a tributary of the Los Angeles River.

Principal water-bearing formations of the basin are unconsolidated and semi-consolidated sediments, which range in size from coarse gravel to fine-grained sands. The surface area of the groundwater basin is approximately 167 square miles. The freshwater storage capacity of the basin is estimated to be about 8.6 million acre-feet (AF) (Main San Gabriel Watermaster 2023). **Table 1** provides a summary of the hydrogeologic parameters in the Main San Gabriel Basin.

Table 1: Summary of Hydrogeologic Parameters of Main San Gabriel Basin

Structure		Yield and Storage	
Aquifer(s)	Unconfined	**Natural Safe Yield**	152,700 AFY
Depth of groundwater basin	800 to 1,600 feet below mean sea level (MSL)	**Operating Yield**	150,000 AFY
Thickness of water-bearing units	300 to 2,000 feet	**Total Storage**	8.6 million AF
		Unused Storage Space	~145,000 AF

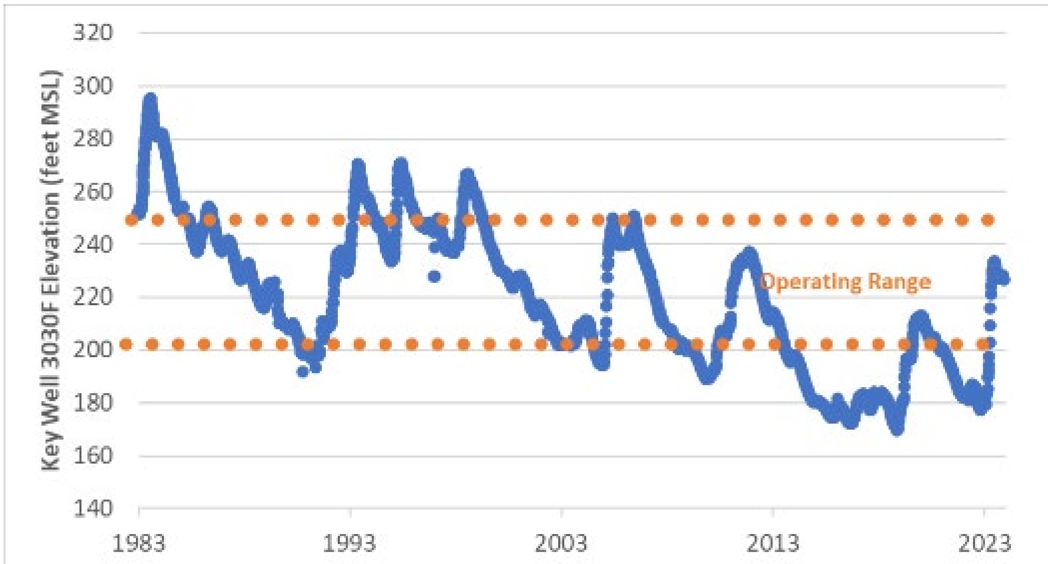
Source: Metropolitan 2007; Main San Gabriel Watermaster 2022a, Main San Gabriel Watermaster 2023.

The major sources of natural recharge to the Main San Gabriel Basin are infiltration of rainfall on the valley floor and percolation of runoff from the adjacent mountains in spreading basins. The Main San Gabriel Basin also receives imported water and return flow from irrigation. Average groundwater recharge over the past 10 years in the Main San Gabriel Basin is about 47,000 AFY, about half of the historical average (Main San Gabriel Watermaster 2022a).

About 85 percent of Main San Gabriel Basin demand is satisfied by local groundwater, 10 percent from treated imported water, and five percent from other local supplies (Metropolitan 2007). Groundwater pumping over the past 10 years has averaged about 210,000 AFY in the Main San Gabriel Basin, with an average operating safe yield of 163,000 AFY. Each year, the Watermaster determines the operating safe yield, which is the amount of water that can be pumped into the basin without incurring a replenishment obligation. The current operating safe yield in the basin is 150,000 AFY (Main San Gabriel Watermaster 2022a; Main San Gabriel Watermaster 2022c).

As a result of reduced groundwater recharge over the past 10 years, water levels in the Baldwin Park key well dropped 58 feet between 2019 and 2022, as shown in **Figure 3**. However, due to increased storm flows since the beginning of the 2023 water year (October 2022 to September 2023), water levels in the key well have increased by over 53 feet.

Figure 3: Hydrograph of Baldwin Park Key Well



Recharge Facilities

About 17 spreading basins in the Main San Gabriel Basin cover more than 1,100 acres, which are operated by the Los Angeles County Department of Public Works (LACDPW) or other agencies capable of capturing storm-water runoff from adjacent canyons and/or imported water. The spreading capacity of existing facilities is more than 850 cubic feet per second (cfs), or 457 mgd. The details of these facilities are summarized in **Table 2.**

Water Quality Issues

Table 3 provides a summary of the Los Angeles Basin Plan objectives for the Main San Gabriel Basin. Three areas of the Main San Gabriel Basin are Superfund Sites. To manage the cleanup more easily, the Superfund Sites have been split into smaller sections called “operable units” (OUs). In the Main San Gabriel Basin there are five OUs. Volatile organic compound (VOC) contaminants such as trichloroethylene (TCE), tetrachloroethylene (PCE), perchlorate, N-nitrosodimethylamine (NDMA), and 1, 4- dioxane impact Whittier Narrows, Baldwin Park, and El Monte areas and are being remediated in the groundwater of the associated OUs.

Table 2: Summary of Spreading Basins in the Main San Gabriel Basin

Basin	Area (acres)	Wetted Area (acres)	Recharge Capacity (cfs)	Source Water	Owner
Ben Lomond	24	17	30	Runoff	LACDPW
Big Dalton	24	8	12	Runoff	LACDPW
Buena Vista	10	6	6	Runoff	LACDPW
Citrus	19	15	28	Runoff	LACDPW
Eaton Basin	16	10	10	Runoff	LACDPW
Fish Canyon	6	4	7	Runoff	California-American Water Company
Forbes	21	10	5	Runoff Imported	LACDPW
Irwindale/Manning	62	30	60	Runoff Imported	LACDPW
Little Dalton	14	5	15	Runoff Imported	LACDPW
Peck Road	157	105	25	Runoff	LACDPW
San Dimas Canyon	22	11	12	Runoff	LACDPW
San Gabriel Canyon	165	140	50	Runoff Imported	LACDPW
San Gabriel River	196	196	180	Runoff Imported	LACDPW
Santa Fe	338	168	400	Runoff Imported	LACDPW
Sawpit	12	4	12	Runoff	LACDPW
Valley Rubber Dam	60	60	0	Runoff Imported	LACDPW
Walnut	16	8	5	Runoff	LACDPW
Total	**1162**	**797**	**857**		

Source: LACDPW 2006

Figure 4 illustrates the locations of the contamination plumes throughout the basin (Main San Gabriel Watermaster 2022a). The areas noted as “less than MCL” on each of the figures represent concentrations that are greater than 50 percent and less than 100 percent of the maximum contaminant level (MCL).

Table 3: Basin Plan Water Quality Objectives and Constituents of Concern for Main San Gabriel Basin

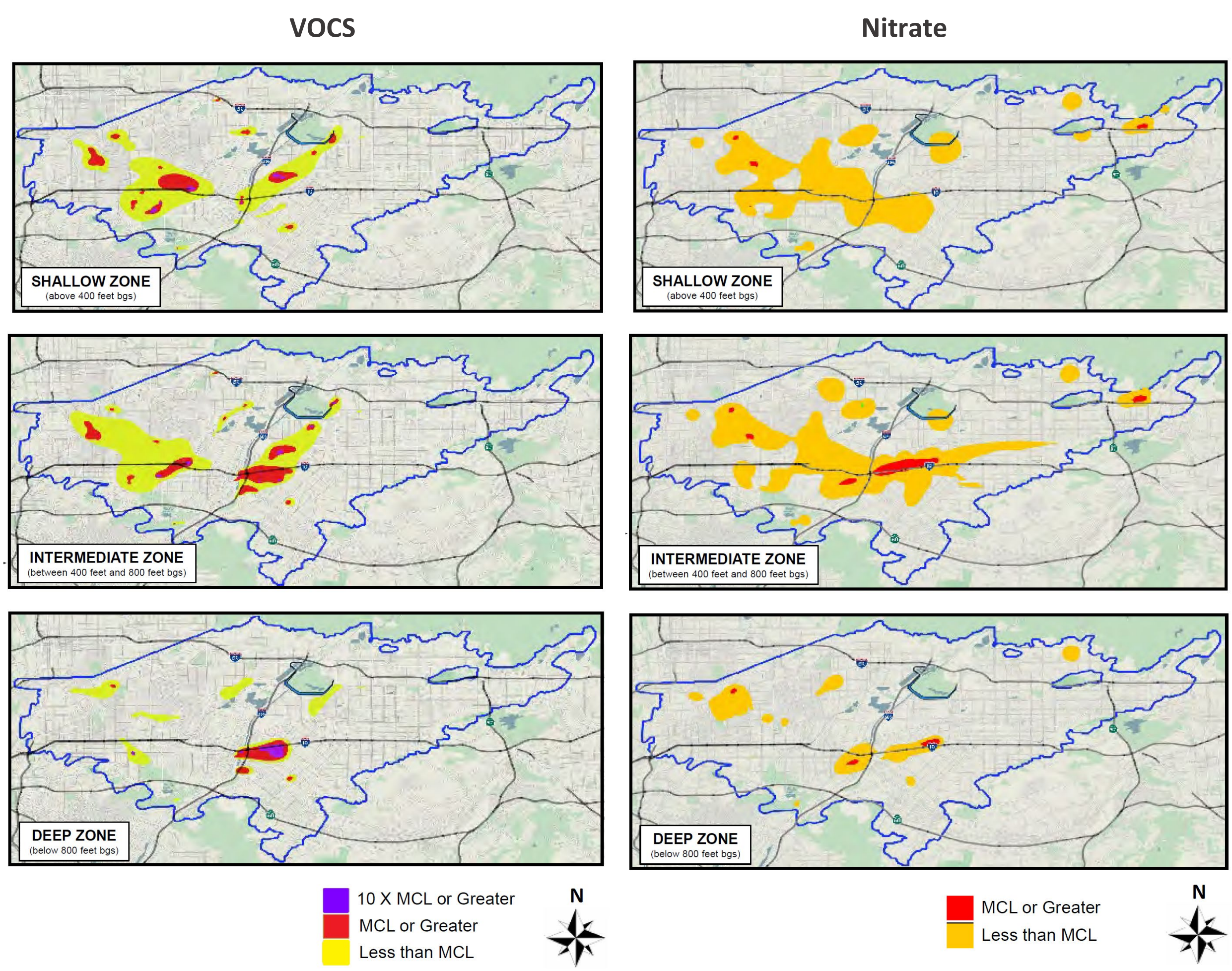
Constituent	Basin Plan Objective Western Area	Basin Plan Objective Eastern Area	Actual Main San Gabriel Basin
TDS	450 mg/L	600 mg/L	290 mg/L
Sulfate	100 mg/L	100 mg/L	52.7 mg/L
Chloride	100 mg/L	100 mg/L	30.3 mg/L
Boron	500 µg/L	500 µg/L	130 µg/L
Nitrate+ Nitrite as N	10 mg/L	10 mg/L	ND to 27.8 mg/L
PCE	5 µg/L		ND to 330 µg/L
TCE	5 µg/L		ND to 499 µg/L
Perchlorate	6 µg/L[1], 1 µg/L[2]		ND to 183 µg/L

Source: Metropolitan (2007), Watermaster (2016), Watermaster (2022a), Watermaster (20222b)

[1] California MCL

[2] California detection limit for purposes of reporting effective 01/01/2024

Figure 4: Main San Gabriel Basin Plume Map



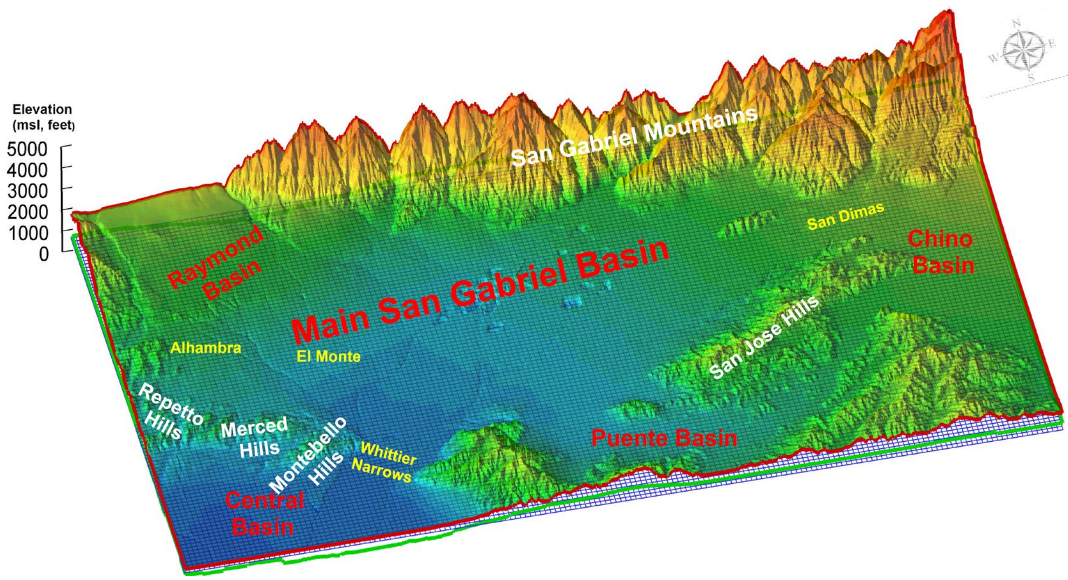
Groundwater Modeling Results

Between 2016 and 2018, Stetson Engineers conducted groundwater modeling for the Main San Gabriel Basin. This section provides a description of the model used for the groundwater modeling effort, a summary of the modeling results, and an evaluation of the impacts of the Program.

Description of the Model

The 3D basin model for the Main San Gabriel Basin was developed using the United States Geological Survey (USGS) modular structure MODFLOW-2005 (Harbaugh 2005) code to perform the regional steady-state and transient groundwater flow analysis for recharge at the Santa Fe Spreading Grounds. Further analyses were performed at the different potential recharge locations. The 3D basin model domain is shown in **Figure 5**.

