# W385 PUMPING TEST 2019/20

Analysis and Discussion

PROFESSIONAL GEOLOGIST
KEITH RAINVILLE
No. 9747
STATE OF CALIFORNIA

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Keith Rainville

PG 9747
Inyo County Water Department
Senior Hydrologist
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# 2019-20 W385 Two-Month Pumping Test Analysis

## Introduction

From December 2019 to February 2020, LADWP conducted a pumping test on well W385 in the Five Bridges area according to monitoring and reporting procedures adopted by the Technical Group and included in legal settlements with the Owens Valley Committee, Sierra Club and California Fish and Wildlife. Numerous technical, regulatory, and legal documents provide the complex history of pumping near the Five Bridges Mitigation Project and the Fish Slough area. These documents are listed in the References section at the end of this report and most can be found on inyowater.org. This report will present relevant hydrologic data on the surrounding hydrologic setting and interpret data collected during the 64-day pumping test conducted on LADWP well W385.

On May 6, 2020, the Inyo-LA Technical Group presented the "*Production Well W385 in Laws Wellfield Two Month Pumping Test, April 2020*" report (Appendix A). This initial report was produced to compile the hydrologic data collected during the pumping test, to present initial hydrographs and cross-sections from project monitoring wells, and to document that no trigger levels were exceeded during the test.  In order to provide a timely summary of data and events that April report contained little data interpretation. The goal of this follow-up report is to provide in-depth examination of the data and to answer many of the numerous questions related to the W385 pumping test, including: how pumping the modified W385 affects the groundwater levels in the shallow aquifer which supports phreatophytic vegetation and encompasses the Five Bridges Mitigation Project; how pumping affects the deeper aquifer zones and the potential discharge of deeper groundwater to the surface in the area; to present additional insights gleaned from the test; and to recommend additional analysis or future actions related to W385 and W386.

## Executive Summary

The main observations and conclusions of the two-month test of W385 are as follows:

- The W385 pumping test complied with the relevant CEQA, Technical Group, Standing Committee, and settlement agreements reached between LADWP and various parties, including spreading surface water on the south side of the Owens River in an equal or greater amount of as pumped by W385 in 2020.
- No triggers levels were exceeded during the W385 pumping test and pumping proceeded for the full 64-day period.
- The water-table remained within the 6.5-foot (2-meter) rooting zone throughout the test in shallow monitoring wells located adjacent to phreatophytic meadow vegetation at the Five Bridges Mitigation Site and in Fish Slough.
- The reduced pumping rate and the modified W385 screen interval resulted in significantly less drawdown on both shallow and deep groundwater levels as compared to the 1993-94 test.

- Less than one-foot of drawdown was observed in the shallow aquifer north of the Owens River during the 2019/20 test. Little or no drawdown was observed in the shallow aquifer south of the Owens River in the Five Bridges Mitigation Site, or in Fish Slough.
- Drawdown in the deep aquifer zone was observed both north and south of W385, including at the mouth of Fish Slough. No drawdown was observed at wells located 1.8 miles to the west, and results were inconclusive in wells located to the east. Drawdown in the deeper aquifer zones approached steady state within approximately one to two weeks of pumping.
- Results indicate that there is "leaky" or partial vertical confinement between the deeper and shallow aquifer zones in the vicinity of W385.
- Due to the heterogeneous hydrogeologic make-up of the W385 area, any additional pumping proposals should be evaluated with caution and with an underlying assumption that differing pumping stresses (amounts of pumping, production wells pumped, or seasonal timing) could produce different hydrologic responses in the shallow and deep aquifer zones.

## Background

*Brief history of W385 and W386*

Wells W385 and W386 were drilled in March 1987 in an active gravel mining operation. As originally designed, these wells were screened from 50-500 feet below ground surface (bgs) in both shallow and deep aquifers zone.  Approximately 8,800 acre-feet (AF) of pumping from wells W385 and W386 occurred between 1987 and 1989. Groundwater levels in the surrounding shallow aquifer were lowered and, as a result, approximately 300 acres of groundwater-dependent vegetation, now known as the Five Bridges Area, was impacted by operation of these wells. Therefore, LADWP stopped operating these wells and mitigation measures related to these impacts were included in the 1991 FEIR.

In 1993 a series of shallow monitoring wells were installed in the Five Bridges area and a 62-day pumping test of W385 and W386 was conducted from November 1993 to January 1994. Both wells were pumped simultaneously with a combined pumping rate of 16.3 cubic-feet-per-second (cfs) and a total of 2,095 AF was pumped. Water levels were monitored in both shallow and deep monitoring wells located on the north and south sides of the Owens River. Pumping W385 and W386 immediately affected groundwater levels in all monitoring wells on both sides of the Owens River, confirming the significant effect of pumping in the original impact area. Inyo and Los Angeles agreed in 1999 to permanently shut off the two production wells

LADWP modified W385 and W386 in 2014 (see Appendix A of LADWP's "*Owens Valley Well Modification Project, January 2015"*) by injecting cement grout into the upper screened sections and sealing both wells to depths greater than 300 feet bgs. After sealing the shallow portion of the screen, a 24-hour pumping test was conducted at each of these wells. Results indicated a substantial reduction in the pumping capacity of these wells (from 10.1 cfs to 3.7 cfs in W385 and from 6.2 cfs to 2.8 cfs in W386).

To evaluate potential impacts of operating modified W385, LADWP conducted a 64-day pumping test from December 16, 2019 to February 18, 2020. A total of 463 AF was pumped from W385 at an average rate of 3.7 cfs.

Groundwater level drawdown "trigger levels" were set to protect groundwater-dependent vegetation and a non-LADWP domestic well from potential, but unanticipated, pumping impacts during the test. If groundwater levels dropped below a given trigger level, pumping would cease. Trigger Levels were set in six monitoring wells in early December 2019 by ICWD, LADWP and DFW staff. None of these trigger levels were exceeded during the test. Data was collected before and after the test using manual and continuous recorders and was summarized in the *"Production Well W385 in Laws Wellfield Two-Month Pumping Test, April 2020"* which was presented at the Technical Group in May 2020.

*Brief history of the Fish Slough area*

Fish Slough is located in the Volcanic Tablelands north of the Owens River and Bishop, approximately one to seven miles north of W385. Fish Slough is a groundwater dependent ecosystem which consists of wetlands and other phreatophytes dependent on spring and seep groundwater discharge which occurs along the prominent north-south trending Fish Slough fault system. It is a federally recognized Area of Critical Environmental Concern and hosts federally and state endangered Owens Pupfish and the Fish Slough Milk Vetch.

Sporadic groundwater and surface flow monitoring has been conducted since the late 1970s with more consistent and laterally extensive monitoring beginning in the mid-1990's. Monitoring wells in the Fish Slough area have shown steady declines in groundwater levels over the past three decades. There are also long-term declines in outflow at Fish Slough Northeast Springs, in the combined outflow of additional springs and seeps at the southern end of the slough, and in groundwater levels to the north and southwest. Both recent and historic studies suggest that Fish Slough is part of a regional groundwater flow system that extends beneath the Volcanic Tablelands north and east into the Tri-Valley area and south to the Owens River. Continued declines in groundwater levels could lead to critical declines in springs/seep outflow, endangering the Fish Slough ecosystem. Recent studies have postulated that regional pumping is contributing to the decline in Fish Slough groundwater levels (Zdon, 2019; Jayko 2010; ICWD, 2016).

## Hydrologic Conceptual Model

A hydrologic conceptual model (HCM) is the framework that describes the important surface and subsurface features that influence the flow and storage of groundwater in a given area. The HCM for the W385 and Fish Slough area has been developed from GIS products, geologic maps, subsurface bore hole logging, fault mapping, gravimetric studies, hydrographic interpretation of ground and surface water monitoring, groundwater chemical analysis, environmental monitoring, and active management actions. Components for the HCM date back to USGS and DWR studies in the 1960s. Additional studies were conducted in the 1980s as part of the development of the Inyo-LA Long Term Water Agreement and associated 1991 EIR. These and more recent studies by BLM, DFW, USGS, ICWD, LADWP, academic institutions, and other contractors are included in the References Section.

Production well W385 is located in the northern portion of the Owens Valley at the confluence of the Owens River and Fish Slough. This HCM encompasses the Dixon-Lane area to the south, the Owens River flood plain to the west, the Fish Slough area to the north, and the Laws/Owens River area to the east. The HCM described in this report synthesizes the previous information and distills the key hydrologic factors relevant to the W385 pumping-test.

*Topography and Surface Water Features*

Production well W385 is located on the Owens River floodplain which flows from west to east in the topographic low of the vicinity Map 1 (LADWP, 2020). Flows in the Owens River adjacent to W385 can be estimated from the measured releases from Pleasant Valley Reservoir to the west minus diversions to the Bishop Creek Canal and diversions to the Upper and Lower McNally Canals. The Bishop Creek Canal contours south of the project area and can provide surface irrigation (metered) to the southern side of the Owens River. The C-Drain, a LADWP managed water conveyance, also lies south of the Owens River and can bring water from Bishop Creek west of town into the project area (unmetered). This water can either flow to the river or can be ponded in a small recharge basin. The Volcanic Tablelands, consisting of the Bishop Tuff pyroclastic flow, outcrops north of the Owens River with bluffs several hundred feet above the floodplain. The two McNally Canals (metered) have diversion points west (upgradient) of the project area and contour along the base of the Bishop Tuff to the north and then east of the project area.

Fish Slough is a small, perennial stream (metered) fed from groundwater discharge from the north-south trending Fish Slough fault system. Fish Slough discharge crosses the McNally canals and can either be diverted east in the canals or continue flowing south through the gravel mining plant past W385/386 to the Owens River. Mining operations have created several pit/ponds that are filled to various levels with surface water depending on hydrologic conditions. The five large pits/ponds are located upgradient to the west, northwest, and north of W385 and also downgradient to the southeast and east.

*Geologic Structures Relevant to Hydrology*

The structural geology of the W385/Fish Slough area has been described in many studies including Bateman, 1965; Hollett, 1981; Danskin, 1998; Zdon, 2019; Jayko, 2010; ICWD, 2016. These studies include detailed investigations of the structures and hydrostratigraphic relationships between the Owens River, Fish Slough and the Tri Valley area (Benton, Hammill, Chalfant) using geologic, geophysical, geochemical, and hydrographic data. They provide extensive information on the tectonic forces acting on the Owens Valley and the regional faults, folds, and geologic units. For the purposes of this report, a focused structural synthesis of current understanding is provided here.

The Owens Valley is the western edge of the Basin and Range geologic province. Regional faulting has uplifted the Sierra Nevada to the west and the White/Inyo Mountains to the east. In addition to these prominent mountain front faults, there are significant basin faults as well, including the Owens Valley and Fish Slough fault zones. The general structural trend of the valley is northwest-southeast. The Sierra consists primarily of granitic rocks; the White and Inyo ranges consist primarily of sedimentary and metamorphic rocks. The Owens Valley is filled with alluvial, fluvial, and lacustrine sediments derived from these mountain ranges. Geologically recent volcanic activity has deposited igneous units in portions of the valley. Located in the northern portion of the Owens Valley, the Volcanic Tablelands is a southeast-dipping deposit several hundreds of feet thick that was formed from the eruption of the Long Valley Caldera approximately 750,000 years ago. The Tablelands consists of the Bishop Tuff unit, a pyroclastic and ash fall deposit that overlies the former valley surface north of the Owens River. Evidence of the tuff is also found in the subsurface at depth underlying the most recent alluvial fill south and east of the river through Bishop towards Big Pine.

The variation in valley-fill sediments including grain size, depositional history and lithification (e.g. gravels, clays, welded tuff, etc.) affect the flow and storage of groundwater, and compositional differences (e.g. granite, limestone, rhyolite) affect the geochemical signature of groundwater.

Geologic mapping and geophysical surveys combined with well logs, where available, provide evidence for the structures in the northern Owens Valley. Gravimetry, which uses the varying densities of sediments (less dense loose alluvium vs. dense crystalline bedrock), and seismic studies, which use the relative differences in velocity as seismic waves pass through materials (faster through hard rock, slower through looser sediments) have been used to determine the depth of fill in the valley, the subsurface bedrock topography, and the locations of major fault systems.