Figure 5: 3D Main San Gabriel Basin Model Domain

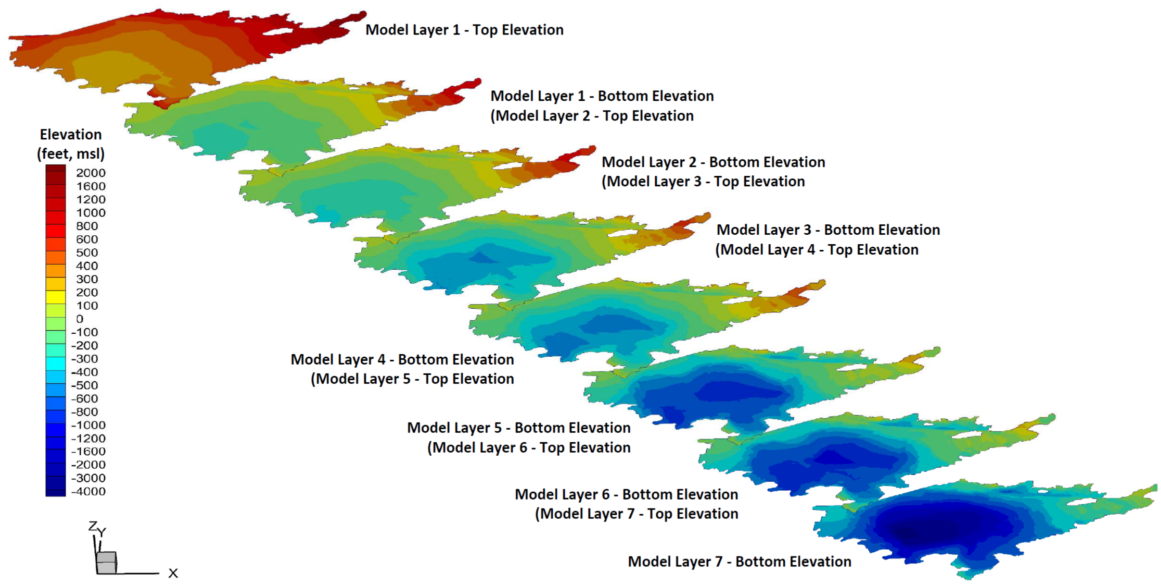


Source: Stetson 2018.

The 3D basin model was calibrated from fiscal year (FY) 1973/1974 to 2014/2015 in the shallow, intermediate, and deep water-bearing formations, including interactions between groundwater and surface water. The 3D basin model was divided into seven model layers to represent the shallow, upper, intermediate, and lower aquifers, as well as three semi-confined units (**Figure 6**). The 32-year simulation period, which follows the calibration period, was separated into 128 quarterly stress periods. The 3D basin model is also coupled with the USGS MT3DMS (Zheng 2010) and MODPATH (Pollock 2016), respectively, to perform solute transport and particle tracking.

Generally, MODPATH uses the simulated groundwater flow from MODFLOW; therefore, travel time can be estimated. A local groundwater mound would form during high flow periods, which would cause water from Pure Water to travel in a radial pattern away from the Santa Fe Spreading Grounds. Dilution of the purified water with existing groundwater is a function of the travel time and distance. Results of the particle tracking simulation were used to identify potentially impacted wells and determine the percent purified water at each well (Stetson 2018).

Figure 6: Model Layers in Main San Gabriel Basin Model



Source: Stetson 2018.

The solute transport simulations were performed using the MST3D-USGS code (Bedekar et al. 2016). Plume migration in groundwater is chemical dependent, and the migration pathways are highly dependent upon the characteristics of the constituents. Despite many other factors that may affect plume migration, groundwater flow (advection) and mixing because of concentration gradient were considered to simulate consistent movement in groundwater. Decay or degradation is not considered. The longitudinal dispersivity of 300 feet and transverse dispersivity of 30 feet were used for solute transport simulations. To analyze plume movement within the Baldwin Park Operable Unit (BPOU), a normalized scale of concentration was developed. The scale is intended to represent the relative concentration of constituents in the plume, with 0 being no concentration and 1 being the highest plume concentration (Stetson 2018).

On average, about 43,000 AFY of imported water (or about 39 mgd) is spread in the Main San Gabriel Basin, primarily at the Santa Fe Spreading Grounds. In 2018, it was assumed that an average of 39 mgd of purified water would be delivered to the Main San Gabriel Basin at the Santa Fe Spreading Grounds on a continuous basis, which is the foundation for the modeling effort. Deliveries to the San Gabriel Canyon Spreading Grounds would remain the same as historically. Since then, with additional refinement in the project, it is currently assumed that an average of 55 mgd of purified water would be spread at the Santa Fe Spreading Grounds and the San Gabriel Canyon Spreading Grounds. The comparison between the modeling assumption and the current Pure Water project is summarized in **Table 4.** The modeling results described below represent the more conservative assumptions. For recharge areas outside of the Santa Fe Spreading Grounds, which were not included in the initial modeling effort (i.e., United Rock No. 3 and San Gabriel Canyon Spreading Grounds), a well impact analysis was also performed using the Darcian flow velocity.

To assess potential impacts to adjacent wells the following formula was used:

V= Ki/n where:

V = groundwater flow velocity in feet per day
K = horizontal hydraulic conductivity in feet per day
i = groundwater gradient
n = specific yield/effective porosity

Table 4: Comparison of Model Assumptions and Pure Water in Main San Gabriel Basin

	Assumption	Santa Fe Spreading Grounds (TAFY)	San Gabriel Canyon Spreading Grounds (TAFY)	United Rock Pit No. 3 (TAFY)	Total (TAFY)	Total (mgd)
Without Pure Water	2018 Model Scenario 1: Historical Pumping and Recharge	Average Historical 43.3	Average Historical 12.4	0	**Average Historical 55.7**	**Average Historical 50**
With Pure Water	2018 Model Scenario 4: Projected Pumping and Constant Recharge	Constant Recharge 43.3	Average Historical 12.4	0	**55.7**	**50**
	Proposed Pure Water	40.9	12.4	3.4	**56.7**	**43-75 avg. 55**

Modeling Results

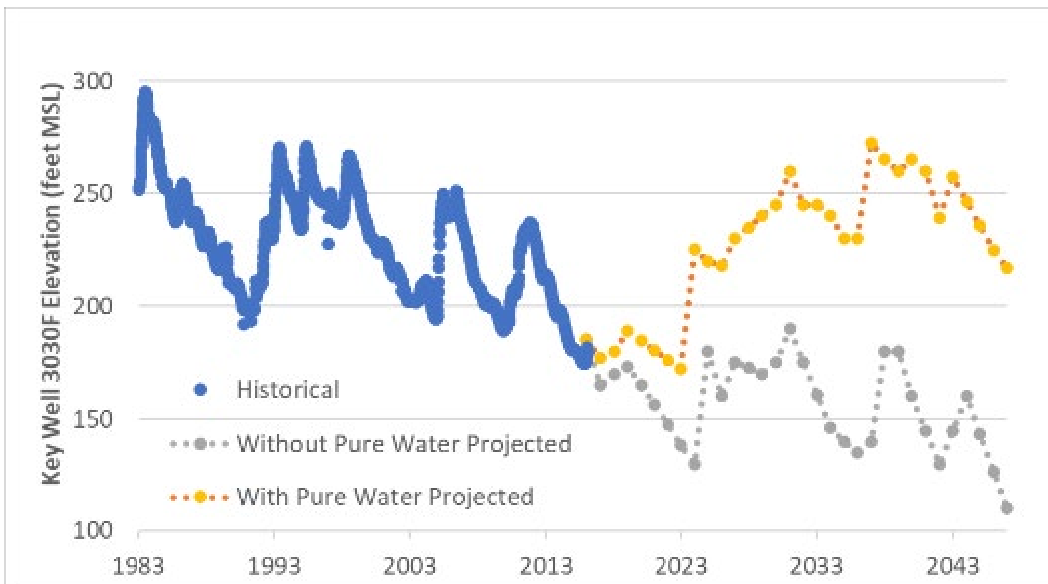
The results of the analysis of the groundwater level changes in the basin are shown in **Table 5**. For this analysis, the initial water level (as of January 2018) was 180 feet above mean sea level (MSL). The target water level for the modeling is between 200 feet MSL (the lower end of the established operating range) and 311 feet MSL (75 feet below ground surface – the highest safe level in the basin). In addition, if water levels drop below 170 feet MSL, wells begin to lose capacity and may go out of service. A hydrograph of the key well (Los Angeles County Well No. 3030F) is shown in **Figure 7**. Note that water deliveries are shown as beginning in 2016 – expected deliveries to Main San Gabriel are expected in 2032. The blue line shows historical water levels at the Baldwin Park key well. The orange line shows projected water levels with Pure Water, and the grey line shows water levels without Pure Water. As shown in this figure, water levels are projected to be 36.9 feet higher than at the beginning of the 32-year analysis, 116.9 feet higher with Pure Water than without the project. Without Pure Water, it is projected that water levels will be below the critical storage level and could reduce groundwater production capability in the basin by as much as 30 percent. Reductions in the groundwater production capability would have profound impacts to water supply reliability.

Table 5: Projected Water Levels at Main San Gabriel Basin Key Well

Scenario	Initial Water Level in Model Run (feet MSL)	Final Water Level after 32-year Model Run (feet MSL)	Maximum Water Level in Model Run (feet MSL)	Maximum Allowable Water Level (feet MSL)
Historical Pumping and Recharge	180	110	190	311
With Pure Water	180	216.9	272.3	311

Source: Metropolitan 2019; Stetson 2018.

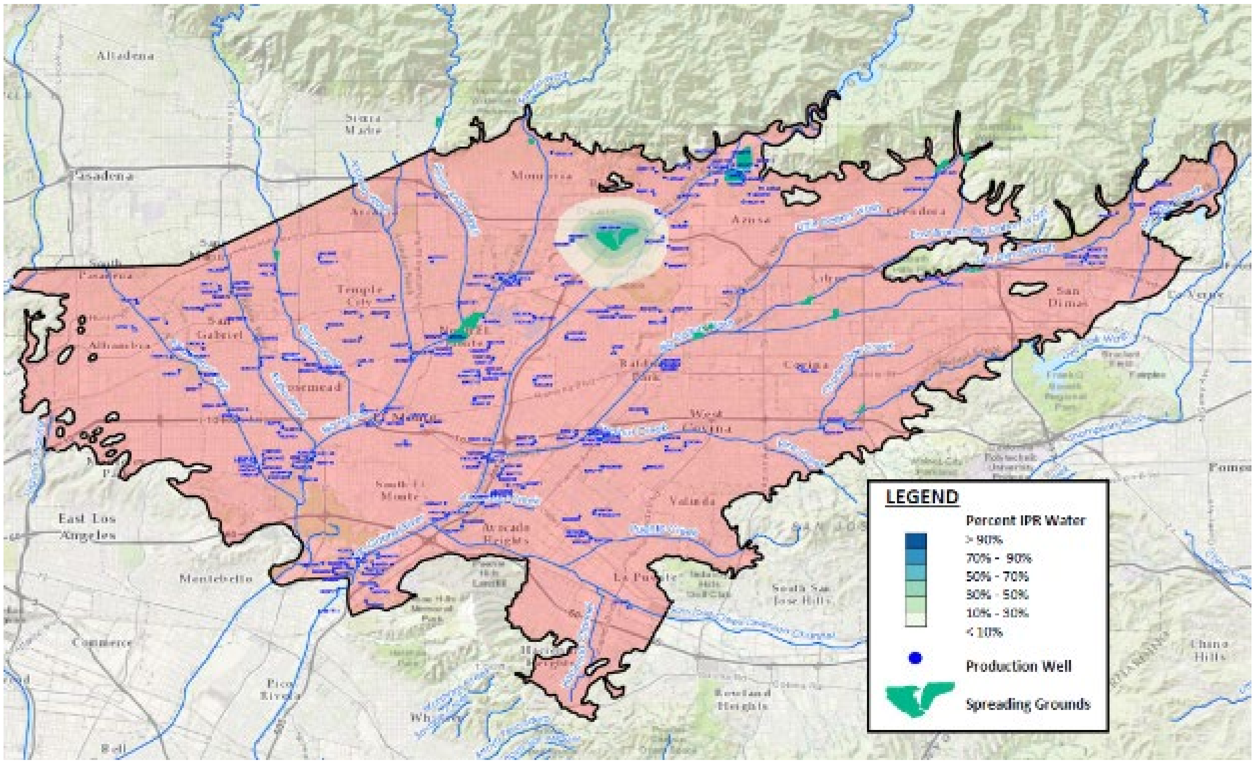
Figure 7: Hydrograph of the Main San Gabriel Basin Key Well with Pure Water



Source: Stetson 2018.

For this analysis, a relatively conservative assumption was used such that a well would have to be relocated if it is within the 12-month travel envelope (capture area) or has more than 50 percent recycled municipal wastewater contribution (RWC). Current groundwater replenishment regulations only require a minimum 2-month travel time. As shown in **Figure 8**, seven wells in the vicinity of the Santa Fe Spreading Grounds might have to be relocated because they are in the 12-month capture area, and one well might require relocation because it is in the area that has more than 50 percent RWC and is likely within the 2-month travel time envelope (Stetson 2018). Further analysis, including tracer analysis and well siting studies for the relocated wells, should be performed.

Figure 8: Main San Gabriel Basin Modeled Travel Estimate After One Year of Pure Water Operation

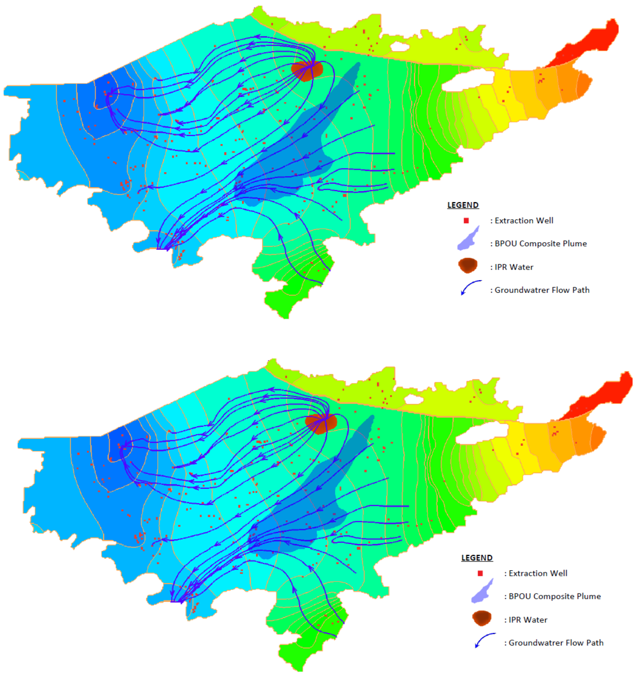


Source: Stetson 2018

MODPATH was used for the particle tracking and travel time estimates from the Santa Fe Spreading Grounds. The results of this effort are shown in **Figure 9**. This figure shows the travel estimate of the purified water after one year and after 15 years from recharge at the Santa Fe Spreading Grounds. After one year, the extent of the purified water is localized near the spreading grounds. After 15 years, the water would move significantly downgradient. The USEPA has established OUs for areas within the basin that have been contaminated by VOCs and require groundwater cleanup.

The BPOU at the San Gabriel Valley Area 2 Superfund Site includes groundwater contamination underlying portions of the cities of Azusa, Irwindale, Baldwin Park, West Covina, La Puente, and Industry. Water treatment facilities have been constructed to treat contaminated water underlying these cities and are operated based on conditions within the basin. Results of the groundwater modeling shown in **Figure 9** indicate the contamination plume associated with the BPOU cleanup may be partially affected by additional recharge at the Santa Fe Spreading Grounds, particularly in the western portion of the BPOU remediation area. Although there is a slight increase in the areal extent of the normalized concentrations, the impacts appear to be minor and can be contained by the existing BPOU operations (Stetson 2018).

Figure 9: Particle Tracking Analysis for Main San Gabriel Basin



After 1 year

After 15 years

Source: Stetson 2018

As described above, for recharge areas outside of the Santa Fe Spreading Grounds, which were not included in the initial modeling effort (i.e., United Rock No. 3 and San Gabriel Canyon Spreading Grounds), a well impact analysis was also performed using the Darcian flow velocity to assess potential impacts to adjacent wells. **Table 6** provides a summary of the Darcian flow calculations.

Table 6: Summary of Darcian Flow Calculations

Site	Hydraulic Conductivity (K) (feet/day)	Hydraulic Gradient (i) (unitless)	Specific Yield/Effective Porosity (n) (unitless)	Flow Velocity (V) (feet/day)	2-month Travel Time Estimate (feet)	Number of Wells that are within 2-month Travel Time
San Gabriel Canyon Spreading Grounds	300	0.006	0.15	11.5	700	Up to 9
United Rock Pit No. 3	400	0.0015	0.15	3.9	250	0

Figure 10 shows the travel time estimates at the San Gabriel Canyon Spreading Grounds. At the San Gabriel Canyon Spreading Grounds, using the 2-month travel time criterion, there are potentially as many as 9 wells that might need to be relocated. If only the lower basin is used, only 4 wells would need

to be relocated because 5 of the wells would be sufficiently upgradient to be outside the 2-month travel time envelope.

Figure 10: Travel Time Envelopes for San Gabriel Canyon Spreading Grounds

Figure 11 shows the travel time estimates from United Rock Pit No. 3. As shown in this figure, there are no wells within the 2-month travel time estimate at this location.

Evaluation of Impacts

Key findings are summarized below:

- Without Pure Water and the associated 55 mgd of recharge, water levels would be 110 feet MSL (70 feet below initial basin levels), assuming historical pumping and recharge. Because water levels would drop below the threshold for maintaining well capacity in the basin, pumping capability would diminish drastically due to these declining water levels.
- With the introduction of an average of 55 mgd, as estimated to be delivered to the Main San Gabriel Basin by Pure Water, water levels in the key well 3030F would be about 36.9 feet above initial levels (or about 216.9 feet MSL). Water levels peak at 272.2 feet MSL, which is still below the upper threshold water level at the key well. Water levels at the key well with Pure Water will be nearly 117 feet above historic conditions. At the Santa Fe Spreading Grounds, water levels are expected to increase about 47 feet above the initial water level at the Santa Fe well.

Higher water levels will help to maintain groundwater production in the basin and are not expected to have substantial impacts to basin operations.

- Results of the groundwater modeling indicate the contamination plume associated with the BPOU cleanup may be partially affected by additional recharge, particularly in the western portion of the BPOU remediation area. Although there is a slight increase in the areal extent of the normalized concentrations, the impacts appear to be minor and can be contained by the existing BPOU remedial systems (Stetson 2018).
- As many as 10 wells might need to be relocated because they are within the 2-month travel time regulatory requirement.
    - One well might require relocation near the Santa Fe Spreading Grounds
    - Zero wells would require relocation near United Rock Pit No. 3
    - Up to nine wells might need to be relocated near the San Gabriel Canyon Spreading grounds. Only 4 wells would need to be relocated if Basin No. 2 (the lower basin) is the only recharge basin used.

Figure 11: Travel Time Envelope for United Rock Pit No. 3

Central Basin

The Central Basin lies within central Los Angeles County. It underlies the service areas of Metropolitan member agencies Central Basin Municipal Water District (Central Basin MWD), West Basin Municipal Water District (West Basin MWD), the City of Compton, the City of Los Angeles, and the City of Long Beach. The cities of Artesia, Bellflower, Cerritos, Compton, Downey, Huntington Park, Lakewood, Los Angeles, Long Beach, Montebello, Paramount, Pico Rivera, Norwalk, Santa Fe Springs, Signal Hill, South

Gate, Vernon, and Whittier overlie the basin (Metropolitan 2007). A map of the Central Basin is provided in **Figure *2*.**

Basin Governance

More than 60 years ago, groundwater overdraft and declining water levels in the Central Basin threatened the area's groundwater supply and caused the intrusion of seawater into the aquifers in the southern part of the basin. However, timely legal action and adjudication of the water rights halted the overdraft and prevented further damage to the Central Basin. Since that time, groundwater extraction from the Central Basin has been limited to the amounts set by a Superior Court Judgment and monitored by a Court-appointed Watermaster.

The first Judgment was finalized and executed in 1965, and it appointed the Department of Water Resources (DWR) as the Watermaster. Since its inception, the Judgment has been amended three times. The Judgment was first amended in 1980 to provide for a transition to an administrative year from a water year (October 1 to September 30) to a fiscal year (July 1 to June 30). The Judgment was amended for the second time in 1985 to modify the annual budget ($20 minimum assessment) and exchange pool provisions. In addition, the second amendment modified carryover and overproduction provisions, defined carryover, and provided for exemptions for extractors of contaminated groundwater. The Third Amended Judgment was finalized on December 23, 2013. For the first time, the Court allowed Parties to have direct input into how the Judgment is administered and enforced. The Judgment confirmed the retirement of DWR as the Watermaster and created three separate bodies that assist the Court in the administration and enforcement of the provisions of the Judgment.

The first body is the Administrative Body, which administers the Watermaster accounting and reporting functions. The Water Replenishment District of Southern California (WRD) was appointed by the Court to fulfill this role. The second body is the Water Rights Panel, which enforces issues related to pumping rights within the adjudication. The Water Rights Panel is made up of seven water rights holders who are elected by rights holders in the Central Basin. Members of the Water Rights Panel include water rights holders from the cities of Downey, Lakewood, Long Beach, Signal Hill, and Paramount, along with Golden State Water Co. and Montebello Land and Water Company. The third body is the Storage Panel, which is comprised of the Water Rights Panel and the WRD Board of Directors; together, they review and approve certain groundwater storage efforts (WRD 2023).

Hydrogeologic Setting

The Central Basin is bounded northeast and east by the Elysian, Repetto, Merced, and Puente Hills. The southeast boundary of the Central Basin is along Coyote Creek, which is used to separate the Central Basin from the Orange County Basin, although there is no physical barrier between the two basins. The southwest boundary is the Newport, Inglewood fault system, which also separates the Central Basin from the West Coast Basin (discussed further below). The hydrogeologic parameters of the Central Basin are summarized in **Table 7**. The depth of the Central Basin ranges from 1,600 to more than 2,200 feet. The main source of potable groundwater in the Central Basin is from the deeper aquifers of the San Pedro Formation (including, from top to bottom, the Lynwood, Silverado, and Sunnyside aquifers), which generally correlate with the Main and Lower San Pedro aquifers of Orange County. The shallower aquifers of the Alluvium and the Lakewood Formation (including the Gaspur, Exposition, Gardena-Gage, Hollydale, and Jefferson aquifers) locally produce smaller volumes of potable water, as shown in **Figure 12**.

Table 7: Summary of Hydrogeologic Parameters of Central Basin

Structure	Storage

Aquifer(s)
• Forebay areas (unconfined)
• Pressure area (confined)
    • Alluvium (Gaspur and Semi-perched aquifers)
    • Lakewood Formation (Gardena and Gage aquifers)
    • San Pedro Formation (Lynwood, Silverado, and Sunnyside aquifers)
	Natural Safe Yield
	• 125,805 AFY

Depth of groundwater basin • Forebay areas – up to 1,600 feet • Pressure area – up to 2,200 feet	**Allowable Pumping Allocation** • 217,367 AFY
Thickness of water-bearing units • Alluvium (up to 180 feet) • Lakewood Formation (up to 280 feet) • San Pedro Formation (up to 800 feet)	**Total Storage** • 13.8 million AF **Available Storage Space** • 340,000 AF

Source: Metropolitan 2007; WRD 2006d; WRD 2023.

In the northern portions of the Central Basin, referred to as the Forebay Area, many of the aquifers are merged and allow for direct recharge into the deeper aquifers. The Central Basin has two Forebay Areas: Los Angeles and Montebello. In the area referred to as the Pressure Area, the aquifers are separated by thick aquitards, which create confined aquifer conditions and protection from surface contamination. Historically, groundwater flow in the Central Basin has been from the recharge areas in the northeast toward the Pacific Ocean in the southwest.

Over the past 10 years, the average pumping in the Central Basin has been about 183,000 AFY, which is about 85 percent of the Allowable Pumping Allocation (APA).

Water levels in the key well in the Montebello Forebay since 1970 are shown in **Figure 13**. As shown in this figure, water levels fluctuate with hydrologic conditions (rising in wet years, declining in dry years). For example, water levels have increased more than 40 feet since the beginning of the 2023 water year. During wet periods, water levels can reach within 15 feet of the ground surface (shown as an orange line on **Figure 13**). Currently, water levels in key well 1611 are about 41 feet from the ground surface.

Figure 12: Cross Section of Central and West Coast Basins

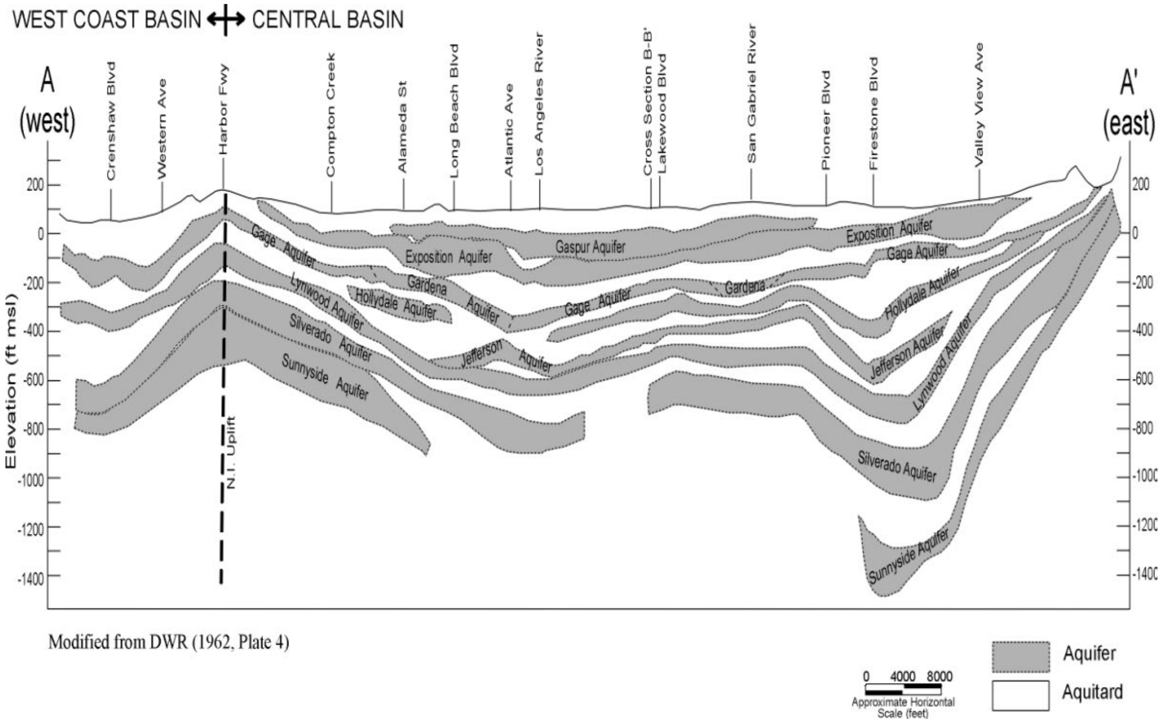
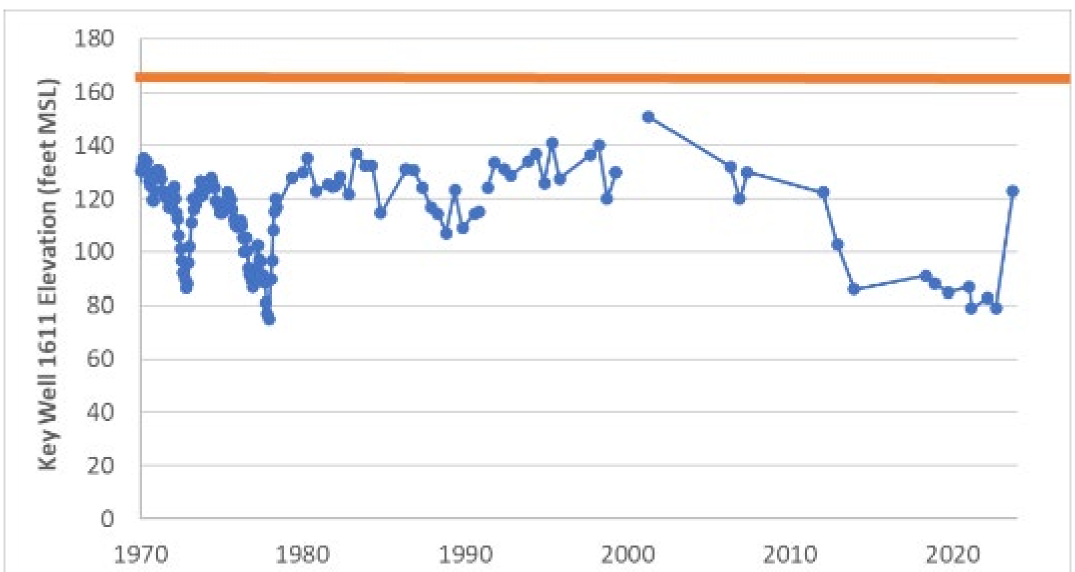
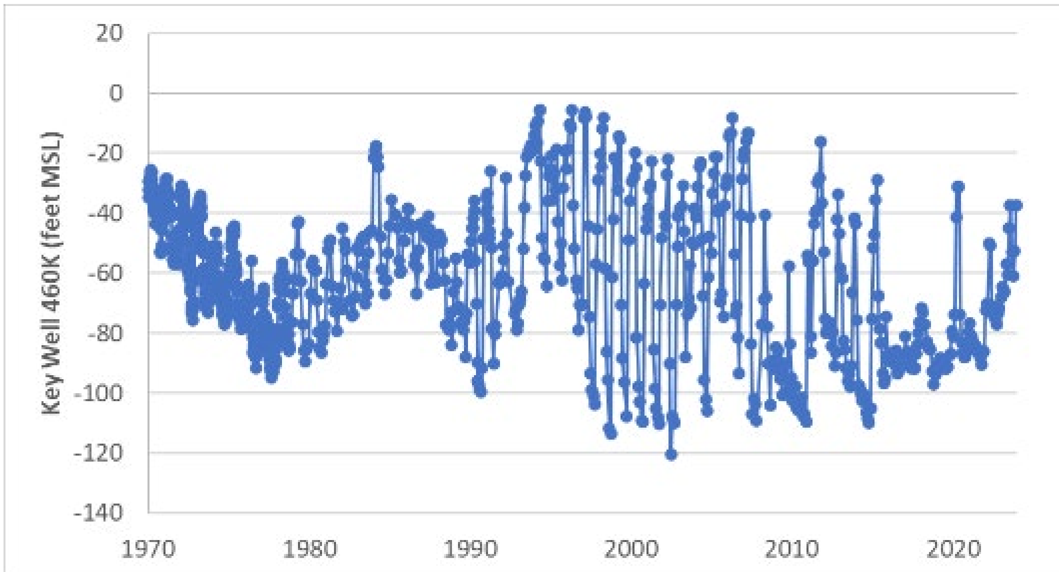


Figure 13: Hydrograph of Key Well in Montebello Forebay



Water levels in the key well in the Long Beach area since 1970 are shown in **Figure 14**. As shown in this figure, water levels fluctuate with hydrologic conditions and indicate confined aquifer conditions. During wet periods, water levels have reached within 19 feet of the ground surface. Currently, after rising about 40 feet in the past year, water levels in key well 460K are about 66 feet below the ground surface.