Gravity data indicate that, along a north-south axis from Hammil Valley to Big Pine, the deepest part of the Owens Valley groundwater basin extends from Hammil Valley south through the Fish Slough/W385 area where it forms a basin underneath the southern extremity of the Volcanic Tablelands. As discussed in the ensuing hydrology section, this structural low contributes to regional groundwater discharge to the Fish Slough/W385 area. Additional gravimetric data combined with structural mapping indicate a prominent subsurface bedrock high exits east of Fish Slough and may deflect the regional groundwater flow path from the northern (Hammill) and eastern (Chalfant) south and west towards the Fish Slough area (Map 2, Hollet 1991).

The W385 and Fish Slough areas are located in a regional fault zone. The north-south trending Fish Slough fault zone crosses the project area and numerous individual fault traces have been mapped by the USGS in the area. This fault zone is easily discerned in the Volcanic Tableland, but in active alluvial environments (e.g. along the Owens River floodplain), recent sedimentation or erosion can obscure the surface expression of the faults, and but the larger faults are likely continuous at depth.

Fish Slough faulting is primarily comprised of a series of normal faults (vertical displacement) with a component of right lateral movement. The fault zone trends north-northeast, linked by step-overs and relay ramps. This has created a half graben (valley) that holds the Fish Slough wetland and the prominent horst (hill) to the east that separates Fish Slough from the eastern Laws/Chalfant area. The Fish Slough springs and seeps discharge from this fractured zone. A series of en-echelon faults extend to the northeast, crossing the Chidago Canyon wash and extending into the southern portion of Hammil Valley; potentially diverting groundwater flow from Hammil to the southwest into the northern Fish Slough area.

An important hydrologic aspect of this faulting is that, due to the “gouge” of fine material created by the grinding fault movement and displacement of geologic units, faults generally interrupt groundwater flow across (perpendicular to) the axis of their trend while preferentially allowing flow along (parallel to) their trend. Therefore, the Fish Slough fault zone could potentially impede west-east groundwater flow while promoting north-south flow creating elongated, north-south, orientated hydrologic “blocks” partially isolated from neighboring blocks. Shallow subsurface alluvium may be less affected by faulting compared to the deeper, older units.

*Subsurface Materials*

Hollet (Map 3, Hollet 1991) and Danskin (Map 4 and Map 5, Danskin 1998) present the generalized hydrostratigraphy of the W385 area, and Bateman presents a regional fence diagram of the Bishop Tuff at depth (Map 6, Bateman’s Figure 64). Additional details regarding the subsurface composition and structural geology of the W385 area have been developed for this report from surface exposures, numerous well logs (lithologic and electronic), and previous structural studies (field mapping and geophysical analysis).

In general, the subsurface layers in the vicinity of W385, from shallow to deep, consist of poorly to moderately consolidated alluvial and fluvial deposits related to the Owens River; Bishop Tuff; and more consolidated older fluvial and lacustrine deposits. Gasses associated with the pyroclastic flow formed voids as the Bishop tuff cooled; the tuff is highly porous but has low primary permeability as these voids are separated by rock matrix. Where faulted, the tuff can become highly transmissive as the brittle rock shatters allowing interconnection between voids. The basal layer of the tuff consists of a poorly lithified ash fall deposit that is easily weathered to clay in the subsurface. The Bishop tuff and/or clay layers at depth related to older lacustrine deposits can create confining or semi-confining layers that separate the recent alluvial and fluvial deposits (“shallow aquifer zone”) from the older buried sediments (“deep aquifer zone”).

Shallow aquifers around the Owens River consists of recent alluvial or fluvial deposits – variable beds composed of cobbles, gravels, and sands that are highly transmissive – interfingered with less transmissive silt and clay zones (Hollet, 1991; SECOR, 2004; area, well logs). The thickness of this shallow layer varies across the site but is encountered in the top 100-200 feet below ground surface (bgs) between the Dixon Ln area (e.g. W410, W756-759 logs) and W385 (e.g. W385, W386 logs). North of W385 near the Volcanic Tablelands, this transmissive aquifer thins to 10-20 feet of unconsolidated tuff-derived alluvium (e.g. Private Well, W249 logs).

In Fish Slough (Map 1), a thin veneer of tuff-derived alluvium exists at depths of approximately 0-60 feet (e.g. FS3, DWR excavations, inferred from FS#1, FS#2 well-construction and hydrographs). Beneath this thin layer of alluvium, Bishop Tuff is found extending to depths of at least 150-250’ (e.g. FS#3, Private, Zack well lithologic and video logs, DWR excavations). The Bishop Tuff is encountered at various depths from 15-325 feet in logs from the Private Well south across W385/W386, T756-759, and the W410 area (and in logs further south and east). Drillers have variously described the Bishop Tuff as tufa, red tuff, volcanic rock, pumice and red sand (in mud-rotary cuttings the ground tuff would appear as a red-sand). Of note, the older lithologic logs reviewed for this report are of higher quality (greater description in more discrete vertical increments) likely owing to the fact that they were primarily developed from the cable-tool drilling method which manually retrieves cuttings at regular intervals by down-bore bucket. Whereas the more modern lithologic logs were developed from mud-rotary drilling which both mixes and dilutes bore-hole cuttings. The more recent lithologic logs focused more on grain sizes and less on fugitive drilling data, formation composition, and grain shape. Less detailed lithologic logging in these mud-rotary wells may have occurred due to the fact that subsequent electronic-logging was planned for each bore hole. In the more modern wells

(T756-59, T752-55, W385, W386), using the electronic logs (e-log) provides additional subsurface information.

In electronic well logs, the Bishop Tuff is distinctive from the overlying and underlying alluvium. The alluvial stringers are an irregular mixture of peaks and valleys in both the spontaneous potential (SP) and the various resistivity logs. Resistivity logs measure the electrical resistance of the subsurface formations. Low resistivity clays have low fluid permeability and are associated with highly conductive fluids while high resistivity sands and gravels are more permeable with typically fresh, less conductive groundwater. The SP responds to electrochemical differences between the drilling mud and formation water, e.g. a transmissive zone of sand or gravel containing non-saline groundwater can alter the electric potential in that section of the bore as drilling mud is juxtaposed with fresh formation water. The alternating alluvial/fluvial deposits, which vary in composition from clays to sand to gravels and in thicknesses from 0-20 feet, create a characteristic varying pattern of peaks and troughs in both the SP and resistivity logs.

The Bishop Tuff, however, is a continuous, more homogenous zone of high resistivity (porous rock filled with air and/or fresh water). SP deflections in the Bishop Tuff are also more consistent and uniform in nature indicating a more stable fluid and formation environment through that section of the borehole. The Bishop Tuff is discernible in e-logs from the W385 bore at 160-300’, from the W386 bore at 210-325’ (Appendix B), from the T756-59 bore at 75-210’, and possibly from the T752-55 bore at 50-210’ with additional erosional influences. The Bishop Tuff is well described in the lithologic logs at W238 and W410 at depths of 190-270’ and 195-255’ respectively. A clay layer is frequently found at the base of the tuff. Studies of the depositional history of the tuff indicate much of the initial ash fall (lowest subsurface layer) was deposited over a lacustrine environment (lake) and poorly lithified. Clays related to subsurface decomposition of the ash fall or to these contemporaneous lake deposits are potential mechanisms for formation of these basal clay zones.

Monitoring wells in the Fish Slough area south to the Private well are drilled in the Bishop Tuff but do not penetrate beneath it. However south and to the east of W385, lithologic and e-logs from the deeper monitoring and production wells describe alternating sequences of alluvial and fluvial/lacustrine deposits (gravels to clays) beneath the tuff. Deeper clays lenses of up to 20’ thick may create localized semi-confined conditions in the deeper alluvium.

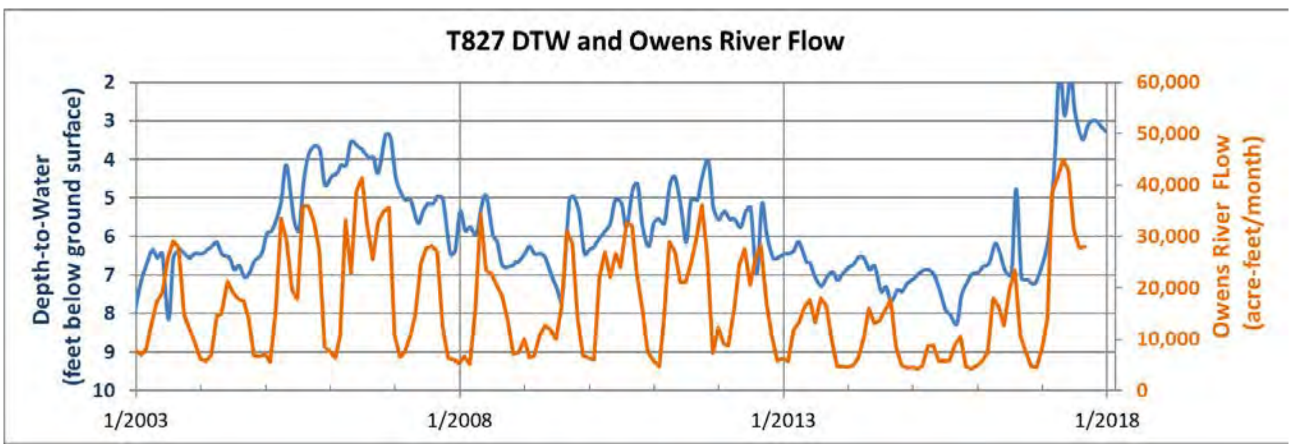
Despite the geologic heterogeneity observed near W385, three hydrostratigraphic units can be identified for the HCM: the shallow alluvial aquifer unit, the Bishop Tuff/ basal clay unit, and the deeper alluvial aquifer unit.  Pumping and monitoring well screens coincide with these units, including the modified screened intervals of W385 and W386. The deep aquifer unit is the zone which the modified wells are now screened in. The shallow aquifer unit is the recent, transmissive alluvial sediments that are above the Bishop Tuff. And the primary confining layer is the Bishop Tuff/basal clays unit, although there are other minor clay stringers in the older sediments (deep aquifer unit) that likely provide some impedance to vertical flow. This report does not seek to separate individual minor aquifer/aquiclude units, but to describe the overall effect of pumping W385 has on the region. This subsurface stratigraphy of young alluvium, Bishop tuff, and older alluvium is consistent with previous HCM/modeling efforts (Danskin, 1998; SECOR, 2004; and Stantec, 2018).

*General Hydrology*

The prevailing direction of surface and shallow groundwater flow in the W385 area parallels the slope of the ground surface from points of recharge in the higher elevations to points of discharge at lower elevations in Fish Slough or near the Owens River. Upgradient surface and groundwater flows towards the Owens River axis from the south, west, and north. Based on groundwater elevations (GWEs) measured in the numerous monitoring wells completed from depths of 20-680 feet, the W385 area is a groundwater discharge zone in its undisturbed state (upward pressure gradient from deeper zones towards the surface). Surface and groundwater outflow generally exit the area to the east/southeast following the path of the Owens River. Principle sources of ground and surface water inflows include: flow moving northeast from the Bishop Creek alluvial fan to the Owens River, flow from the west in and along the Owens River, and flow from the north from the Volcanic Tablelands and Fish Slough.

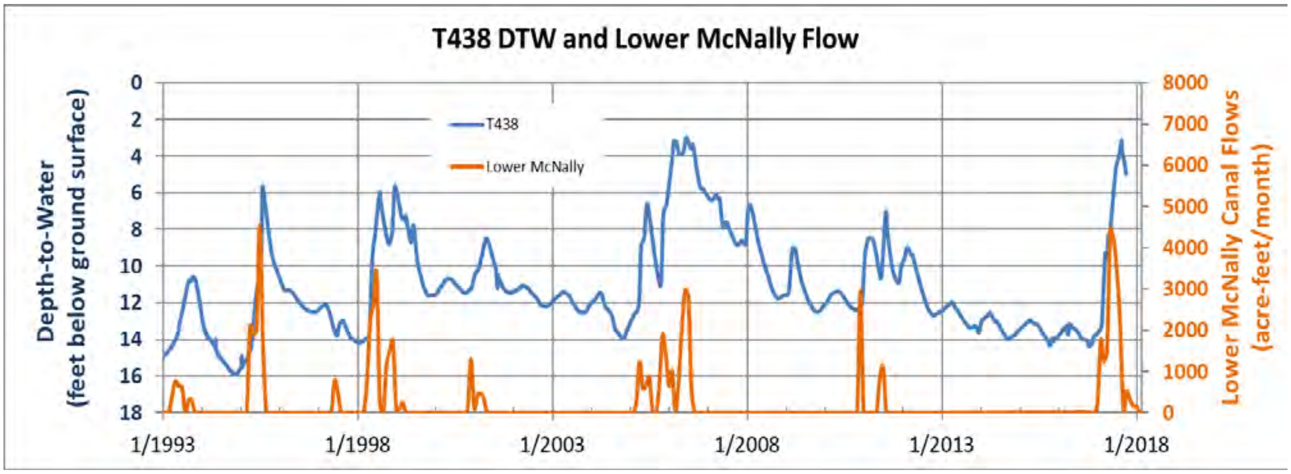
Surface flows from Fish Slough increase from fall through winter as evapotranspiration (ET) demand ebbs due to vegetation senescence. Flows in the Owens River are actively managed by LADWP and controlled by releases from Pleasant Valley Reservoir. These flows normally ramp-up from late spring through early fall, based on availability and demand, and then lessen in late fall through winter (Figure 1).

*Figure 1: Owens River monthly flow and groundwater levels in adjacent T827*



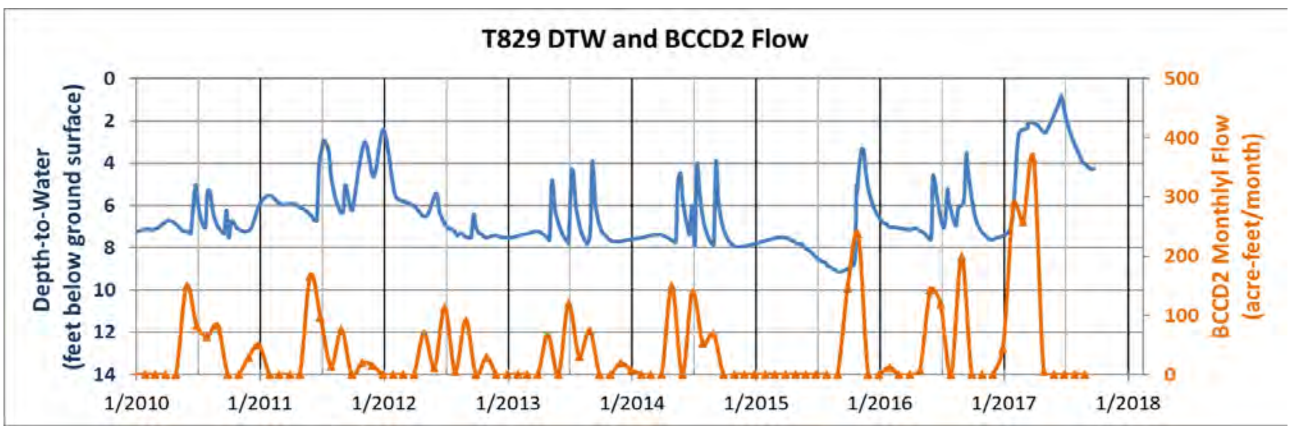

Additional sources of surface water inflow can include LADWP-managed, sporadic diversions from the Owens River proper into the Upper and Lower McNally Canals which are located approximately one-quarter miles to the west and north of W385. The McNallys are unlined and upgradient of W385 and provide significant surface seepage, when active, to recharge the shallow, water-table aquifer north of the Owens River; for example, Figure 2 comparing groundwater levels in T438 and Lower McNally flows. High flows in the Owens and McNallys also communicate quickly with the gravel pits, raising the stage of these ponds.

*Figure 2: Lower McNally monthly flow and groundwater levels in T438*




LADWP manages diversions to the west and south of the Owens River through the Bishop Creek Canal (and the C-Drain). This surface water can supply substantial and immediate recharge to shallow water table on the south side of the Owens (Figure 3).

*Figure 3: Bishop Creek Canal Diversion 2 flows and T829 groundwater levels*

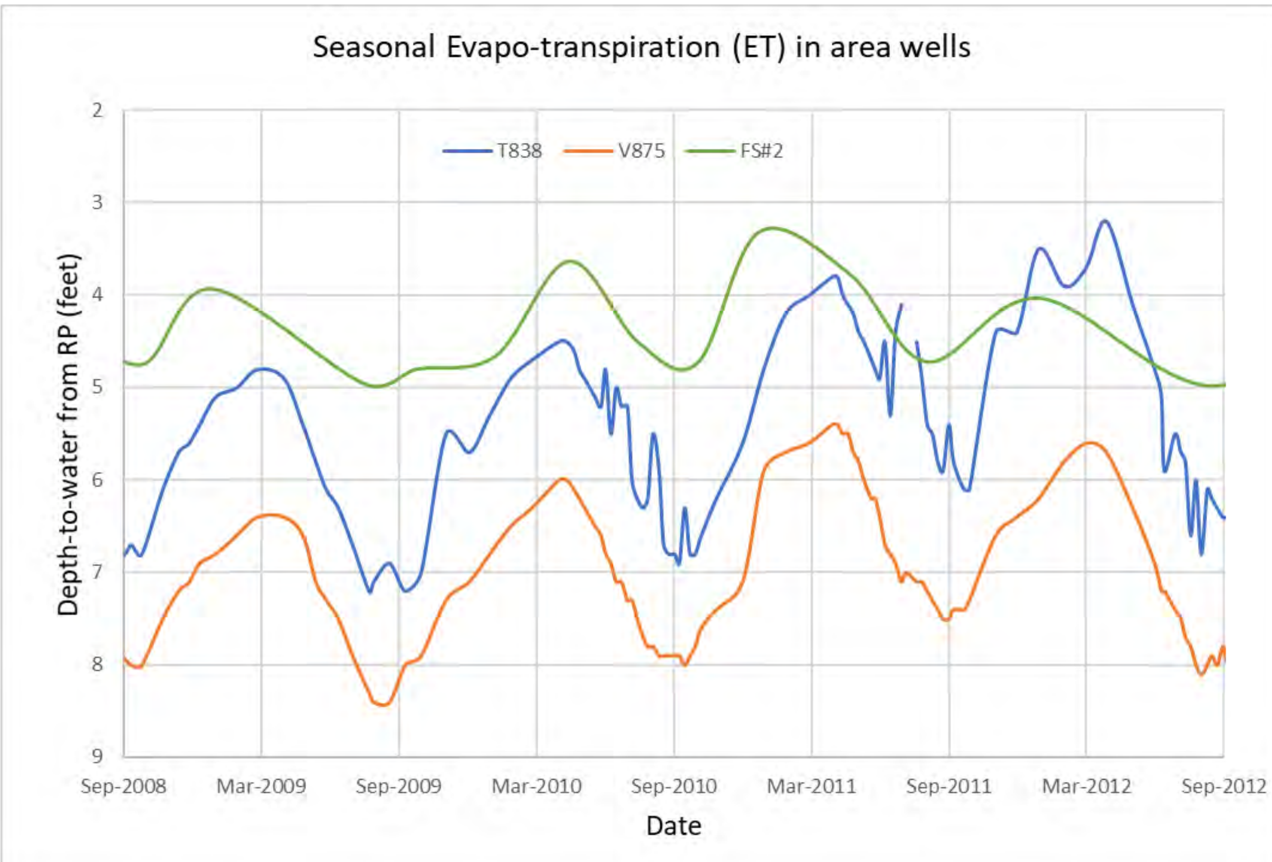



Only one domestic well located about one-half mile northwest that likely pumps less than 2 AF/yr. LADWP production well W410 is located on the south side of the Owens River appx. 1.75 miles south of W385. For the past decade there has been consistent annual pumping from this well (average pumping rate of appx. 4 cfs) in all but high-runoff years. Pumping W410 affects groundwater levels in the deeper aquifers zones (as evidenced in hydrographs from T757-759, Figure 20 below) and also the shallow water-table aquifer on the south side of the river to a lesser degree (as evidence in hydrographs from T831 and T756, Figure 7). Three LADWP production wells W247-249 are located about 1.3, 2, and 2.6 miles east-northeast of W385. These wells are pumped more irregularly but can affect the shallow water-table east of W385 (as evidence in T438) when operated for longer periods of time.

In addition to changes in surface flows and groundwater pumping, other management actions can influence the local hydrology. Gravel mining operations sporadically include pumping from individual gravel pits to allow additional surface mining. For example, midway through the 2019-20 test, surface water pumped from the northeast gravel pit was diverted to the east and is clearly evident in the T438 hydrograph (Figure 16 below).

Additional outflow components of the hydrologic system include evaporation and plant transpiration (ET). Groundwater levels in water table aquifers near phreatophytic vegetation generally exhibit declines due to ET in the spring through summer, and recovery from fall through winter. The effects of seasonal ET can be seen in hydrographs of shallow monitoring wells in the area, for example: in Fish Slough at FS#2, north of the Owens River at V875, and south of the Owens at T838.

*Figure 4: Seasonal ET influence on shallow groundwater levels in project area*




Shallow groundwater temperature typically reflects the annual mean ambient surface temperature (50-60 deg. F in the Bishop area). Warmer groundwater (70-90 deg F) temperatures typically reflect longer flows paths, deeper discharge, or hydrothermal sources.

## Monitoring Network

The hydrologic monitoring network for the two-month pumping test consists of surface and groundwater monitoring points with recent and historic periods of record. The monitoring network is described in detail in the June 2018 monitoring plan. Table 1 lists the 29 monitoring wells that are a combination of shallow test wells (generally less than 50 feet deep) screened in the water-table aquifer and deeper wells screened in or beneath the Bishop Tuff.

*Table 1. Monitoring wells for the two-month pumping test of W385*

| Monitoring Well | Depth (ft) | Distance from W385 (ft) | Direction from W385 | Location relative to Owens River |
|---|---|---|---|---|
| T438 | 37 | 3,330 | NE | N. of River |
| T704 | 32 | 570 | S | N. of River |
| T733 | 674 | 585 | S | N. of River |
| T752 | 680 | 9,422 | W | N. of River |
| T753 | 100 | 9,422 | W | N. of River |
| T754 | 210 | 9,422 | W | N. of River |
| T755 | 490 | 9,422 | W | N. of River |
| T756 | 45 | 3,560 | SW | S. of River |
| T757 | 310 | 3,560 | SW | S. of River |
| T758 | 575 | 3,560 | SW | S. of River |
| T759 | 210 | 3,560 | SW | S. of River |
| T826 | 17 | 1,880 | S | N. of River |
| T827 | 16 | 2,220 | S | N. of River |
| T828 | 15 | 2,680 | S | S. of River |
| T829 | 17 | 3,090 | S | S. of River |
| T830 | 14 | 2,920 | SW | S. of River |
| T831 | 10 | 6,490 | SW | S. of River |
| T838 | 37 | 4,310 | SE | S. of River |
| V875 | 21 | 3,080 | SE | N. of River |
| W248 | 602 | 10,592 | NE | N. of River |
| W386R | 560 | 530 | S | N. of River |
| Private Well | 160 | 3,400 | N | N. of River |
| FS#1 | 61 | 7.1 miles | N | N. of River |
| FS#2 | 46 | 4.0 miles | N | N. of River |
| FS#3s | 35 | 2.8 miles | N | N. of River |
| FS#3d | 145 | 2.8 miles | N | N. of River |
| FS#4 | 8 | 6.4 miles | N | N. of River |
| Zack | 257 | 5.2 miles | N | N. of River |
| T397 | 180 | 7.1 miles | N | N. of River |