Figure 14: Hydrograph of Key Well in Long Beach



Recharge Facilities

Natural replenishment of the groundwater in the Central Basin occurs largely from surface flow and underflow through the Whittier Narrows from the San Gabriel Valley. Additionally, rainfall over the Central Basin infiltrates into deeper aquifers of the basin.

Intentional replenishment of groundwater in the Central Basin is accomplished by capturing and spreading water at the Rio Hondo and the San Gabriel Coastal Spreading Grounds in the Montebello Forebay. The details of these facilities are summarized in **Table 8**. The sources of this replenishment water include local storm runoff, local dry weather urban runoff, imported water purchased from Metropolitan, and recycled water purchased from the Sanitation Districts. About 17,000 AFY of imported water has been replenished in the Central Basin in the past 10 years. WRD's Albert Robles Center for Water Recycling and Environmental Learning (ARC) advanced water treatment facility began operation in 2019. The purpose of ARC was to reduce the need for the historical, and variable, imported water recharge in the Montebello Forebay, replacing it with advanced treated recycled water. No imported water has been spread in the Montebello Forebay since ARC came online.

Seawater intrusion in the Alamitos Gap near the mouth of the San Gabriel River poses a threat to the groundwater in the Central Basin. The Alamitos Gap Seawater Barrier Project (Alamitos Barrier Project) is designed to prevent seawater intrusion into the freshwater aquifers and is situated both in the Central Basin and Orange County Basin. WRD's Leo J. Vander Lans (LVL) advanced water treatment facility provides advanced treated recycled water to the Alamitos Barrier Project. The LACDPW operates the Alamitos Barrier Project, which is comprised of 43 injection wells that create a groundwater pressure ridge to halt seawater intrusion. The project includes 220 observation wells that are used to monitor groundwater levels and quality in the area. The seawater intrusion problem is contained by the Barrier Project (LACDPW 2023a).

Two aquifer storage and recovery (ASR) wells were constructed in the City of Long Beach. In addition, two existing wells have been converted to ASR. The combined extraction capacity of the four wells is estimated to be at least 4,333 AFY. The injection capacity of the ASR wells is estimated to exceed 3,250 AFY.

Table 8: Summary of Recharge Basins in the Central Basin

Spreading Basin	Area (acres)	Wetted Area (acres)	Capacity (cfs)	Source Water	Owner
Rio Hondo Coastal Spreading Grounds	570	430	400	Runoff Imported Recycled	LACDPW
San Gabriel Coastal Spreading Grounds	128	96	75	Runoff Imported Recycled	LACDPW
San Gabriel River	308	308	75	Runoff Imported Recycled	LACDPW
Total	**1,006**	**834**	**550**	**--**	**--**

Source: LACDPW 2023b.

Water Quality Issues

In both the Central Basin and West Coast Basin, WRD monitors the groundwater quality. The Central Basin contains VOCs, primarily PCE and TCE, which have impacted production wells in the Montebello and Los Angeles Forebays. **Table 9** provides the Los Angeles Regional Board's Basin Plan (Basin Plan) objectives for the Central Basin.

Between January 2019 and September 2020, WRD completed an assessment for the presence of per- and polyfluoroalkyl substance (PFAS) constituents, including perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA), in WRD nested monitoring wells and production wells (WRD 2021). PFAS are a large group of artificial compounds, including the two most studied: PFOA and PFOS. They have been used for several decades all over the world in industrial manufacturing, firefighting foams (aqueous film forming foam [AFFF]), and several consumer products, including fast food wrappers, pizza boxes, stain-resistant carpets, nonstick cookware (Teflon™), clothing (Gore-Tex ®), and fabric protectant (Scotchgard™). However, PFOA and PFOS have been phased out of production in the United States since the 2000s.

Table 9: Basin Plan Objectives and Summary of Constituents of Concern in Central Basin

Constituent	Basin Plan Objective	Actual in Central Basin
TDS	700 mg/L	538 mg/L [4]
Sulfate	250 mg/L	51 mg/L[4]
Chloride	150 mg/L	73 mg/L [4]
Boron	1,000 µg/L	152 mg/L [4]
Nitrate + Nitrite (as N)	10 mg/L	0.28 mg/L[4]
Perchlorate	1 µg /L[3]	ND to >24 µg /L
PFOS	6.5 ng/L[2], 4 ng/L[1]	ND to >70 ng/L
PFOA	5.1 ng/L[2], 4 ng/L[1]	ND to >40 ng/L
PCE **TCE**	5 µg/L	ND to 20 µg/L ND to 32 µg/L

Source: WRD, 2023

[1] Federal Primary MCL

[2] Current California Notification Level

[3] California detection limit for purposes of reporting

[4] Central Basin, including coastal areas (WRD 2015)

Groundwater Modeling Results

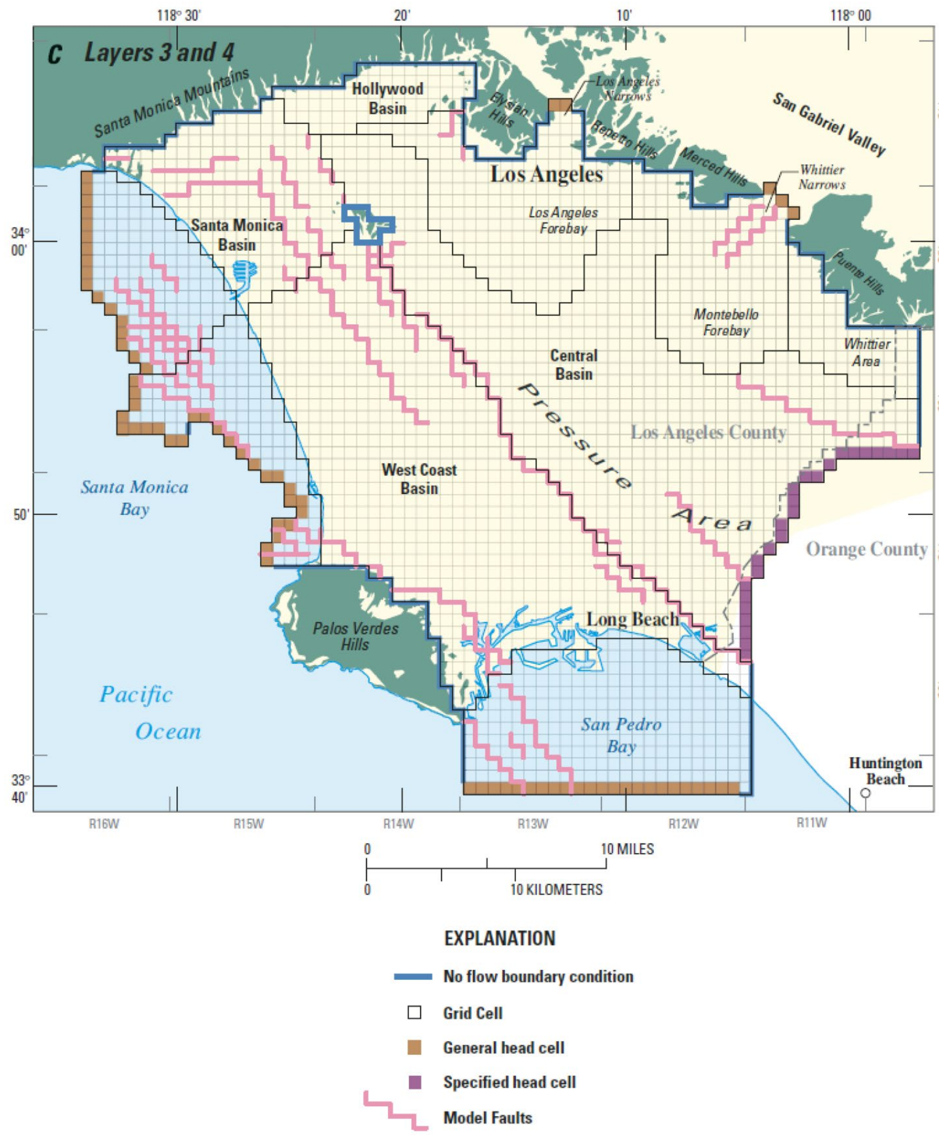
WRD and its sub-consultant, CH2M, were contracted by Metropolitan to run WRD's groundwater model of the Central and West Coast Basins. These basins were modeled together because WRD manages both basins. The existing model area includes the Central, West Coast, Santa Monica, and Hollywood Basins. CH2M used the model to evaluate scenarios developed by Metropolitan to evaluate the sustainable quantities of purified water that could be delivered to the Central and West Coast Basins for groundwater recharge and extraction.

Description of the Model

WRD/USGS developed a groundwater simulation model of the Los Angeles Coastal Basins, including the Central and West Coast Basins, to serve as a tool to evaluate alternative groundwater management strategies. The model, which uses the USGS MODFLOW program (McDonald and Harbaugh 1988; Harbaugh and McDonald 1996), is described in detail by the USGS (2003). A map of the model domain is shown in **Figure 15**.

Several modifications were made to the WRD/USGS model to support the evaluation of scenarios. The original WRD/USGS model covered the simulation period of water years 1971 through 2000. The model was extended through water year 2010. Annual stress periods were converted to monthly stress periods in a "Pre-baseline" model. This update facilitated the evaluation of seasonal variations. Baseline operating conditions were established in the Baseline model to include purified water recharge from ARC that began operation in 2019. ARC was represented by replacing a portion of the historical, and variable, imported water recharge in the Montebello Forebay with the constant recharge from ARC. The Baseline model represents the operating conditions against which the impact of Metropolitan's Pure Water project alternatives was evaluated.

Figure 15: Central and West Coast Basins Groundwater Model Domain



The extent of the model domain is shown in **Figure 15**, which covers the entire Los Angeles County portion of the Los Angeles Coastal Basin, including offshore extensions of the basins' aquifers.

The grid consists of a uniform finite-difference grid (three-dimensional grid blocks), with each cell 0.5-mile by 0.5-mile on a side, with variable thickness. The grid and boundaries of the model are also shown on this figure.

The hydrogeology, including variations in hydrogeologic properties (such as transmissivity and storage coefficient) of the Central and West Coast Basins, is represented by four layers (from top to bottom), including the following aquifers as identified by the California Department of Water Resources (1961):

- Layer 1 – Semi perched and Gaspur aquifers
- Layer 2 – Ballona, Exposition, Artesia, and Gardena, Gage, and 200-Foot Sand aquifers
- Layer 3 – Hollydale, Jefferson, Lynwood, 400-Foot Gravel, and Silverado aquifers, which are the principal aquifers tapped by production wells in the West Coast and Central Basins
- Layer 4 – Sunnyside and Lower San Pedro aquifers

Faults throughout the basin, such as the Newport-Inglewood Fault zone, are represented using the MODFLOW hydraulic flow barrier package, which acts to partially impede the movement of groundwater flow across these faults.

Boundary conditions include the following:

- Constant head boundaries are used to represent the movement of water between the Orange County Groundwater Basin and the Central Basin. Values of hydraulic head vary through time based on observed historical groundwater levels along the boundary with Orange County.
- General head boundaries are used to represent inflow from the San Fernando Valley Basin through the Los Angeles Narrows, and inflow from the Main San Gabriel Basin through the Whittier Narrows. Heads are constant through time at both boundaries.
- General head boundaries where aquifers are in contact with the Pacific Ocean, which also account for the density differences in freshwater and heavier ocean water.
- Mountain Front (groundwater entering from the surrounding hills and mountains) and interior recharge (areal recharge over the surface of the basins) from precipitation and applied water, which varies based on precipitation at the Downey precipitation station (USGS 2003).

Recharge and discharge stresses include stormwater, recycled water, and imported water diverted to the spreading grounds in the Montebello Forebay Spreading Grounds (San Gabriel Coastal Spreading Grounds and Rio Hondo Spreading Grounds), injection of imported water and advanced treated recycled water at the three injection barriers (Alamitos Barrier, West Coast Basin Barrier, and Dominguez Gap Barrier), and pumping by groundwater purveyors within the basin. Recharge locations are presented in **Figure 16**.

The simulation period covers water years 1971 (October 1, 1970, through September 30, 1971) through 2010. The stress periods are monthly, resulting in 480 stress periods. For the purposes of this evaluation, historical conditions and stresses were assumed to be appropriate for this feasibility level evaluation. Historic water level variations during the modeled period (water years 1971 through 2010), particularly within the Central Basin, allow assessment of Metropolitan's scenarios over a wide range of basin-wide head conditions. The only exception to the use of historically prescribed fluxes was the use of ARC (a constant source of recharge in the Montebello Forebay in lieu of historical, periodic recharge with imported water). This exception was considered appropriate because the location of ARC recharge is very close to the potential location of Metropolitan recharge.

Additional modeling assumptions include the following and those shown in **Table 10**. This table shows that the modeling estimated recharge of 14,000 AF for the Central Basin, while Pure Water estimates that 9,000 AF will be recharged. This is a minor difference and should not have a significant impact on operations or estimated water levels.

- 4,000 AFY of new injection in the existing 4 ASR wells in Long Beach. 4,000 AFY of new pumping in the City of Long Beach.
- 10,000 of new injection in the Montebello Forebay (including the San Gabriel Coastal and Rio Hondo Spreading Grounds) and 10,000 AFY of new pumping from the City of Los Angeles' Manhattan well field.

Figure 16: Central and West Coast Basins Model Recharge Assumptions

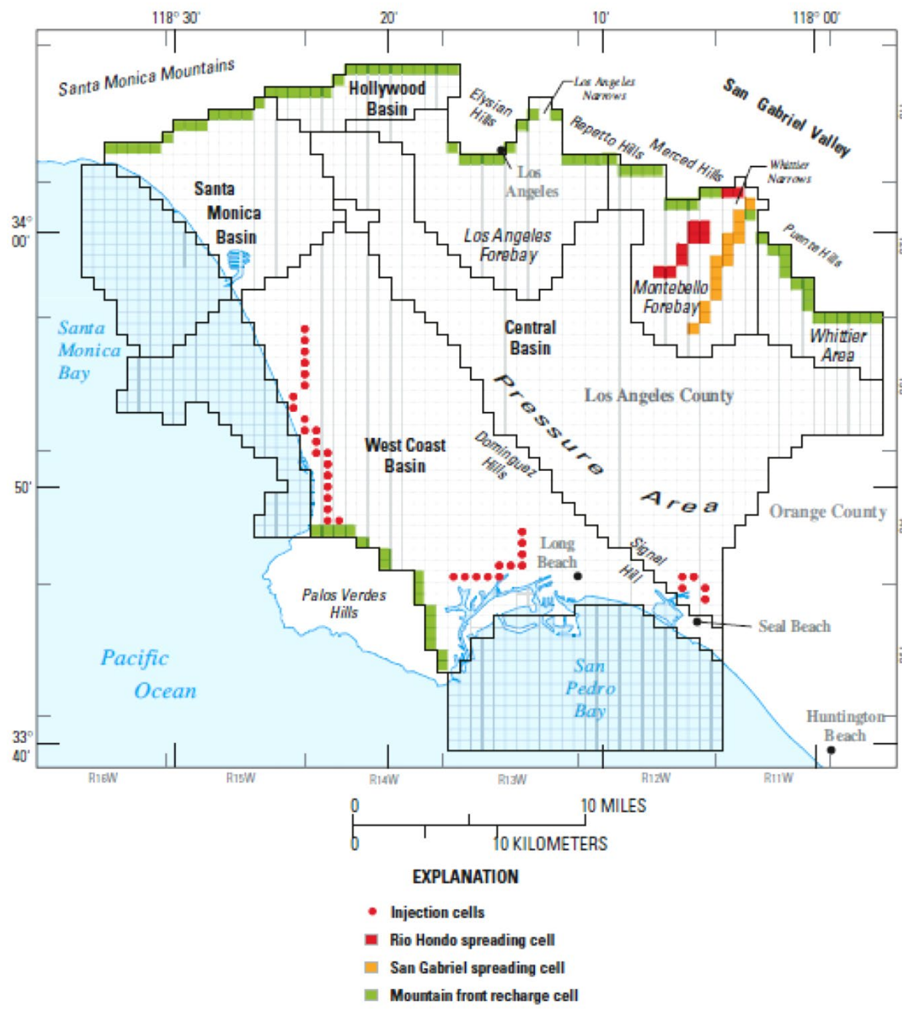


Table 10: Summary of Model Assumptions in Central Basin

	Assumption	Montebello Forebay (TAFY)	City of Long Beach (TAFY)	Total (TAFY)	Total (mgd)
Without Pure Water	2018 Model Baseline	0	0	**0**	**0**
With Pure Water	2018 Model Scenario 3a	10	4	**14**	**13**
	Proposed Pure Water	4.6	4.6	**9.2**	**0-20 avg. 9**

Modeling Results

Figure 17, **Figure 18**, and **Figure 19** summarize the groundwater level increases and potential wells impacted within the 12-month travel time.