*Table 2. Surface water features monitored during W385 pumping test*

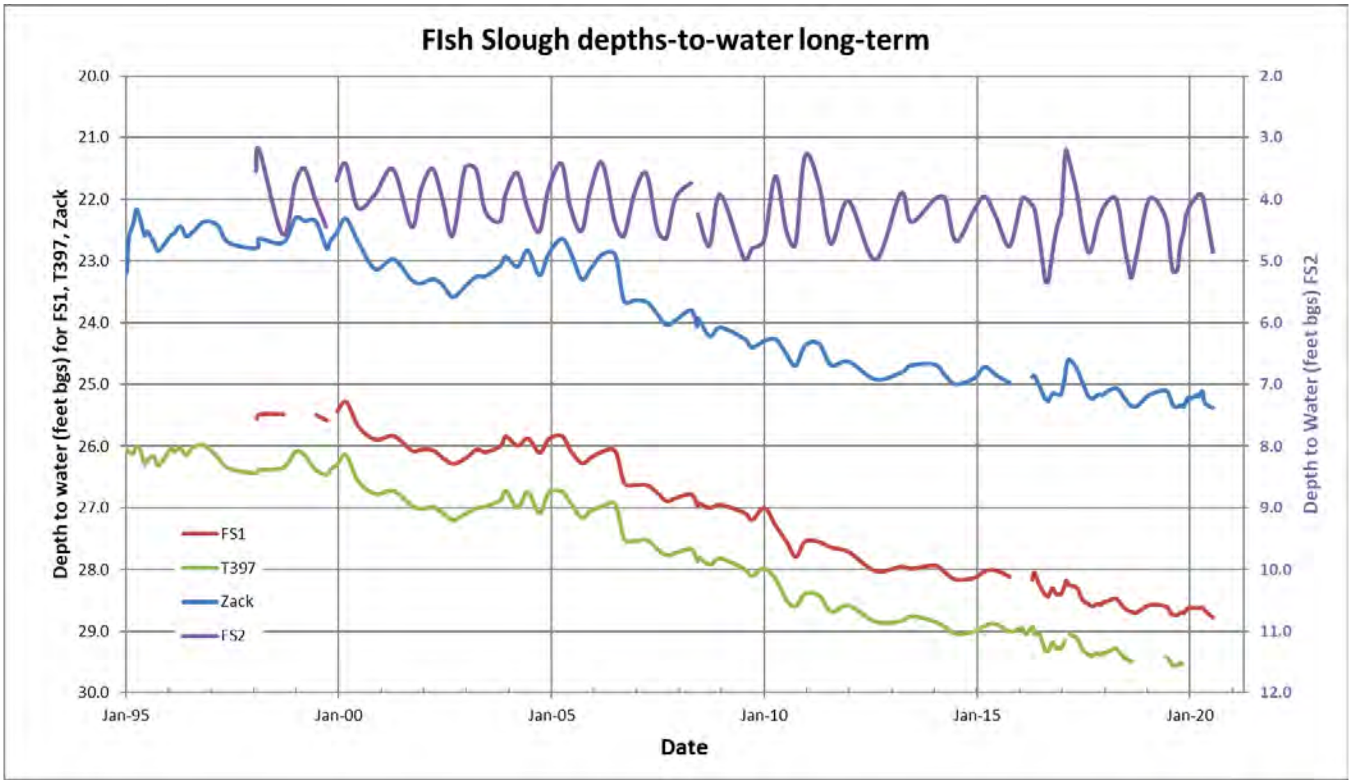
| Station | Name | Notes |
|---|---|---|
| 3208 | FISH SLOUGH SPRINGS BELOW POND #1 | Northern most station at Fish Slough |
| 3209 | FISH SLOUGH SPRINGS AT B.L.M. SPRING | Fish Slough near FS#2 |
| 3216 | FISH SLOUGH AT L.A. STATION #2 | Fish Slough at Upper McNally Canal |
| 3217 | Fish Slough Spring below Ponds 2 and 3 | Fish Slough Spring south of T397 |
| 3207 | FISH SLOUGH AT OWENS RIVER | Fish Slough at Owens River |
| 3242 | BISHOP CK CANAL DIV. TO 5 BRIDGES #2 | Diversion No.2 off Bishop Creek |
| | Owens River Staff Gauge | North shore of Owens River |
| 3343 | West Pont Staff Gauge | pond west of W385R |

Map 1 shows locations of the monitoring components. The Technical Group's April 2020 report on the W385 test presents data collected from the test including manual measurements, daily water levels developed from datalogging devices recording at 1-hour intervals, flow amounts developed from datalogging devices recording at 15-minute intervals, pumping amounts, and water quality sampling and analyses collected before and during the pumping (Appendix A).

To aid in interpretation and analysis of the 2019-20 two-month pumping test, several additional details related to the various monitoring points are now described.

For the Fish Slough area, monitoring wells FS#2, FS#4, and new well FS#3s are shallow wells (less than 50') that are completed in the near-surface volcanic alluvium or at the alluvial/Bishop tuff interface. No wells logs exist for FS#2 and FS#4, but some inferences can be made based on their hydrographic records and measured completion depths. FS#4 is shallow (8' deep), dry, and its data are of little value. FS#2 is 46' deep and reflects the sinusoidal groundwater pattern associated with the annual ET cycle: high groundwater levels in winter and early spring, declining water levels through summer with annual lows in early fall (Figure 5). The amplitude of change in the water table at FS#2, ranges from 1-2 feet each year. FS#2 is located along the axis of the slough and the cool groundwater temperature (about $56^{o}$ F) and hydrograph variations suggest this well reflects changes in the water table aquifer.

*Figure 5: Longterm groundwater trends in northern Fish Slough wells; FS#2 data on right axis*



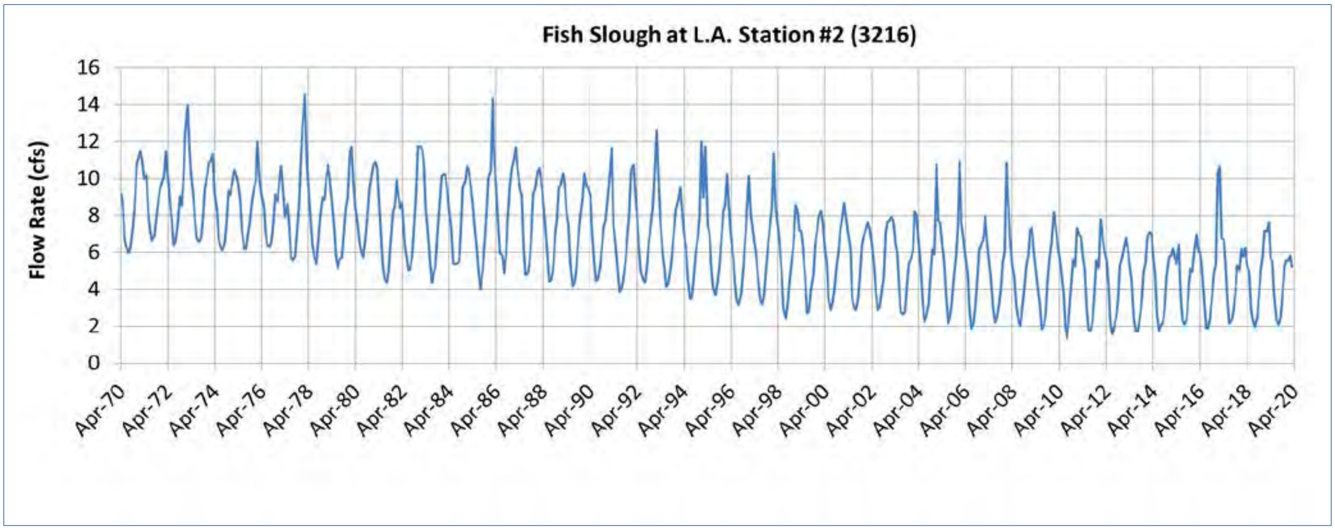

FS#3s was installed in Fall 2019, so data from only one annual groundwater cycle has been collected (Figure 23 below). The intra-annual pattern is similar to FS#2 but the amplitude was approximately 0.8' slightly less than FS#2. Groundwater was encountered at the alluvial/tuff interface while drilling FS#3s and the depth-to-water (DTW) in the well is similar to the well's elevation above Fish Slough surface water. Based on preliminary data, there appears to be both a seasonal ET signature in this well and also elevated temperature (appx 67 $^{o}$ F).

Monitoring wells FS#3d, Zack, and T397 are greater than 140' deep and completed in the Bishop Tuff based on well logs or video logging of open bore. There is a multi-decadal decline in groundwater levels super-imposed on the annual variation in the deeper Fish Slough monitoring wells (Figure 5). With a 25-year period of record, annual DTW changes in Zack well typically range between 0.1'-0.3' per year with shallow levels in the spring and lower levels in the fall. Groundwater temperature is appx. 73 $^{o}$ F. This magnitude of seasonal change is similar to T397 which has a typical annual range between 0.1' and 0.2' and groundwater temperatures of appx. 64 deg. Both wells have experienced greater annual deviations in large runoff years, 2017, 2006. FS#1 is located approximately 20-yards from T397 and is 61' deep.  We do not have a well log. Although FS#1 is shallower than other deep wells, its hydrograph is parallel to T397, has similar groundwater temperature (appx 64$^{o}$ F), and the annual DTW is nearly identical. The video log for T397 encounter Bishop tuff at 68' as the well transitioned from steel casing to uncased, open bore. Based on these similarities, FS#1 is likely either completed in the Bishop tuff at the tuff/alluvial interface or is in strong hydrologic communication with this layer. FS#1 is essentially a duplicate monitoring point of T397. For the purposes of this report, FS#1 will be grouped with the Fish Slough wells that reflect the deeper aquifer zone.

FS#3d was installed in Fall 2019 and, based on the limited data (one annual cycle), the seasonal variation is approximately 0.6’ with warm groundwater (appx. 73$^{o}$ F).

Flow at Fish Slough Northeast springs (Sta. ID 3208) is measured immediately adjacent to the spring discharge in a Parshall flume. The Northeast Spring discharges warm water (65-71$^{o}$ F, Zdon 2018), and has relatively stable seasonal discharge (10% reduction in summer versus winter). Discharge at Northwest Springs (Sta. ID 3217) and BLM Springs (Sta. ID 3209) is also warm (65-70$^{o}$ F), but is measured at less accurate weir/flume installations.

*Figure 6: Fish Slough surface water discharge at southern-most gauging station 3216*




South of the three primary spring vents is Fish Slough at LA Station#2 (Sta. ID 3216). This flume measures the total outflow of all surface flow leaving the slough. There is a large annual fluctuation in outflow at 3216 due to summer ET losses (50% reduction in flow summer vs. winter), also the temperature range in the outflow reflects large (greater than 25$^{o}$ F) seasonal temperature swings. Based on temperature and flow variations observed during the 2019-2020 winter (Figure 24 below), weekly variations in 3216 flow were likely attributable to colder weather systems freezing surface flows in the slough and/or in the ponds south of the spring vents themselves.

The “Private Well” is located at the mouth of Fish Slough, is completed in the Bishop Tuff, and is located less than 400 feet from the Upper McNally Canal. It is an active domestic supply well; therefore, static water level measurements were made when the domestic pump was inactive. Based on data collected from 2015 to 2020, water level in this well appears to respond either to increased recharge and runoff from wet winters and/or surface flow in the McNally canals, suggesting some hydrologic communication between the shallow alluvium and Bishop Tuff at this location. According to the well log, water in this well is warm (appx. 78$^{o}$ F)

One effective way to look at the various monitoring wells in the W385 area is to create “cluster wells” which have shallow, intermediate, and deep screened components. Two multiple completion wells, T752-755 and T756-759, have four monitoring wells screened from shallow to deep intervals in the same large borehole. Two additional cluster groups of wells provide similar data on the response to pumping in differing hydrostratigraphic units. FS#3s and FS#3d are one cluster; and T704, W386 and T733 form a second. These four clusters are located to the west (T752-755), the south (T756-759), the north (FS3s-FS3d) and in the immediate vicinity (T704, W386, T733) of W385. By comparing drawdown response from W385 pumping in monitoring wells with differing screened intervals, one can make inferences as to the hydrologic properties, vertical gradients, and communication between aquifer zones.

## Pre-test Hydrologic Conditions

*2019 pre-pumping conditions*

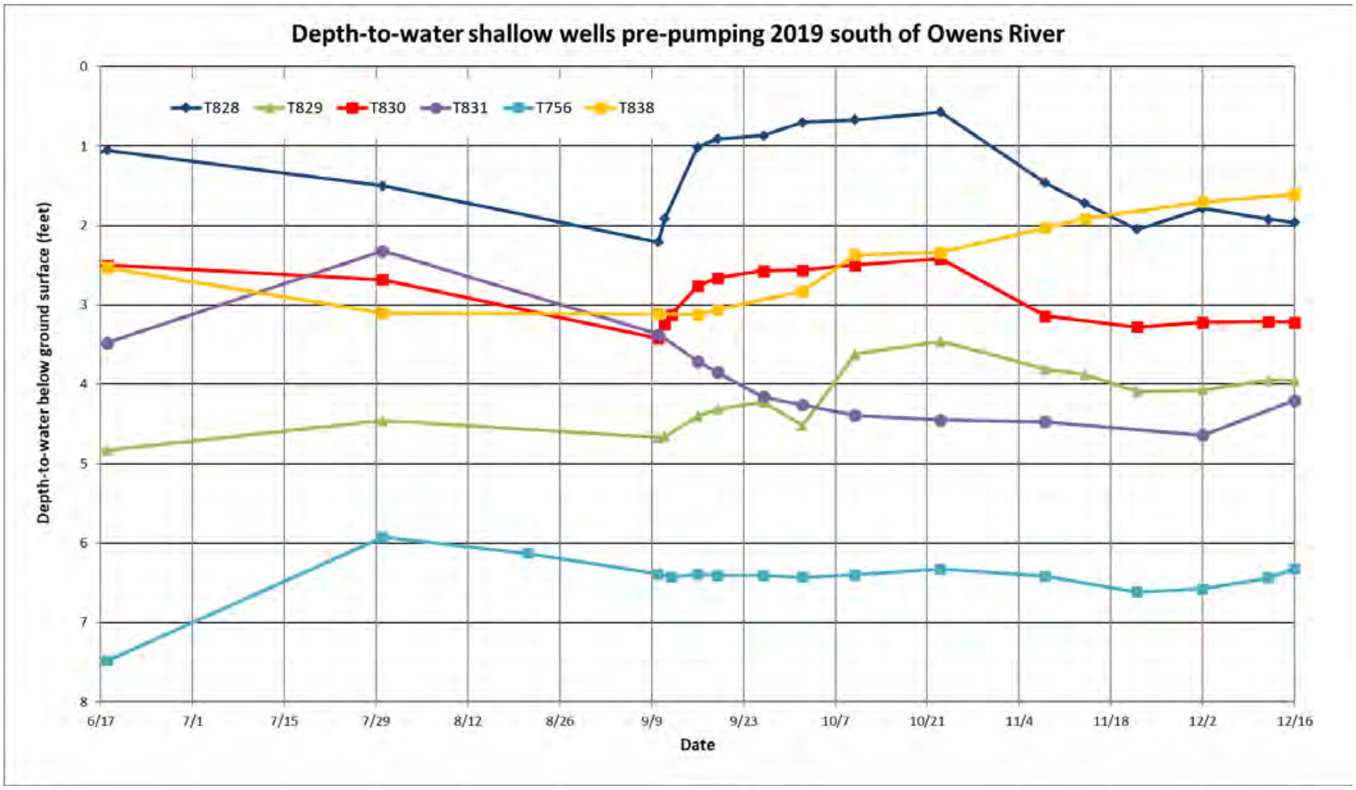
The proposed two-month pumping test of W385 was planned for winter to be most comparable with the 1993/4 pumping test conducted from November to January. Also, during the winter months, other hydrologic factors such as irrigation to Five Bridges, changes in stage to the Owens River, and seasonal changes related to evapotranspiration, are less variable.

Due to the-above average 2019 runoff season, the hydrologic conditions leading up to the 2019-20 test consisted of groundwater levels at or near historic highs (shallow). Hydrologic conditions preceding the test were deemed “favorable” with water table levels within the 6.5’ rooting zone of meadow phreatophytes at area monitoring wells (T825-T831, T838, V875, T704). Although LADWP attempted to limit active water management activities in the months immediately prior to the test, it is likely that the pre-test management had some effects during the test.

On the south side of the Owens, Bishop Creek Canal Diversions 2 and 6 (Sta. IDs 3242, 3317) released water from January through September 2019, and additional surface water from the C-Drain was diverted into a spreading basin south of T831 throughout the summer. The effects of this spreading can be seen in pre-test groundwater levels in southern monitoring wells (T828-T831) with rising or stable water levels in spite of the summer ET demand (Figure 7).

LADWP operations also required the movement of a significant amount of water from Long and Pleasant Valley reservoirs through the Owens River in September and October 2019. Late-fall flows were significantly greater than typical for that time of year. Owens River flows in October below Pleasant Valley (Sta. ID 3289) are typically between 300-400 cfs (mean of 330 cfs per month) but in October 2019, flows ranged between 600-700 cfs (monthly avg. 690 cfs). Based on staff gauge measurements located in the Owens River between T828-T827, the additional flows resulted in a river stage of more than 3.3 feet, approximately two-feet higher in October 2019 than July 2019 (stage 1.4 ft) when the river was flowing at 400 cfs. The higher flows raised shallow water levels on both sides of the Owens River.

*Figure 7: Pre-test groundwater levels in the shallow aquifer in 2019 south of Owens River*

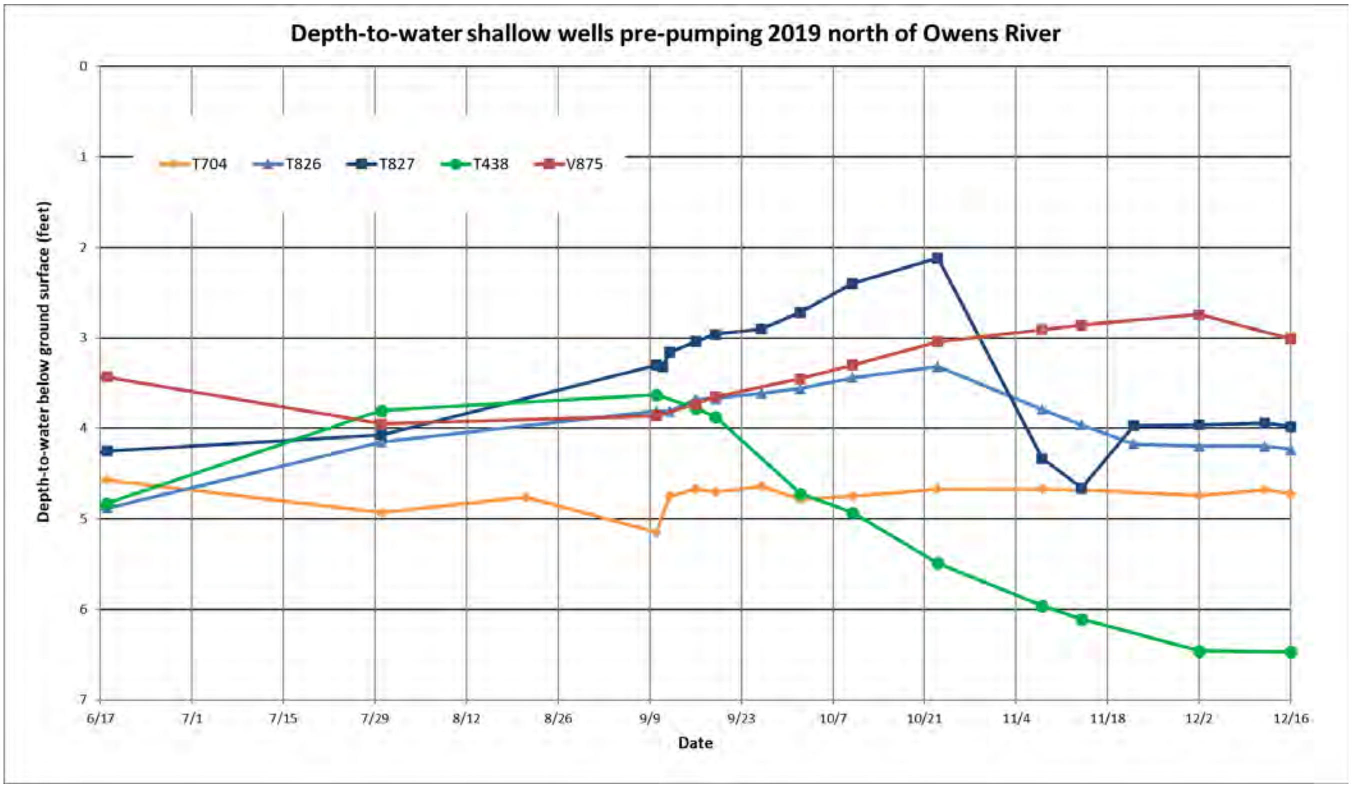



The shallow aquifer in the floodplain is coupled with river stage (Figure 3); and hydrographs from October 2019 reflect this with a notable peak and high plateau (T825-830, T704, T838, V875, Figure 7 and Figure 8). At the beginning of November 2019, flows in the Owens River were reduced from 600-700 cfs to 125-150 cfs and held in that range throughout the pumping test. Stage in the Owens ranged from 0.7’ to 0.9’ from mid-November through March 2020. In November, within days, shallow groundwater levels dropped in response to lowered river stage.

Groundwater levels in most wells stabilized in early December 2019 at a shallower-than-normal seasonal level (Figure 7 and Figure 8). Exceptions to stable water levels in the shallow wells were: T831, T756, T838, and V875. Both T831 and T756 began to recover on December 10, likely in response to the shut-off of W410 which remained off throughout the test (see additional discussion below in deep aquifer section). Groundwater levels in T838 and V875 east of W385 appeared to follow their standard fall/winter recovery from ET stress as in past years.

On the north side of the Owens River, surface water was diverted into the McNally canals from February through September 2019. Groundwater levels in the vicinity (T438, T704, T826, V875, Figure 8) rose in response to seepage and remained shallow as compared to historic (non-spreading) levels (Figure 11).

*Figure 8 Pre-test groundwater levels in the shallow aquifer in 2019 north of Owens River*

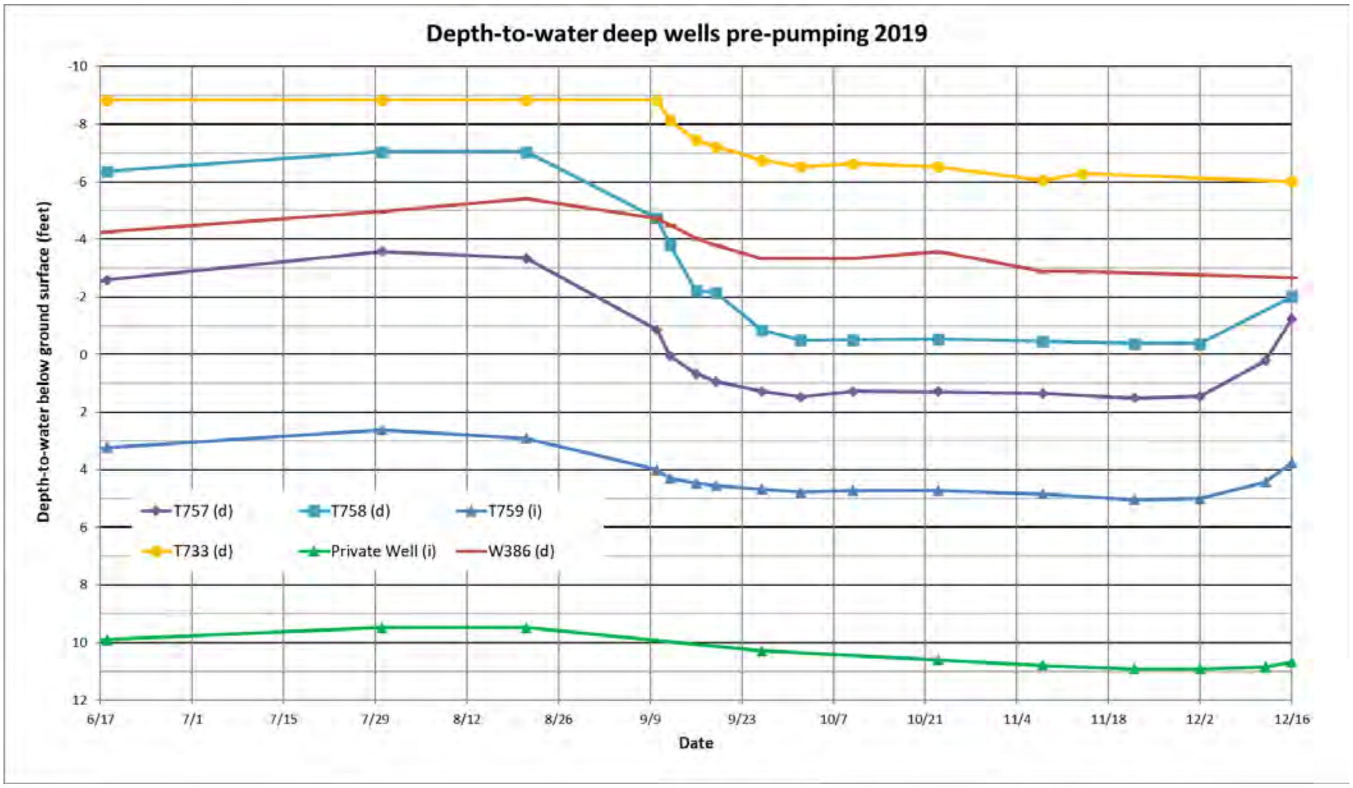



Once McNally diversions ceased in early fall, the high flows in the Owens River from September through the first week of November 2019 maintained the elevated groundwater levels in most northern wells. However, monitoring well T438, due to its proximity to the McNallys canals, is particularly sensitive to canal seepage. Its water level began to decline in September when canal flow ceased and stabilized in early December (Figure 8). As the Owens River flows were held at a constant, low rate in the final month prior to the W385 test, groundwater levels appeared to have stabilized in the final two weeks of early December before the W385 test began except for diurnal and weather-system related pressure changes which can temporarily alter levels a few tenths of a foot.