Table 11 summarizes the groundwater level increases and potential wells impacted within 12 months. Water level changes in the Central Basin because of Pure Water are summarized below:

- Long Beach area: Predicted water level rise of 6 feet in the Long Beach injection area is insignificant and will not result in changes in operations.
- Montebello Forebay: Model results predict a water table rise of 8 feet that could limit the recharge capacity of the Montebello Forebay in the Central Basin during periods of high water levels. Since water levels in the Montebello Forebay already rise within 15 feet of the ground surface during wet periods (as shown in **Figure 13**), an 8-foot increase could drastically reduce the ability of the water recharged in the Montebello to infiltrate and impact LACFCD's operations. In this case, Pure Water deliveries to the Montebello Forebay would be suspended until the water levels decline to a level at which it is prudent to resume operations (water levels at least 20 feet below the ground surface).

The impact to boundary flows in the Central Basin is described below:

- A cumulative storage deficit of over 100,000 AF was simulated, mostly caused by reduced inflow from the Main San Gabriel Basin in response to recharge in the Montebello Forebay. Because the Main San Gabriel Basin water level changes as a result of Pure Water weren't included in the WRD model, this storage deficit is likely overestimated.
- Travel times to production wells in the vicinity of the injection wells are generally longer than 3 months. Where simulated travel times are less, it is likely that injection wells could be sited in different locations to maintain travel times to production wells of more than 3 months.
- There are no production wells within reach after 12 months of particle tracking from the Long Beach injection wells. However, there is a production well known to be within ¼-mile

of one of the proposed injection locations, and the model with its ½-mile grid may lack sufficient resolution to properly simulate solute transport. Ongoing monitoring and studies during operations, such as tracer studies, will be performed once the project is online to address the travel time requirement to protect nearby wells. The monitoring and tracer analysis plan will be approved by the Regional Board as part of the Title 22 permit. A tracer study involves the introduction of a tracer chemical into the recharged water. Upstream and downstream wells are monitored to determine if the tracer chemical is present. Alternatively, if there is no tracer chemical suitable, an intrinsic chemical, which is a constituent that is significantly different from the ambient groundwater (e.g., boron, sulfate, or chloride), would be used to track changes. If these studies show that the tracer could reach the well in under 2 months, then the well would need to be relocated. For example, If the tracer reaches halfway to the nearest well in under 1 month (half the regulation of 2-month travel time), the well will likely need to be relocated before the recharged water reaches the well. This measure would prevent any substantial impacts and give the well owner some time to turn off the well and investigate alternative locations.

- There are three production wells within reach of the 12-month particle tracking from the Montebello Forebay injection wells. These wells would need to be relocated.

Figure 17: Central and West Coast Basins Modeling Results

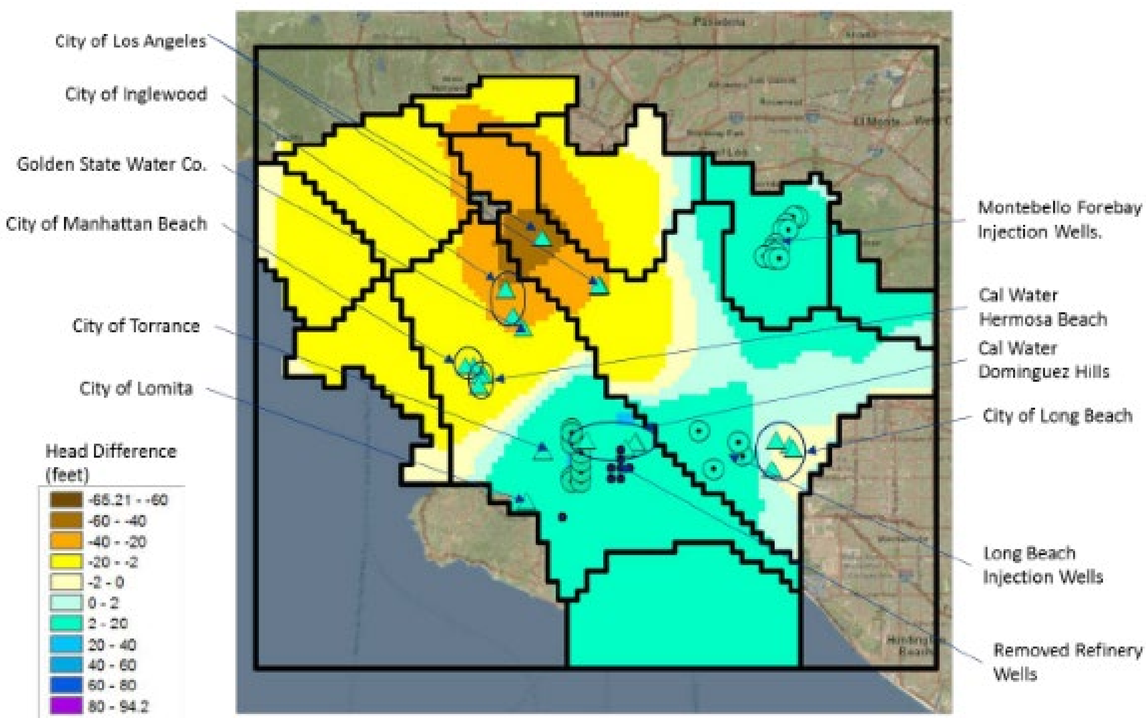


Figure 18: Travel Time Estimates at Long Beach

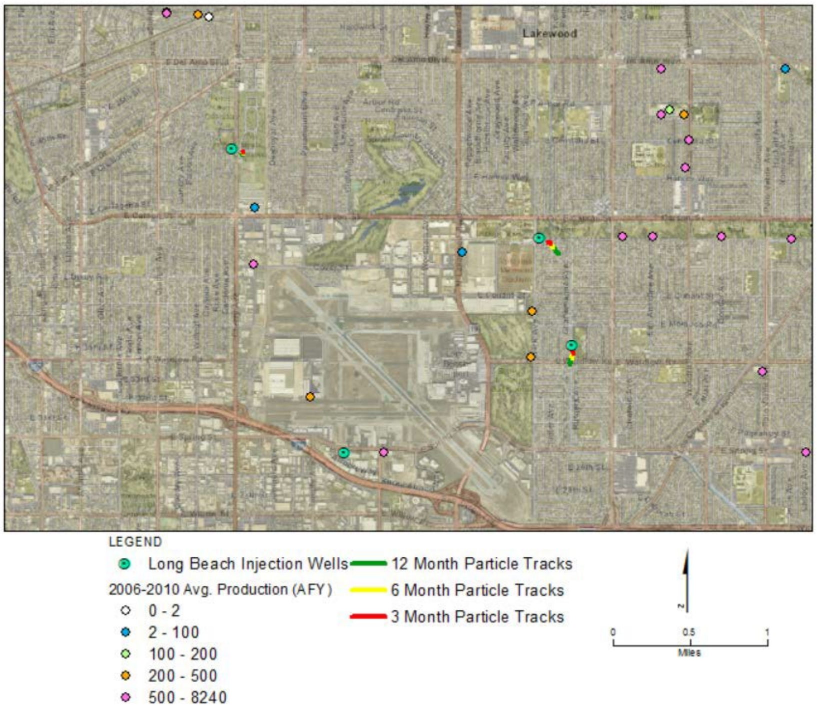
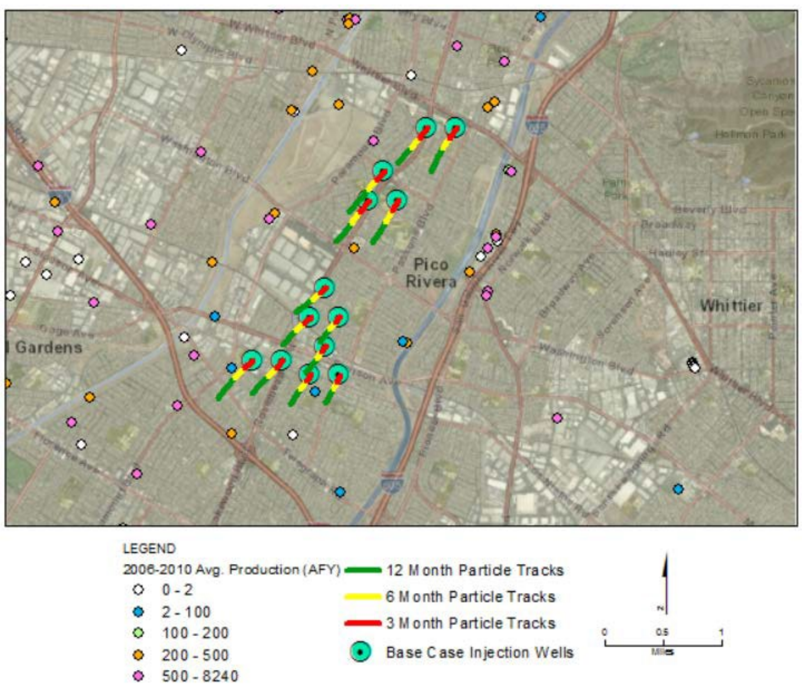


Figure 19: Travel Time Estimates at Montebello Forebay



West Coast Basin

The West Coast Basin lies along the coast in western Los Angeles County. It underlies the service areas of Metropolitan member agencies: West Basin MWD, the City of Los Angeles, the City of Torrance, and the City of Long Beach. The cities of El Segundo, Manhattan Beach, Hermosa Beach, Redondo Beach, Torrance, Inglewood, Hawthorne, Gardena, Lomita, Carson, and Long Beach overlie the basin. A map of the West Coast Basin is provided in **Figure 2.**

Basin Governance

The West Coast Basin adjudication (Judgment) was finalized in 1961 and capped annual production at 64,468 AFY. The Judgment allows annual carryover of unpumped adjudicated right, not to exceed 20 percent, and allows up to 20 percent excess production to be made up by under-production the following year. The Judgment also allows up to 10,000 AF of emergency over-pumping under specified conditions. DWR serves as Watermaster. WRD, established in 1959, has the statutory authority to replenish the groundwater basin and address water quality issues. LACDPW owns and operates the seawater intrusion barrier including the West Coast Barrier Project and the Dominguez Gap Barrier Project in the West Coast Basin. WRD procures imported and recycled water to be recharged by LACDPW at these facilities.

Hydrogeologic Setting

The West Coast Basin is bounded on the south and west by the Pacific Ocean, on the north by the Ballona Escarpment, on the east by the Newport-Inglewood Uplift, and on the south by the Palos Verdes Hills. Hydrogeologic parameters for the West Coast Basin are summarized in **Table 12.**

Groundwater in the West Coast Basin is generally confined. The Silverado aquifer underlying most of the West Coast Basin is the most productive aquifer in the basin. It ranges from 100 to 500 feet thick and yields 80 to 90 percent of the groundwater extracted annually. This aquifer generally correlates with the Main aquifer of the Orange County Basin. Minor yield also comes from the Gage, or “200-foot sand,” aquifer; the Lynwood, or “400-foot gravel,” aquifer; and the Sunnyside, or Lower San Pedro, aquifer.

Over the past 10 years, an average of about 34,000 AFY has been pumped from the West Coast Basin, which is about 50 percent of their adjudicated rights. The groundwater levels in the key well 460 K in the West Coast Basin have varied from about 43 feet below MSL to 8 feet above MSL over the past 10 years, as shown in the hydrograph **Figure 20**. This represents an increase of more than 50 feet since 1970.

Recharge Facilities

To combat seawater intrusion, two seawater intrusion barriers were developed in the West Coast Basin.

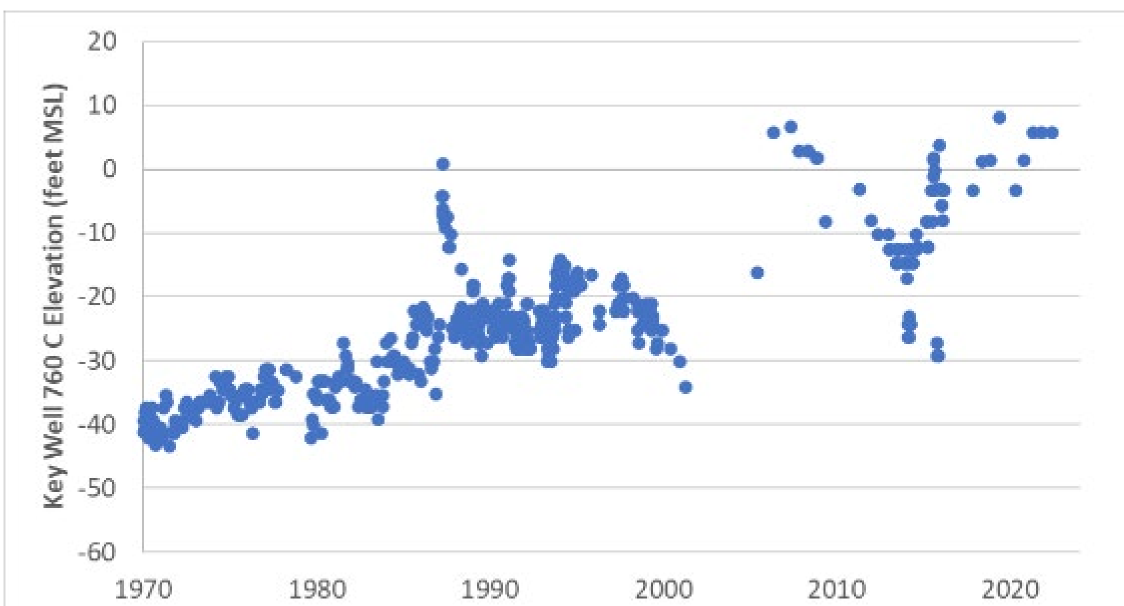
The first barrier is the West Coast Basin Barrier Project, which is in the cities of Manhattan Beach and Hermosa Beach. The second is the Dominguez Gap Barrier which is located along the Dominguez Channel in the Cities of Wilmington and Carson. Both barriers currently utilize high-quality recycled water.