The pre-test hydrologic conditions in intermediate and deeper zones were also at or near historically high levels based on hydrographs of T733, T757-759, and artesian flow from both W385 and W386. There was an upward hydraulic gradient from deep aquifer zones to shallow (Figure 18).

Groundwater rose in these intermediate and deep aquifer wells in 2017 in response to increased recharge from large winter snowpack and accompanying high flows in the Owens River and McNally canals, and rose again in 2019 following another strong winter and runoff season (Figure 9). Historic data from these cluster sets, also demonstrate that the W385 area is a groundwater discharge area with an upward pressure gradient during times when W385/W386 are not pumped. In the final week before the W385 test, water levels in T757-759 and T733 were rising, likely in response to W410 being shut off. W410 pumps at approximately 4 cfs, is screened across both the shallow and deeper aquifer zones, and is located between 1-2 miles south of the project area.

*Figure 9: Pre-test groundwater levels in the deeper aquifer zone 2019*



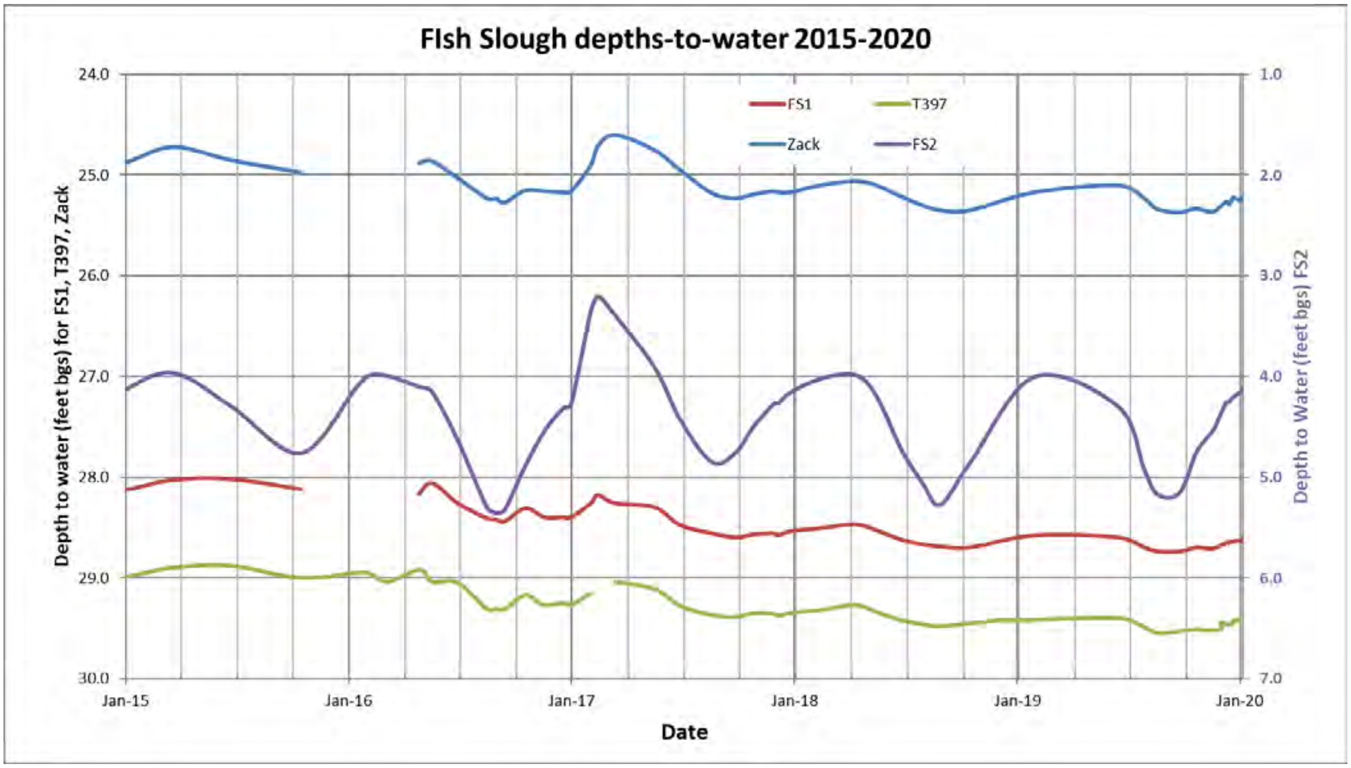

*Note: T733, T757, T758, W386 are screened in the deep aquifer unit; T759 and Private are screened in the Bishop Tuff unit*

Fish Slough wells have two superimposed trends. The deeper wells (T397, Zack, FS#1) have a multi-decade downward trend (Figure 5 above) and an intra-annual pattern of lows in the fall and flat or slight recovery by spring (Figure 10). By early December immediately preceding the W385 test, these three monitoring wells had recovered 0.1 feet from their September 2019 lows.

The shallow well FS#2 experiences lows in early Fall, due to ET demand, and then recovers significantly during the winter to a spring high. In early December immediately preceding the W385 test, FS#2 had already recovered 1’ from its September 2019 low.

Monitoring wells FS#3 shallow and deep were installed in September 2019 and have limited data. Both wells displayed an upward trend from initial fall lows. FS#3 shallow had recovered 0.4’ prior to the initiation of W385 pumping, and FS#3 deep had recovered 0.25’. The greater degree of recovery in the shallow well is likely attributable to being in more robust hydrologic communication with the shallow aquifer with its greater magnitude of seasonal ET change.

*Figure 10: Recent groundwater levels from northern Fish Slough; FS#2 data on right axis*

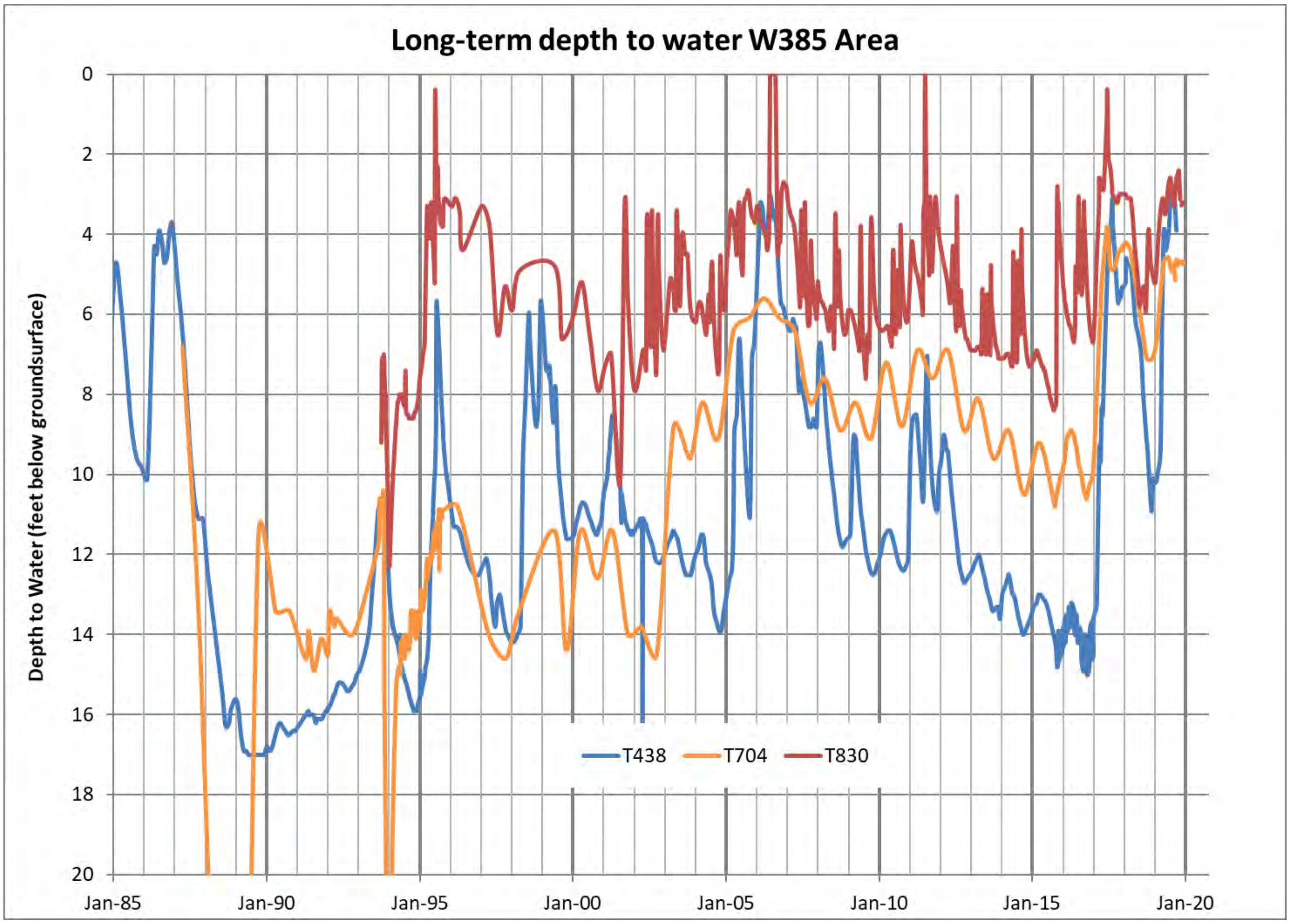



<u>*1993 pre-pumping conditions*</u>

Results from the 2019/20 test are compared to the 1993/94 test; therefore, a description of the 1993/94 pre-test hydrologic conditions is included. The 1993/94 test was conducted over 62-days from November 8, 1993 to January 10, 1994. The runoff from 1993 winter was approximately 110% of average and broke the historic 1987-1992 drought. Surface water flowed in the McNally canals from April through early October 1993, primarily in the Upper McNally. At the time, the two gravel ponds to the west of W385 and the pond immediately east existed, but the two more recent ponds farther east did not. Flows in the Owens River averaged 150 cfs in November, 205 cfs in December, and 136 cfs in January, these flows were slightly greater than the 2019/20 test period.

In 1993 DTWs in the shallow aquifer north of the Owens River were stable (less than 0.5' of change in weeks preceding test) and approximately 10-11 feet bgs (as compared to 1-5' bgs in 2019). South of the river DTWs were also stable and between 7-9 ft bgs (as compared to 2-6' in 2019). An upward gradient existed at both T756-759 and T704/T733 between the deep and shallow aquifer zones. DTW in both shallow and deep aquifers were stable but near historic low levels (deep) and still recovering from a 5-year drought (Figure 11). However, water levels preceding the 2019-20 test were stable and near historic highs due to a three-year run of favorable runoff and extensive surface water spreading.

*Figure 11: Longterm shallow groundwater levels in area monitoring wells*




In 1993, surface water in the West Pit was stable and approximately 4149' above mean sea level (amsl). The surface water elevation of both the West Pit and Owens River were similar to the 2019/20 pre-test conditions; however, water levels in both the shallow and deep aquifer were several feet lower in 1993/94. In the shallow aquifer in 1993, the stage of the Owens River was above the water table and the river was a losing reach both preceding and throughout the test but still hydrologically connected with the floodplain water table. In contrast, the Owens River was a gaining reach at the onset of the 2019/20 test with neighboring groundwater elevations above the river stage.

DTW in the Private well was approximately 1 foot deeper in 1993 than in 2019. In Fish Slough, based on data from deep well T397, DTW was shallower in 1993 by approximately 3 feet compared to 2019.