Table 11: Summary of Hydrogeologic Parameters of West Coast Basin

Parameter	Description
Structure	
Aquifer(s)	Pressure area (confined) Alluvium (Gaspur and Semi-perched aquifers) • Lakewood Formation (Gardena and Gage "200-foot sand" aquifers) • San Pedro Formation (Lynwood "400-foot gravel," Silverado, and Sunnyside aquifers)
Depth of groundwater basin	~800 to 2,000 feet
Thickness of water-bearing units	Alluvium (up to 180 feet) Lakewood Formation (up to 320 feet) San Pedro Formation (up to 1,050 feet)
Yield and storage	
Natural safe yield	26,300 AFY
Adjudicated Rights	64,468.25 AFY
Total Storage	6.5 million AF
Portion of Unused Storage Space Available for Storage	125,000 AF

Source: Metropolitan 2007; WRD 2006d; WRD 2023.

Figure 20: Hydrograph of Key Well in West Coast Basin



Water Quality Issues

Table 13 provides a summary of the water quality objectives for the West Coast Basin. The West Coast Basin does not currently have detections of TCE or PCE. However, elevated total dissolved solids (TDS) concentrations in the West Coast Basin were observed along the coast from Redondo Beach to LAX, in the Torrance area, the Inglewood area, and the Dominguez Gap area. The West Coast Basin has two injection barriers to combat seawater intrusion.

Table 12: Los Angeles Basin Plan Objectives for West Coast Basin

Constituent	Basin Plan Objective	Actual in West Coast Basin
TDS	800 mg/L	890 mg/L [4]
Sulfate	250 mg/L	73 mg/L [4]
Chloride	250 mg/L	306 mg/L [4]
Boron	1,500 µg/L	130 µg /L [4]
Nitrate + Nitrite (as N)	10 mg/L	0.05 mg/L [4]
Perchlorate	1 µg/L[3], 6 [1]	ND to 12 µg/L
PFOS	6.5 ng/L[2], 4 ng/L[1]	ND
PFOA	5.1 ng/L[2], 4 ng/L[1]	ND
PCE **TCE**	5 µg/L	ND to 0.8 µg/L ND to 18 µg/L

Source WRD, 2023 4 and WRD, 2015

[1] Federal Primary MCL

[2] Current California Notification Level

[3] California detection limit for purposes of reporting

[4] Average West Coast Basin – no coastal areas (WRD, 2015)

Groundwater Modeling Results

Modeling for the West Coast Basin was integrated with the modeling of the Central Basin as discussed above. A comparison between what was modeled and the assumptions for Pure Water is provided in **Table 14**. In the modeling effort, up to 15,000 AF of recharge was assumed for the West Coast Basin to assess the maximum potential impact. For Pure Water, it is estimated that only about 3,000 AF will occur. Therefore, impacts will be less than estimated here. Analysis specific to the West Coast Basin is provided below.

Additional modeling assumptions not included in the Central Basin portion include:

- Shift 11,733 AFY of pumping by refineries, Tesoro/Marathon, and Phillips to Program and reallocate this volume to other pumpers inland in the West Coast Basin. This would mean these refineries, located in Carson and Wilmington, would stop pumping from the basins and would rely on recycled water instead. 11,733 AFY represents the historical average combined pumping from Tesoro and Philips, from 1971 through 2010.
- 15,000 AFY of new injection in the West Coast Basin and pumping in the West Coast Basin to balance the new injection. Distribution of the additional 15,000 AFY of pumping shifted to other pumpers in the West Coast Basin, except there was no additional pumping from Golden State Water Company, City of Inglewood, or California Water Services Hermosa-Redondo wells.

That additional pumping instead was assigned to California Water Services Dominguez District wells.

Table 13: Summary of Model Assumptions in West Coast Basin

	Assumption	West Basin Injection (TAFY)	Refinery Reallocation TAFY)	Total (TAFY)	Total (mgd)
Without Pure Water	2018 Model Baseline	0	0	**0**	**0**
With Pure Water	2018 Model Scenario 3a	15	11.7[1]	**26.7**	**24**
	Proposed Pure Water	3	11.7[1]	**14.7**	**15-50 avg. 26**

[1] Total assumed for refinery demand offset by Pure Water is 24 mgd, or about 24,800 AFY. 11,733 AFY is groundwater reallocated to other producers in the basin. The remainder is imported water offset.

Modeling Results

Table 15 shows a summary of the water level and particle tracking results in the West Coast Basin.

Table 14: Summary of Water Level and Particle Tracking Results in West Coast Basin

Area	Change in Water Level (feet)	Number of Wells Potentially Impacted
West Coast Basin	24	1

Source: CH2M 2018

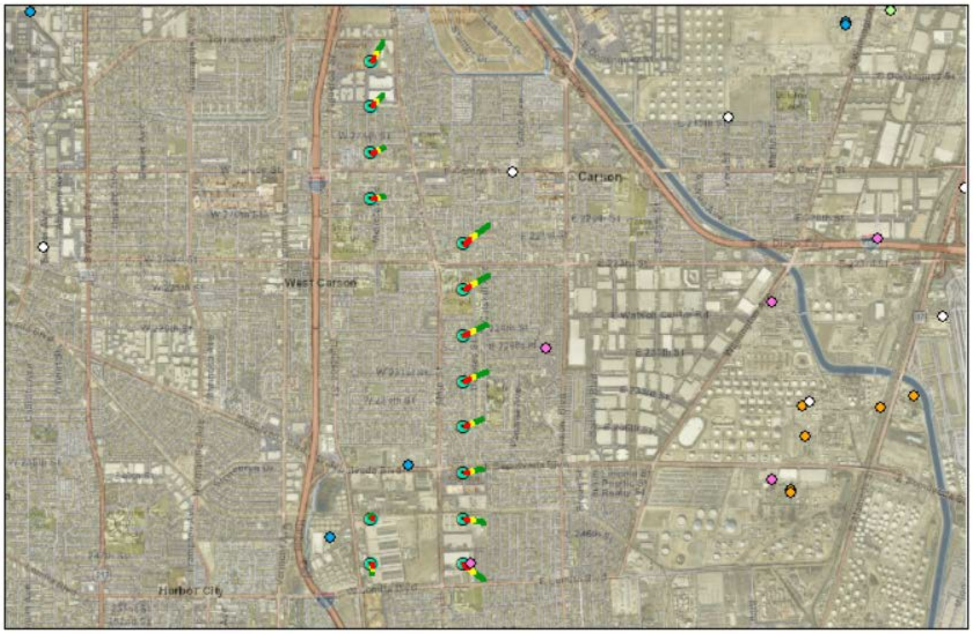
Water levels in the West Coast Basin are projected to increase by up to 24 feet in the Carson area immediately surrounding the injection wellfield. Since the basin is an unconfined pressure system, this increase will not impact operations significantly.

Travel times to production wells in the West Coast Basin are shown in **Figure 21**. There is one production well within reach of the 3-month particle tracking from the Carson injection wells in the West Coast Basin. At this location, the injection well could be sited farther away.

Orange County Basin

The Orange County Basin is in north and central Orange County within the lower Santa Ana River watershed. Member agencies within the Orange County Basin include Anaheim, Fullerton, Santa Ana, and the Municipal Water District of Orange County (MWDOC). The Orange County Basin has been divided into three sub-basins: Yorba Linda, Main, and Irvine. A map of the basin is provided in **Figure 2.**

Figure 21: Travel Time Estimates at Injection Well Sites in West Coast Basin



Basin Governance

The Orange County Basin is a managed basin. The Orange County Water District (OCWD) has managed the Orange County Basin since 1933 pursuant to a special act of the State. OCWD has managed the basin based on the principle of seeking to increase supply rather than restricting access and to provide for uniformity of cost.

The basin groundwater pumping is not operated on a safe-yield basis each year. Rather, the goal is to maintain an approximate balance over a period of several years. The amount of production from the basin is governed through financial incentives based on establishing an annual Basin Production Percentage (BPP), which is the percentage of groundwater production out of the total water demand for the Orange County Basin. Pumping up to the BPP is charged a fee on a per AF basis, i.e., the Replenishment Assessment (RA). Groundwater production above the BPP is charged the RA plus the Basin Equity Assessment (BEA). The BEA is typically set so that the cost of groundwater production above the BPP is similar to the cost of purchasing alternative supplies. Pumping agencies do not accrue individual storage rights if they pump less than the BPP, which is a major difference compared to most adjudicated basins. Additionally, agencies cannot transfer groundwater-pumping rights.

Hydrogeologic Setting

The Orange County Basin is bounded by the Coyote and Chino Hills on the north, the Santa Ana Mountains on the northeast, the San Joaquin Hills on the south, and the Pacific Ocean and the Newport-Inglewood fault zone on the southwest. The Orange County Basin is separated from the Central Basin along Coyote Creek and the County line, although there is no physical barrier between the two basins. The Newport-Inglewood fault zone acts as a complete barrier to flow from the ocean along most of its length in Orange County except at ancient river-crossing gaps, most notably the Alamitos Gap along the Los Angeles County line and the Talbert Gap in Huntington Beach and Costa Mesa. At these two locations, permeable river deposits cross the fault barrier, providing the opportunity for seawater to flow into the Orange County Basin. Recently, elevated chloride levels have been monitored in the Bolsa-Sunset Gap. OCWD has been evaluating the possibility of constructing a third seawater intrusion barrier for the Bolsa-Sunset Gap.

The hydrogeology of the Orange County Basin is characterized by a deep structural alluvial basin (**Figure 22**) containing a thick accumulation of interbedded sand, silt, and clay, as shown, providing a summary of hydrogeologic parameters for the Orange County Basin. The Orange County Basin contains three defined aquifer units: the Upper, Principal (or Middle), and Lower aquifers (see **Table 16**). In the northern portions of the Orange County Basin, referred to as the Forebay area, many of these aquifers are merged and allow for direct recharge into the deeper aquifers. In the area referred to as the Pressure Area, these aquifers are less hydraulically connected and create confined aquifer conditions.

Historically, groundwater flow in the Orange County Basin has been from the recharge areas in the north toward the Pacific Ocean. As shown in **Figure 23,** in June 2022, the principal aquifer's water levels in the Orange County Basin ranged from a high of about 300 feet above MSL in the north portion of the basin upgradient of the spreading grounds to a low of about 80 feet below MSL in the coastal areas. Water levels and flow vary among the three aquifer systems.

Over the past 10 years, about 288,000 AFY was pumped from the Orange County Basin, an average of about 70 percent of the total demand over this period. **Figure 24** shows a hydrograph of a key well in the Anaheim area of Orange County Basin. As shown in this figure, water levels have increased about 80 feet since the Groundwater Replenishment System (GWRS), an indirect potable reuse partnership between OCWD and the Orange County Sanitation District to spread purified water in the Anaheim Forebay, was online in January 2008. Currently, GWRS has a capacity of 130 mgd.

Recharge Facilities

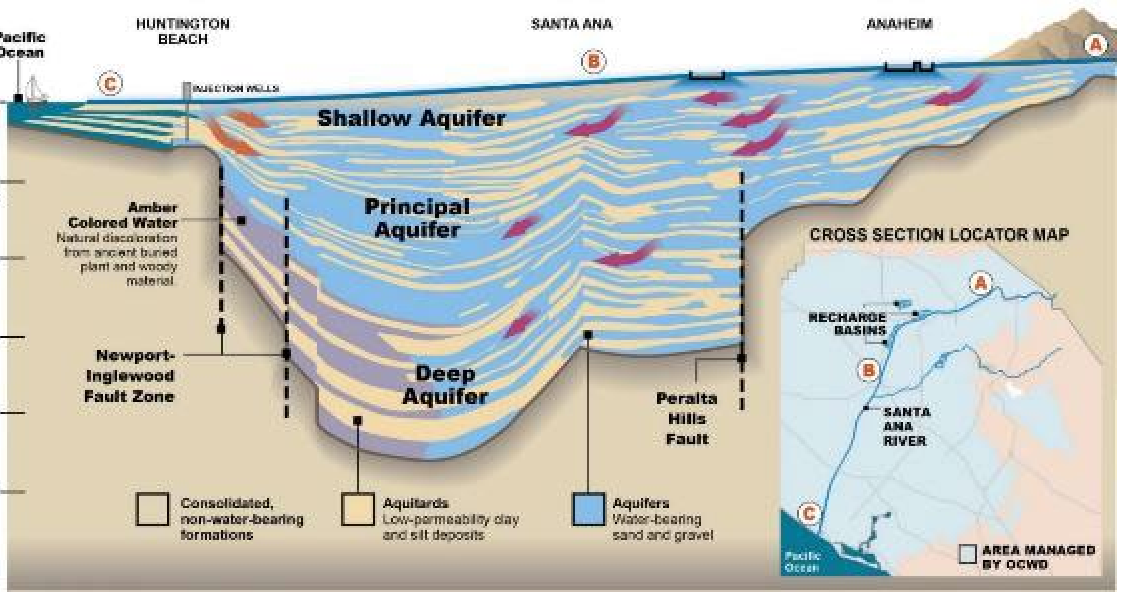
The Orange County Basin contains two seawater intrusion barriers. The first is the Alamitos Gap Seawater Barrier Project, which was previously discussed in the Central Basin section. The second is the Talbert Seawater Intrusion Barrier, which spans the Talbert gap in the cities of Fountain Valley and Huntington Beach. OCWD also has a mid-basin injection well field, consisting of five wells, in the City of Santa Ana. Both the Talbert Barrier and the mid-basin injection well field utilize recycled water from OCWD's GWRS.

The Orange County Basin contains an extensive system of recharge facilities. Facilities include nearly 500 production wells, 800 monitoring wells, more than 1,000 acres of recharge ponds (see **Table 17**) in the Forebay areas, two seawater intrusion barriers, a mid-basin injection well field, three desalters, the GWRS, the Prado wetlands, and Prado Dam. OCWD operates and maintains many of these facilities. The location of these recharge facilities is shown in **Figure 25.**

Table 15: Summary of Hydrogeologic Parameters of Orange County Basin

Parameter	Description
Structure	
Aquifer(s)	Forebay areas (unconfined) Pressure areas (confined) • Upper aquifer system • Principal aquifer system • Lower aquifer system
Depth of groundwater basin	> 2,000 feet
Depth of producing zones or screen intervals	200 to ~2,000 feet
Thickness of water-bearing units	Upper aquifer: Up to 300 feet (average ~200 feet) Principal aquifer: 500 to > 1,600 feet (average~ 1,000 feet) Lower aquifer: ~300 to 1,000 feet
Yield and Storage	
Natural Safe Yield (Natural Incidental Recharge)	183,000 AFY
Basin Production Percentage (2021/22)	77 percent
Total Storage	Upper aquifer: 5 million AF Principal aquifer: 32.9 million AF Lower aquifer: 25.1 million AF Aquitards: 3 million AF Total: 66 million AF
Accumulated Overdraft	206,000 AF

Figure 22: Hydrogeology of Orange County Basin



Source: OCWD 2023.

Figure 23: OCWD Groundwater Contour Map of Principal Aquifer – June 2022

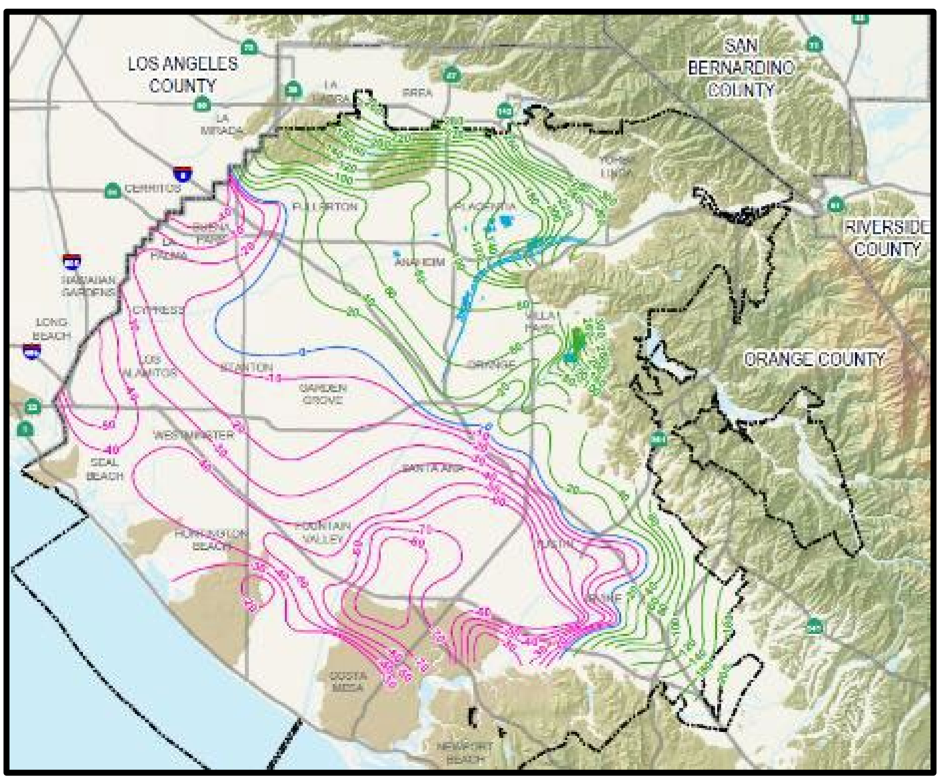


Figure 24:Hydrograph of Key Well in Orange County Basin

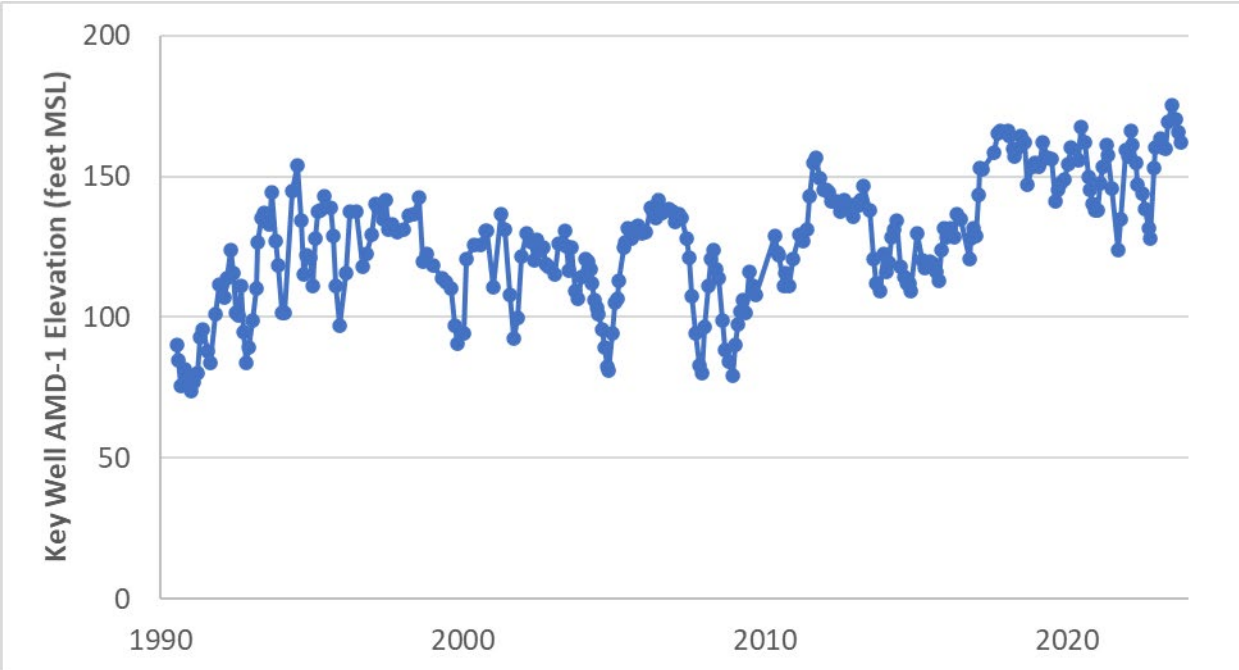
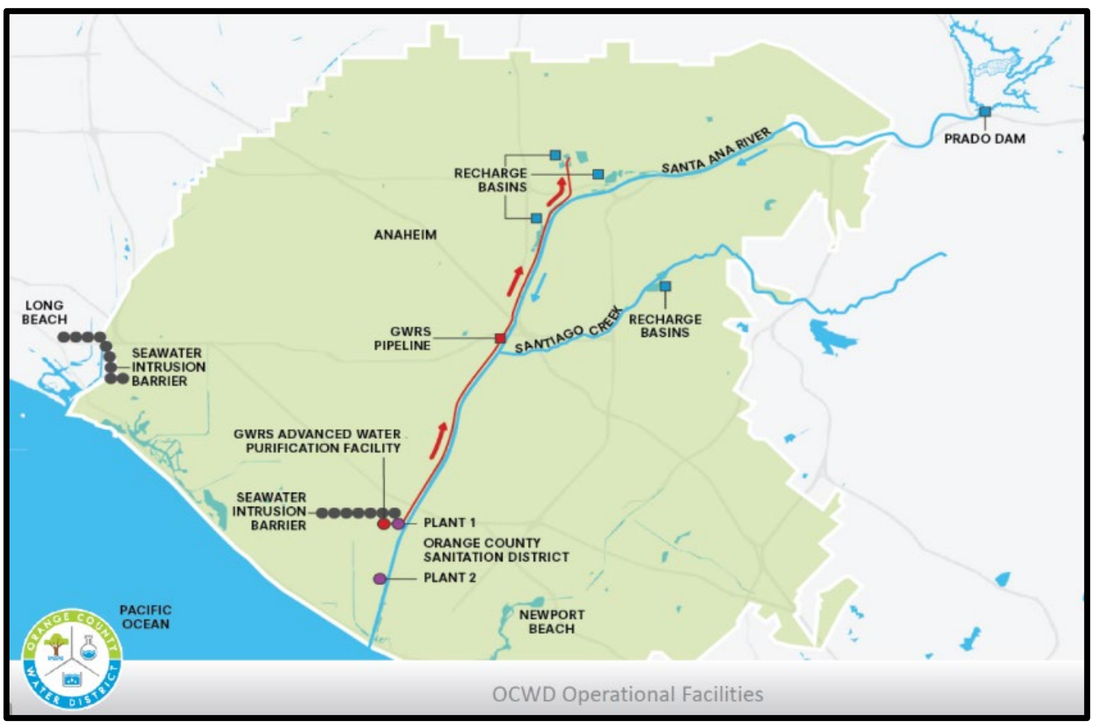


Figure 25: OCWD Operational Facilities



OCWD actively manages the Santa Ana River to recharge the Orange County Basin and operates the GWRS. OCWD partners with the Army Corps of Engineers to store storm flows behind Pardo Dam. These flows are gradually released to allow OCWD to divert the flow to a series of recharge basins. OCWD also uses imported water from Metropolitan and recycled water from OCWD's advanced purification facility, the GWRS, to recharge the basin. In April 2023, OCWD completed the GWRS final expansion to increase the facility's capacity to 130 mgd.

Table 16: Summary of Recharge Basins in Orange County Basin

Recharge Basin/System	Area (acres)	Recharge Capacity (cfs)[1]	Source water	Owner
Main Santa Ana River	245	80 to 130	Runoff[2] Imported	OCWD
Off-River	126	15 to 40	Runoff[2] Imported GWRS	OCWD
Deep Basin	318	90 to 390	Runoff[2] Imported GWRS	OCWD and OC Resources Development and Management Department
Burris Pits/ Santiago Basin	378	110 to 220	Runoff[2] Imported	OCWD
Total	**1,067**	**313 average[3]**	**--**	**--**

Source: OCWD 2004

[1] Percolation rate range represents clogged and clean capacities

[2] The primary source of recharge water enters the facilities from the Santa Ana River downstream of Prado Dam.

[3] Average for period 1989 to 2005

Water Quality Issues

In general, groundwater in the main producing aquifers of the basins is of good quality, with an average concentration of TDS in the basin of 402 mg/L in 2022. High TDS groundwater can be found in the Irvine Sub-basin and the Seal Beach area. A few localized areas of shallow VOC contamination plumes exist in the basin; however, very little water is pumped from the shallow aquifers. **Figure 26** shows the location of the two shallow VOC plumes in the Orange County Basin. The northern plume, referred to as the Orange County North Basin Superfund Site, focuses on a six-and-a-half-square-mile portion of the groundwater aquifer located under Fullerton, Anaheim, Placentia, and Buena Park. In September 2020, the Orange County North Basin Superfund Site was listed by the United States Environmental Protection Agency (EPA) as a National Priorities List (NPL or Superfund) site. The goal of the Superfund listing is to get contamination contained and cleaned up, and to compel parties responsible for the contamination to implement and pay for the cleanup (OCWD 2024). Primary contaminants detected include TCE, PCE, and perchlorate. OCWD and its member agencies have implemented various treatment technologies across the basin to lower nitrate, TDS, VOCs, perchlorate, iron, manganese, NDMA, and color to acceptable levels in groundwater produced.

Table 17: Santa Ana Basin Plan Water Quality Objectives for Orange County Basin

Constituent	Basin Plan Objective	Actual Orange County Basin
TDS	580 mg/L	402 mg/L
Sulfate	250 mg/L	133 mg/L
Chloride	250 mg/L	63 mg/L
Boron	1,000 µg/L	N/A
Nitrate (as N)	3.4 mg/L	1.6 mg/L
Perchlorate	1 µg/L[3]	ND to 6 µg/L
PCE	5 µg/L	ND to 5.5 µg/L
TCE	5 µg/L	ND to >5 µg/L
PFOS	6.5 ng/L[2], 4 ng/L[1]	ND to 23 ng/L
PFOA	5.2 ng/L[1], 4 ng/L[1]	ND to 16 ng/L

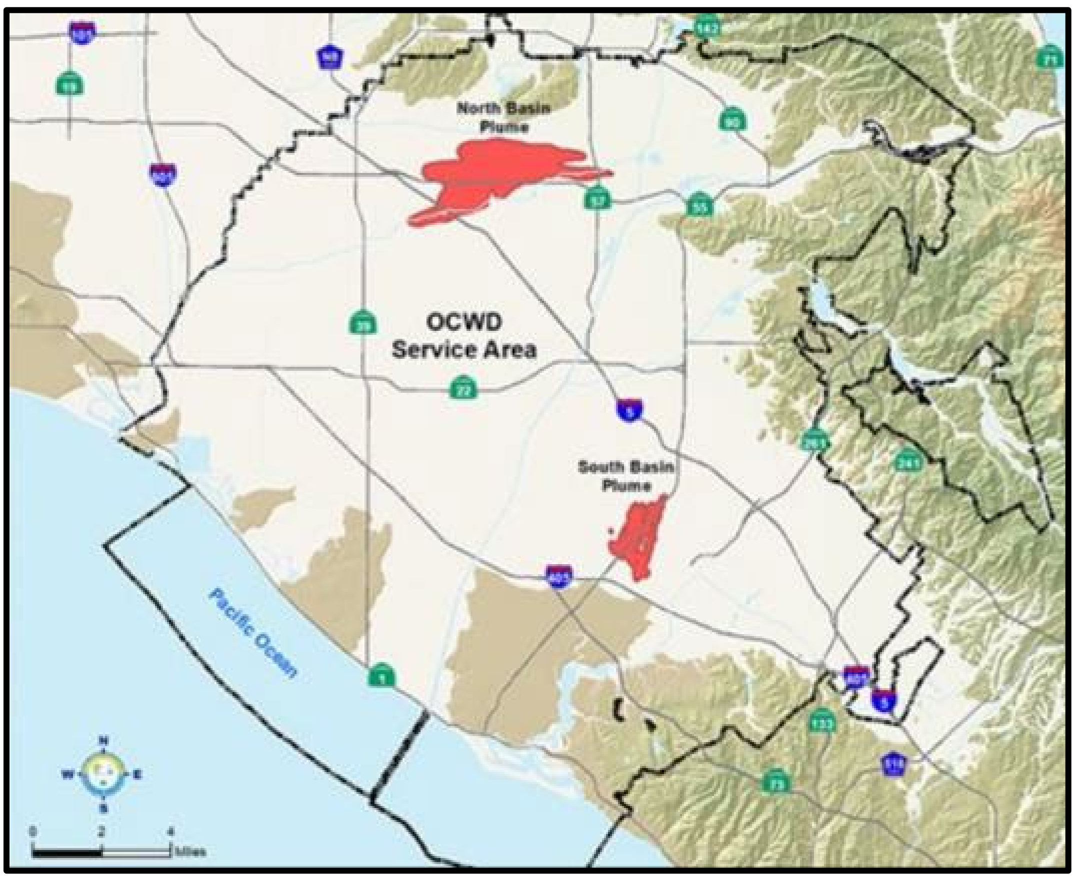
Source: Metropolitan 2007; OCWD 2022

[1] Federal Primary MCL

[2] Current California Notification level

[3] California detection limit for purposes of reporting

Figure 26: OCWD VOC Plume Map



]

In recent years, PFAS have been detected in the Orange County Groundwater Basin, entering primarily via the Santa Ana River, whose flows infiltrate into the basin. PFAS inputs to the Santa Ana River include treated wastewater discharges and stormwater runoff from upstream communities in San Bernardino and Riverside counties. OCWD has worked with its member agencies to develop numerous PFAS treatment facilities, including the Nation's largest ion exchange PFAS treatment plant, the Yorba Linda Water District Ion Exchange (IX) PFAS Water Treatment Plant. OCWD has estimated that PFAS contamination will cost Orange County $1.8 billion over the next 30 years.

Groundwater Modeling Results

OCWD conducted groundwater modeling in 2017 to evaluate the potential effects of Metropolitan recycled water recharge in Orange County in the forebay area on groundwater elevations, groundwater flow direction, and travel time. The OCWD modeling description and results are presented below.

Recharge is assumed to occur within the City of Anaheim, the northeastern portion of Orange County, California, into a new proposed basin and/or several existing groundwater recharge basins, such as Kraemer, Miller, and Anaheim Lake, etc. operated by OCWD, as shown in **Figure 27**. Land use in the vicinity is industrial and commercial.