LADWP production well W238 (located at W410 and screened across shallow and deep aquifer zones) was operating before and during the 1993/94 test at an average rate of 3.7 cfs. In 2019, W410 (W238's replacement also screened across both aquifer zones) was turned off in early December, and remained off through early spring 2020. For both the 1993/94 and 2019/20 tests W249, located 1.3 miles east of W385, was pumped. During 1993/94 W249 was pumped at an average rate of 3.9 cfs, and during the 2019/20 W249 was pumped at an average rate of 4.5 cfs. During the 1993/94 test W248, 2.0 miles east of W385, was also pumped at an average rate of 4.7 cfs; W248 was not pumped in 2019-20 but used as a passive groundwater monitoring well.

## Discussion and Analysis

*Groundwater Response to Pumping*

Grouping monitoring wells by their hydrostratigraphic unit is necessary to assess the pumping effects from W385 and the efficacy of LADWP's efforts to seal the upper portion of that well. Shallow monitoring wells reflect the water-table aquifer that supports phreatophytic vegetation. Deeper monitoring wells can be examined to determine if the changes in groundwater levels in or beneath the Bishop Tuff indicate confinement or separation between the shallow and deep aquifers. Finally, examining cluster wells can determine the impact of pumping W385 on the vertical groundwater gradient in the area which supports springs and seeps discharge. Data from the 2019/20 test can also be compared to data from the 1993/94 test to determine if pumping rate or well-modifications to W385 affected the hydrologic response.

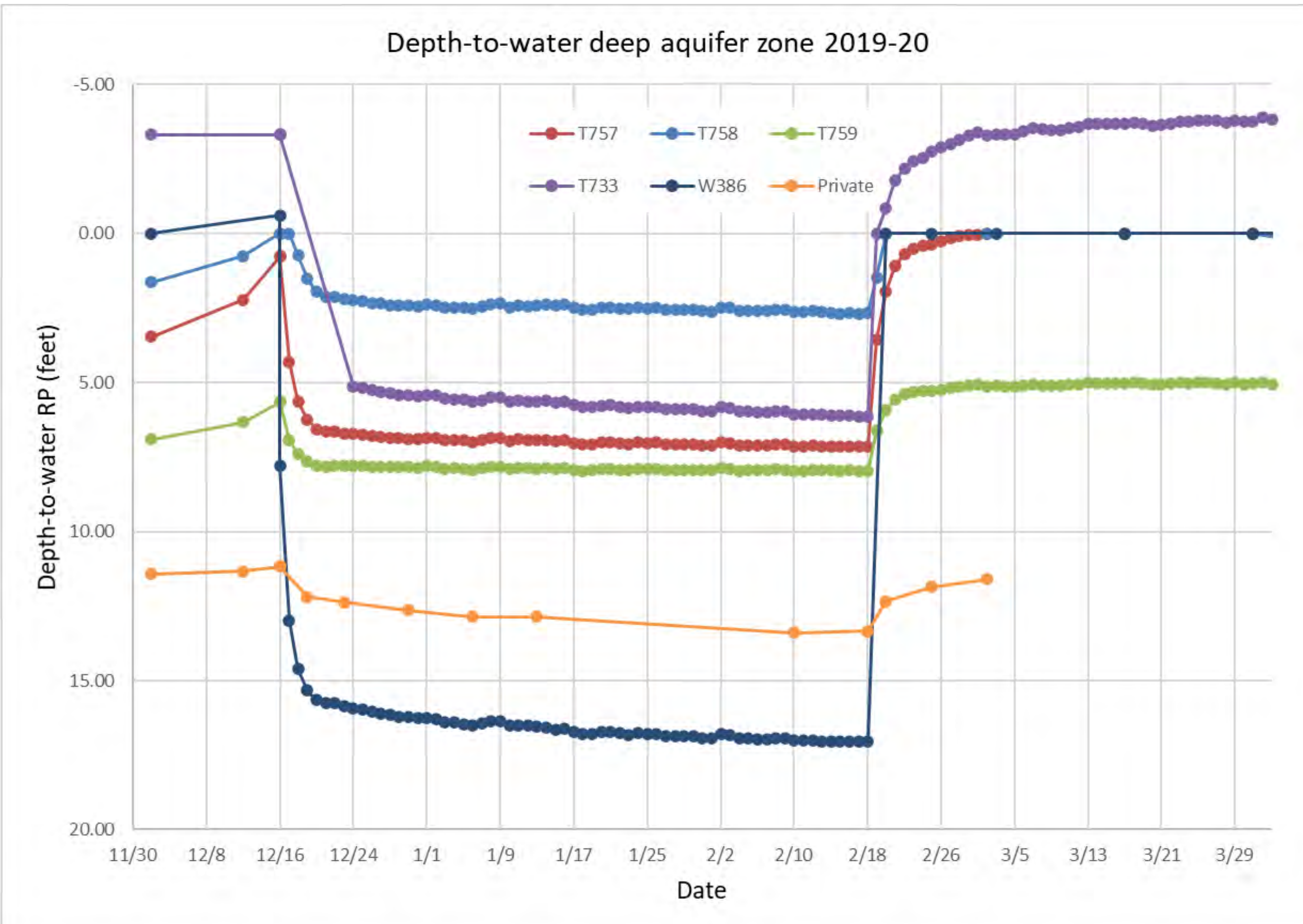
Groundwater levels initially decrease in hydraulic pressure or in the actual water table level near the pumped well. This drawdown cone creates a flow gradient towards the well. As pumping proceeds, flow contributions from aquifer zones occur, gradients begin to stabilize, and the rate of drawdown near the pumped well decreases. Eventually, if there is enough groundwater flow to supply the pumped amount, the rate of drawdown reaches a steady-state condition where inflows now equal the outflow of pumped water and nearby groundwater levels or pressures no longer decline. The pumping rate, the transmissivity of the subsurface materials (ease of horizontal groundwater flow from the surrounding subsurface zones), the degree of aquifer confinement (ability for groundwater to flow vertically across stacked aquifer/aquitard zones or horizontally across faults or other barriers/changes in materials), and the storativity (amount of water released as pressure or groundwater levels decline) all influence the amount of drawdown in the vicinity of a pumped well. The area of influence (AOI) represents the vertical and lateral area that a pumped well can affect at a given pumping rate.

In 2019/2020 pumping in W385 was initiated at 10 a.m. on December 16, 2019. The pumping rate averaged 3.7 cfs over the 64 days of pumping and a total of 463 AF of water was pumped. For comparison, during the 1993/94 test W385 pumped at a rate of 10.1 cfs and W386 pumped at a rate of 6.2 cfs for a combined rate of 16.3 cfs and a total of 2,095 AF of withdrawal. Before, during and after both pumping tests, changes in groundwater levels were measured in area monitoring wells. Groundwater level declines are referred to as drawdown and groundwater level increases are referred to as recovery. Hydrographs of drawdown and recovery from area monitoring wells were analyzed in an attempt to assign causality to the observed changes.

*Deep Aquifer Response to Pumping*

Based on manual and electronic DTW reads, groundwater levels in monitoring wells completed in or beneath the Bishop Tuff (intermediate and deep aquifer units) responded quickly to W385 pumping (Figure 12). Within hours, deep aquifer wells near W385 (T733 and W386) registered several feet of drawdown. Within 72-hours of pumping, drawdown of more than 1 foot was observed and as far north as the Private Well (o.6 miles north) and as far south as T757-T759 (0.7 miles south). However, the rate of drawdown in the deeper aquifer decreased significantly between 4-7 days and was approaching steady-state (equilibrium) by day 7 after the onset of pumping. This rapid stabilization indicates that either additional sources of groundwater were captured by W385 or that the deeper aquifer is highly transmissive.

*Figure 12: Changes in deep aquifer groundwater levels during 2019-20 pumping*




*Note: T733, T757, T758, W386 are screened in the deep aquifer unit; T759 and Private are screened in the Bishop Tuff unit*

In the intermediate and deep units, the shape of the drawdown curves (plotted on logarithmic scales for typical hydrologic assessment) fit a drawdown curve that is indicative of a partially confined or "leaky" aquifer (Figure 13 and Figure 14). Analysis using the curve matching software (AQTESOLV) also describes the deep aquifer response as leaky or partially confined (LADWP, 2020).

*Figure 13: Drawdown in moitoring well W386 plotted on logarithmic scale axis.*

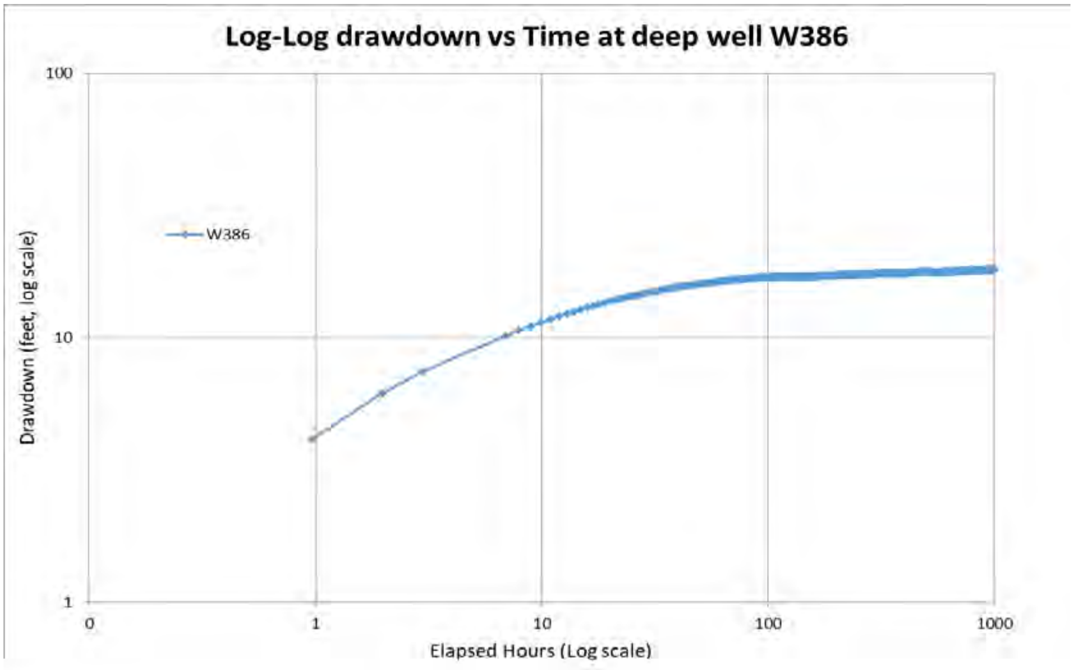
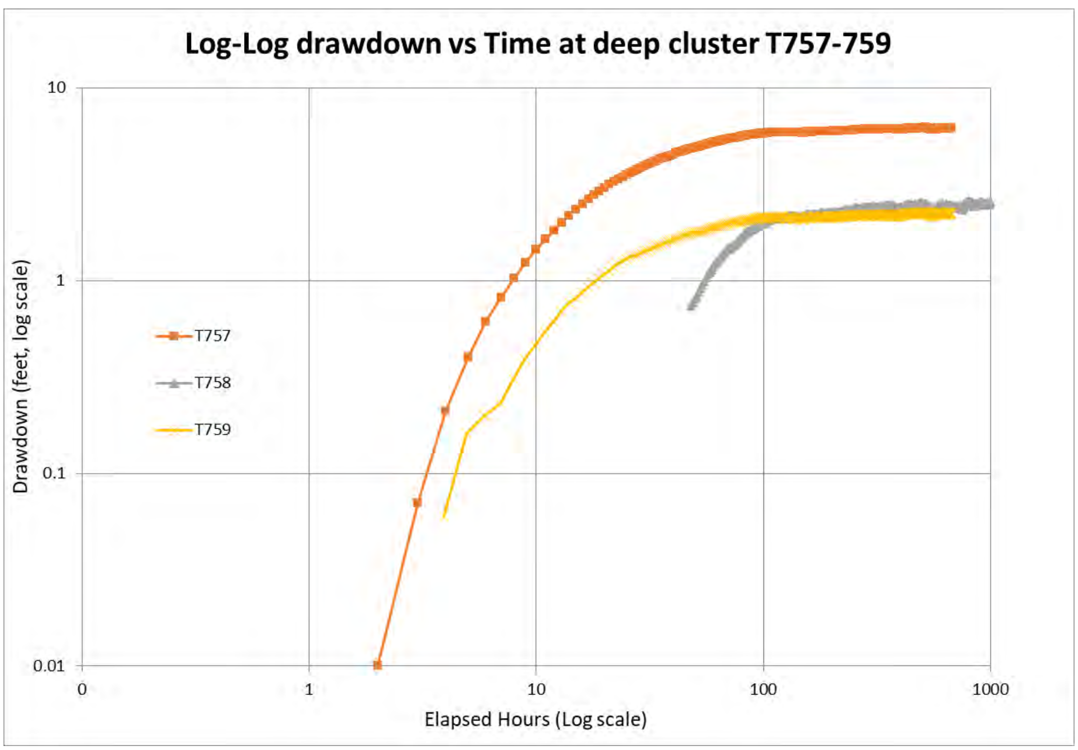



*Figure 14: Drawdown clustered monitoring wells plotted on logarithmic axis*




*Note: Screen intervals from deepest to shallow are T758, T757, T759.*

West of W385 and the significant fault zone, groundwater levels in deep aquifers wells T752 and T755 were unchanged or rose slightly (<0.5 feet) during the test (Figure 19 below). It's likely that the distance from W385 (1.8 miles), the intervening low conductivity fault zone, and upgradient recharge insulated groundwater levels in these monitoring wells from W385 pumping effects.