Description of Model

The Orange County Groundwater Basin Model (Basin Model) was used for this evaluation. The Basin Model was developed, calibrated, and utilized by OCWD to effectively manage the basin. The model has been proven to be a good representation of actual basin groundwater levels over the years. The Basin Model is a transient numerical flow model using the widely accepted MODFLOW code. The Basin Model accounts for variations in aquifer properties, monthly variations in the volume of applied recharge, and monthly variations in boundary conditions along the edges of the model domain.

Two scenarios were simulated for this evaluation. One scenario assumed a proposed new basin that recharges 45 mgd of recycled water, while the second scenario assumed all recycled water from Metropolitan was recharged using existing recharge basins (OCWD, 2017). The assumptions for the modeling compared to what is considered for Pure Water are provided in **Table 19**.

Table 18: Comparison of Modeling Scenarios to Pure Water

Component	Scenario 1	Scenario 2	Pure Water
Yield	45 mgd	45 mgd	0 mgd [1]
New Basin	22.9 acre	N/A	N/A
Simulation Period	9 years beginning in fiscal year 14/15	9 years beginning in fiscal year 14/15	N/A

[1] Today, it is assumed that OCWD is not interested in purchasing Pure Water. However, in the future, OCWD may be interested in purchasing Pure Water. If they choose to purchase water from the Program in the future, no new facilities are anticipated to be required to deliver water to the existing recharge basins.

Model Assumptions

- Both simulations are balanced, i.e., total water into the groundwater basin equals to total water out, and basin storage was kept relatively constant.
- The sources of water during the entire simulation were the Santa Ana River base flow, storm flow, incidental recharge, GWRS including final expansion, Pure Water, and Alamitos Barrier injection.

- Accumulated overdraft (volume of empty storage below a full basin condition) was maintained at approximately 200,000 AF over the simulation duration.
- Average hydrology condition was assumed: 52,000 AFY Santa Ana River base flow; 51,600 AFY Santa Ana River storm flow.
- 65,000 AFY Metropolitan recycled/imported water for recharge.
- A 9-year simulation period was performed, which was equivalent to the length of the original transient model calibration period and considered to be sufficiently long for the recharge-induced water level changes to stabilize.
- Both simulations used actual 2014-15 groundwater production as a starting point. Minor adjustments were made to include new production wells installed after 2015 and eliminated wells that were permanently removed from service after 2015. The production data was then repeated for each of the nine years of the simulation.
- The annual production amount from large system wells (excluding the water quality improvement wells) was adjusted in each simulation to maintain a balanced (negligible basin storage change) condition. Demand from each producer was not exceeded.
- In Scenario 1, 50,400 AFY or 45 mgd was distributed to a proposed new basin, and the rest was distributed to Kraemer Basin and/or Miller Basin. Based on existing data of percolation performance in the vicinity of this location (Miller Basin, Kraemer Basin, Miraloma Basin, and La Jolla Basin), to reach desired 45 mgd percolation rate, four 500 feet by 500 feet model grid cells were used to simulate the new basin area; therefore, the total modeled new basin recharge area was 1000,000 sq. feet or 22.9 acres; The same percolation rate of 45 mgd was assumed to remain constant for all nine-year duration.
- In Scenario 2, no new basin was proposed. All recycled water was recharged to Kraemer, Miller, and Anaheim Basins.
- Burris Basin, Santiago Basin, and Santiago Creek were assumed to be permitted to recharge GWRS water.
- Metropolitan recycled water was evenly distributed monthly, i.e., approximately 5,400 AF per month recharge.

To balance the model, overall groundwater pumping was adjusted to 375,300 AFY, representing an 84.5% BPP (excluding water quality projects) based on projected demand of 435,000 AF.

The main purpose of this evaluation is to estimate travel time for purified water under different scenarios. Particle tracking analyses were conducted by running the computer code MODPATH along with flow results from both scenarios. The particles were placed in the Basin Model grid cells corresponding to the edges of the proposed new basin, other existing basins, and Santa Ana River below Carbon Creek diversion or Five Cove rubber dam. The vertical placement of each particle was determined by the depth of each basin. The particles were released 6 months before the end of the model simulation.

Model Results

Figure 27 shows the simulated 6-month particle traces in the forebay area and Santa Ana River for both scenarios. Different color particle trace was used to illustrate the recycled water movements between aquifers or model layers (OCWD 2017). No significant changes in water level are expected because of Pure Water.

Particle traces show that most of the purified water remained in shallow groundwater units (model Layer 1) around shallow basins, but particles originated from Santiago Basin, Santiago Creek, Anaheim Lake, and a small reach of the Santa Ana River (close to Five and Lincoln basins) traveled to the principal aquifer (model layer 2) within the 6-month period.

Under an average hydrology year, existing basins are capable of recharging MWD recycled water equally every month, with a total of 65,000 AFY, although in winter months, all basins reached their respective maximum capacities, and Burris Basin along with Santiago Basin, Santiago Creek were needed to recharge GWRS water. Therefore, during wet years (above average rainfall), there would be limitations on the amount of purified water forebay facilities can take in addition to stormwater.

Impact Assessment

Table 20 summarizes the water level and particle tracking results from the modeling in the Orange County Basin. It is assumed that a well would likely be impacted and would have to be relocated within the 6-month travel envelope. Based on the modeling data, six wells could be impacted and would have to be relocated: one below the existing spreading basins and five surrounding Anaheim Lake. Further analysis, including evaluation of previous tracer studies (or potentially new tracer analysis) and well siting studies for the relocated wells, should be performed.

Table 19: Summary of Water Level and Particle Tracking Results in Orange County Basin

Area	Change in Water Level (feet)	Number of Wells Potentially Impacted
Anaheim	0	6

Source: OCWD 2017

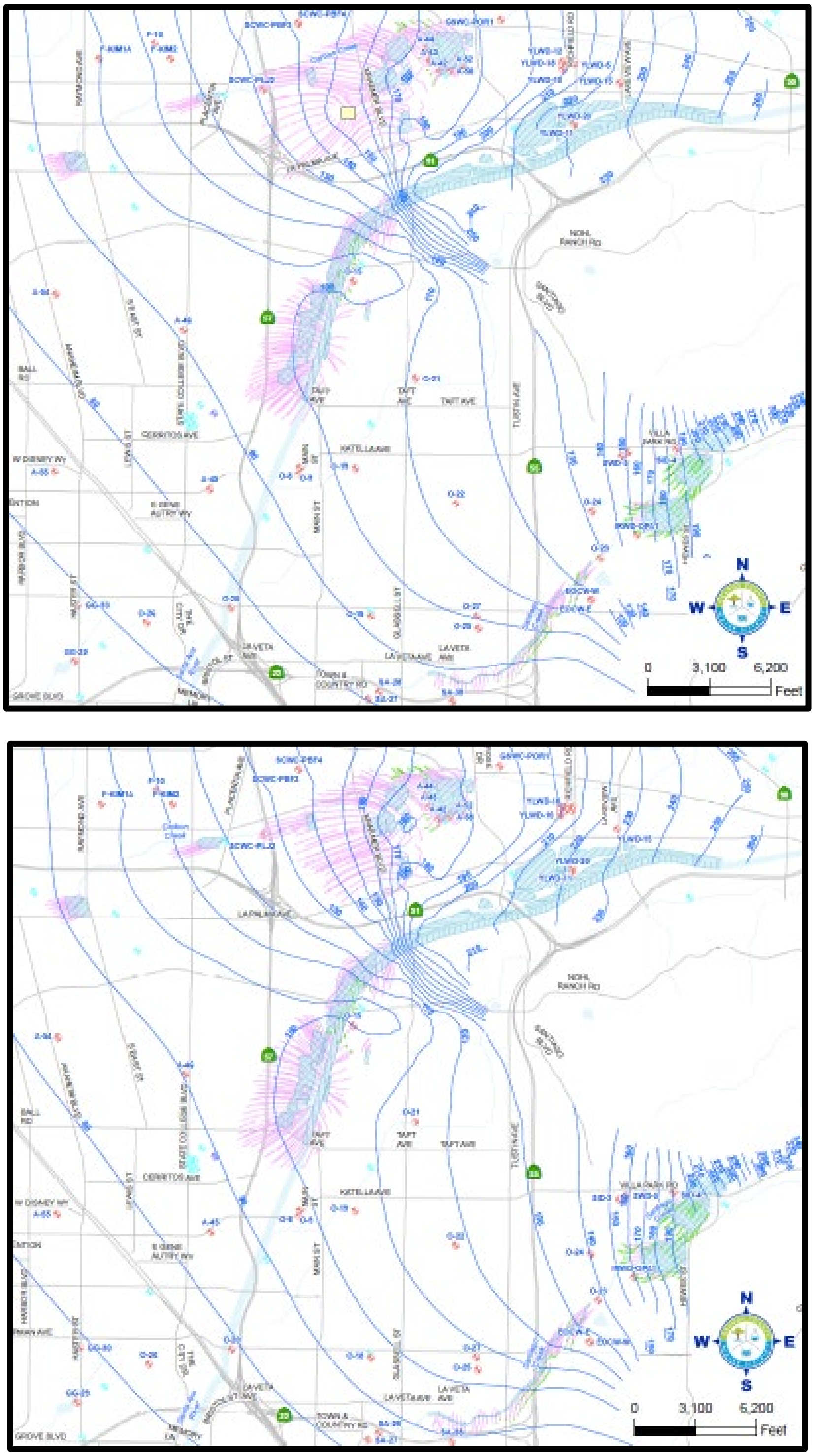
Summary and Recommendations

The Pure Water project area includes four diverse groundwater basins. Preliminary evaluations of these basins have concluded that there are recharge facilities and storage capacity available to the Program. Metropolitan will need to coordinate with groundwater managers and basin watermasters to fully evaluate the capacity of each basin. The Program can provide each of the four basins, and Metropolitan's service area, a reliable and high-quality local source of water that would supplement existing supplies.

Summary

Table 21 provides a summary of the groundwater level changes because of Pure Water. In addition, it provides a summary of the number of potentially impacted wells that are within the travel time envelope.

Figure 27 Metropolitan Recycled Water Recharge Evaluation 6-Month Particle Trace with and without Proposed New Basin



Source: OCWD 2017

Basin water levels are expected to increase by as much as 47 feet above existing conditions during the modeling period because of Pure Water.

A total of 16 wells would potentially need to be relocated. Without Orange County, the total number of wells that would need to be relocated is 10. It is important to note that the Santa Fe Well, owned by California-American Water Company, is no longer in operation and will no longer need to be relocated. New well locations have not been selected and would need to be coordinated with local agencies.

Table 20: Summary of Water Level Changes and Well Impacts

Area	Change in Water Level during Modeling Period (feet)	Number of Wells Potentially Impacted
Main San Gabriel Basin		
• Santa Fe	47	1[1] (7)
• San Gabriel Canyon	4	4 (9)
• United Rock Pit No. 3	35	0
• Baldwin Park Key Well	37	0
Central Basin		
• Montebello Forebay	7	4
• Long Beach Wells	6	0
West Coast Basin		
• Carson	24	1
Orange County Basin		
• Anaheim	0	6
Total		**16 (27)**

Data in () represent wells that are within the 1-year travel time, but outside the 2-month travel time.
[1] This well is no longer in operation.

Recommendations

The following additional groundwater investigations are recommended:

1. Perform physical tracer studies to confirm the results of solute transport and particle tracking. Tracer analysis would help to determine the RWC and travel time requirements and the impacts to existing wells. Ongoing monitoring and studies during operations, such as tracer studies, will be performed once the project is online to address the travel time requirement to protect nearby wells. The monitoring plan and tracer analyses will be approved by the Regional Board as part of the Title 22 permit. A tracer study involves the introduction of a tracer chemical into the recharged water. Upstream and downstream wells are monitored to determine if the tracer chemical is present. Alternatively, if there is no tracer chemical suitable, an intrinsic chemical, which is a constituent that is significantly different from the ambient groundwater (e.g., boron, sulfate, or chloride), would be used to track changes. If these studies show that the tracer could reach the well in under 2 months, then the well would need to be relocated. For example, If the tracer reaches halfway to the nearest well in under 1 month (half the regulation of 2-month travel time), the well will need to be relocated before the recharged water reaches the well(s). This threshold would prevent any substantial impacts and give the well owner some time to turn

off the well and investigate alternative locations. If there are opportunities for an intrinsic tracer (e.g., introduction of Colorado River water in the Main San Gabriel Basin, which is higher in chloride and sulfate than ambient groundwater), then this analysis may be able to be completed before final completion of the project.

2. Perform water compatibility studies for the injection wells and the spreading basins to assess whether there would be any potential interactions between the purified water and the native groundwater. If a potential interaction is determined to be possible, additional actions may be needed to prevent biofouling in the wells or precipitation of minerals. Water compatibility testing will be completed during the preliminary design phase of the project. Water compatibility testing may include spreadsheet models or bench-scale testing. If scaling or biofouling is shown to be a potential concern, preventative measures may need to be implemented by Metropolitan or the member agency. Scaling is common in injection wells and is not completely preventable. However, to help prevent scaling or biofouling in the injection wells, water from the AWPF should have a target Langelier Saturation Index, or LSI, of slightly negative to slightly positive (-1.5 to 0.5) – this will help stabilize the water and reduce the risk of adverse impacts from calcium carbonate scaling, the most common scaling in injection wells and spreading basins (Stantec 2024). Based on the water compatibility testing, pH and alkalinity may also need to be adjusted for injection wells. At Orange County's GWR, pH and alkalinity goals are 8.5 and 50 mg/L as $CaCO_3$.

   In addition, iron-manganese biofouling is a potential issue in the Long Beach area due to high levels of iron and manganese in the groundwater basin. Creating a reducing environment (limited oxygen) at the wellhead by purging with nitrogen gas, which reduces the oxygen saturation, can help to reduce the potential for this biofouling in the injection well. When scaling or biofouling does occur, the member agency would need to rehabilitate the well (either chemically or physically) to remove the scaling. Acid washing with an acid such as hydrochloric acid is an effective rehabilitation technique for removing iron-manganese biofouling. Regular rehabilitation of injection wells and spreading basins is typically part of normal operation and maintenance of injection wells and does not pose a substantial impact to the groundwater basin or the long-term operation of the facilities.

3. Confirm siting of the proposed injection wells and relocated production wells. The well siting or relocated production well process will be performed by the member agency or agency that will be constructing the injection wells or relocated wells. All new wells must comply with DWR standards outlined in Bulletin 74-81 and Bulletin 74-90 (DWR, 1981 and DWR, 1990). These standards include requirements for the construction of the wells, minimum separation distances from potential sources of pollution or contamination (e.g., septic tanks or sanitary sewers), and well abandonment. Well abandonment will need to be performed for each well that will require relocation to prevent migration of contamination. The member agency or agency that will be constructing or abandoning each well will be responsible for complying with all regulatory requirements. As part of permitting new sources such as injection wells, water systems are required to prepare a drinking water source water assessment for the proposed site to ensure compliance. Under the direction of the Regional Board, the assessment includes a delineation of the area around a drinking water source (e.g., injection well) through which contaminants might

move and reach that drinking water supply; an inventory of possible contaminating activities that might lead to the release of microbiological or chemical contaminants within the delineated area; and a determination of the possible contaminating activities to which the drinking water source is most vulnerable. The member agency or the agency constructing the well is responsible for preparation of the drinking water source assessment. This process is part of the normal permitting process and is not anticipated to have substantial impacts to groundwater.

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