W248 is 2.0 miles east and separated from W385 by the Fish Slough fault zone. It is 0.7 miles east of W249 which pumped during the test for the McNally Ponds and Pasture Enhancement and Mitigation project. Data from W248 is not useful for analysis of the 2019/20 test due to interference from W249 pumping and surface discharge. It is recommended (if LADWP continues to pursue pumping/long-term operation of W385/W386) that a dedicated deep monitoring well be installed closer to W385 and the Fish Slough fault zone to further characterize the east margin of the area influenced by W385/386 pumping.

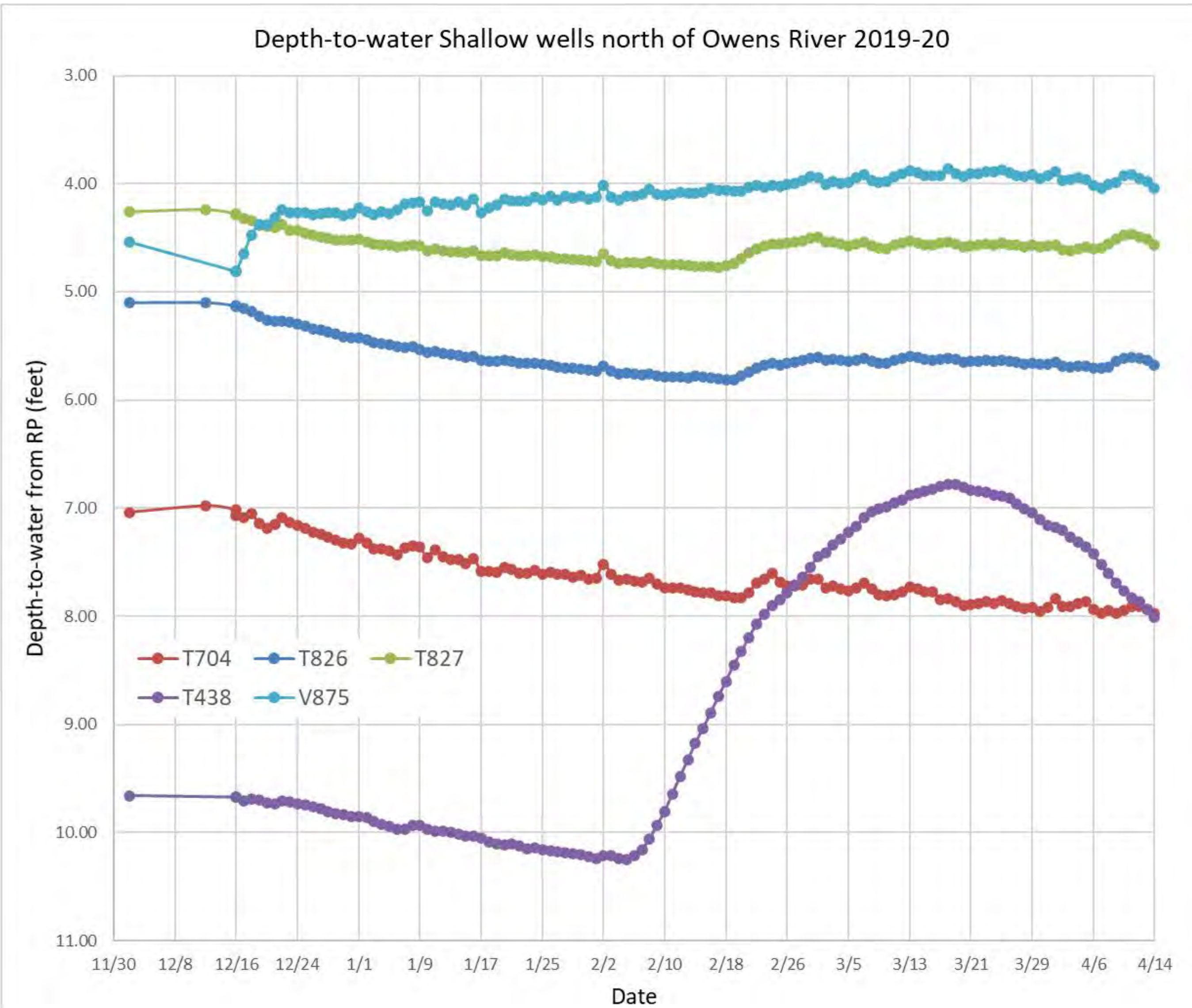
*Shallow Aquifer Response to Pumping North Side of Owens River*

Measurable drawdown related W385 pumping was seen in the shallow aquifer on the north side of the Owens River near the gravel pit. Stage in the West Pit and the Owens River were generally stable before the initiation of W385 pumping. However, the stage of the West Pit began to decline within the first few days of the test and the rate of decline remained near-constant during the pumping (Figure 15). If the West Pit surface water declines were solely due to natural drainage in the subsurface, one would expect the rate of decline to decrease as ET deceased and the surface mounding and groundwater levels approached equilibrium. This was not observed during the test. Moreover, the rate of decline decreased significantly when the test pumping stopped (less water lost once pumping stopped), suggesting that pumping affected the West pit.

*Figure 15: Owens River and West Pit stage elevations during 2019/20 pumping*


The shallow test wells on the north side of the river (T826, T827 and T704) displayed a similar pattern as stage in the West Pit. Water levels were stable the week before the test, declined steadily during the test, and recovered after pumping ceased on Feb. 18, 2020 (Figure 16). The onset of the decline in shallow aquifer wells roughly coincides with the stabilization of the drawdown rate in the deeper aquifer. Declines in the shallow aquifer were less than 1-foot on the north side of the river, and groundwater levels remained within 6.5’ (2 meters) of the surface. These results are consistent with partial/leaking vertical confinement between shallow and deeper aquifers.

*Figure 16: Groundwater levels in shallow aquifer on north side of Owens River 2019/20 pumping*



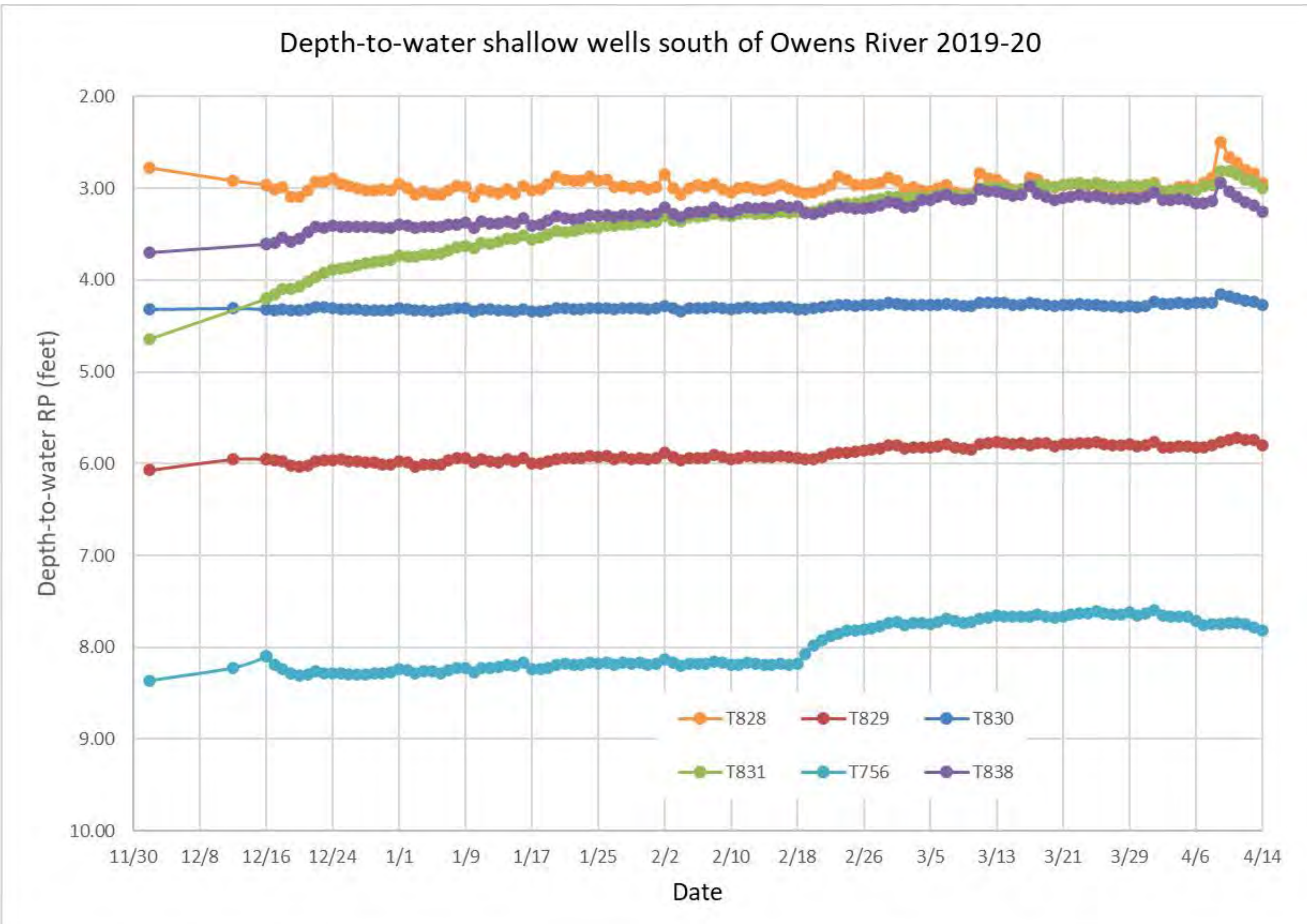

One exception to the common shallow well response was T438. DTW in T438 initially followed a similar rate of decline as the other shallow, northern wells but in early February, gravel mining operations transferred water from the north pit eastward in ditches towards T438. Groundwater levels in T438 rose in response to this water spreading and data after 2/9/20 is not useful for W385 pumping analysis.

Shallow groundwater levels to the west (T753-T754; Figure 19) and east (V875; Figure 16) recovered throughout the pumping test and showed no obvious drawdown. Shallow monitoring wells T753-54 are located 1.8 miles west of W385, upgradient and occluded by the highly sinuous Owens River. Shallow monitoring well V875 is located 0.6 miles east on the downgradient side of two gravel ponds and within 0.1 mile of the Owens River. Likely explanations for this recovery include the normal winter recovery after ET diminished, distance from W385, uninterrupted recharge from surface water and isolation by the north-south trending fault system.

*Shallow Aquifer Response to Pumping South Side of Owens River*

In the shallow aquifer on the south side of the Owens River, little or no drawdown was observed (T828-T831, T838; Figure 17). These five wells had either stable (less than 0.1' of groundwater level change) or rising water levels during the test. Likely explanations for this recovery include the normal response after ET diminished, Owens River seepage, and recovery from W410 pumping.

*Figure 17: Groundwater levels in shallow aquifer on south side of Owens River 2019/20 pumping*




At T756, the shallowest well in the 756-759 multiple completion well, groundwater levels appear to respond slightly to both initiation and cessation of W385 pumping (Figure 17). Groundwater levels decline approximately 0.2 feet in the first week following W385 pumping (12/16/19) and recover a similar amount in the week following W385 shut-off (2/18/20).

*Cluster Well Response to Pumping*

As noted in the Monitoring Network section, there are several clusters of monitoring wells with differing screen intervals that can be used to examine the effect of W385 pumping on the various hydrostratigraphic units.

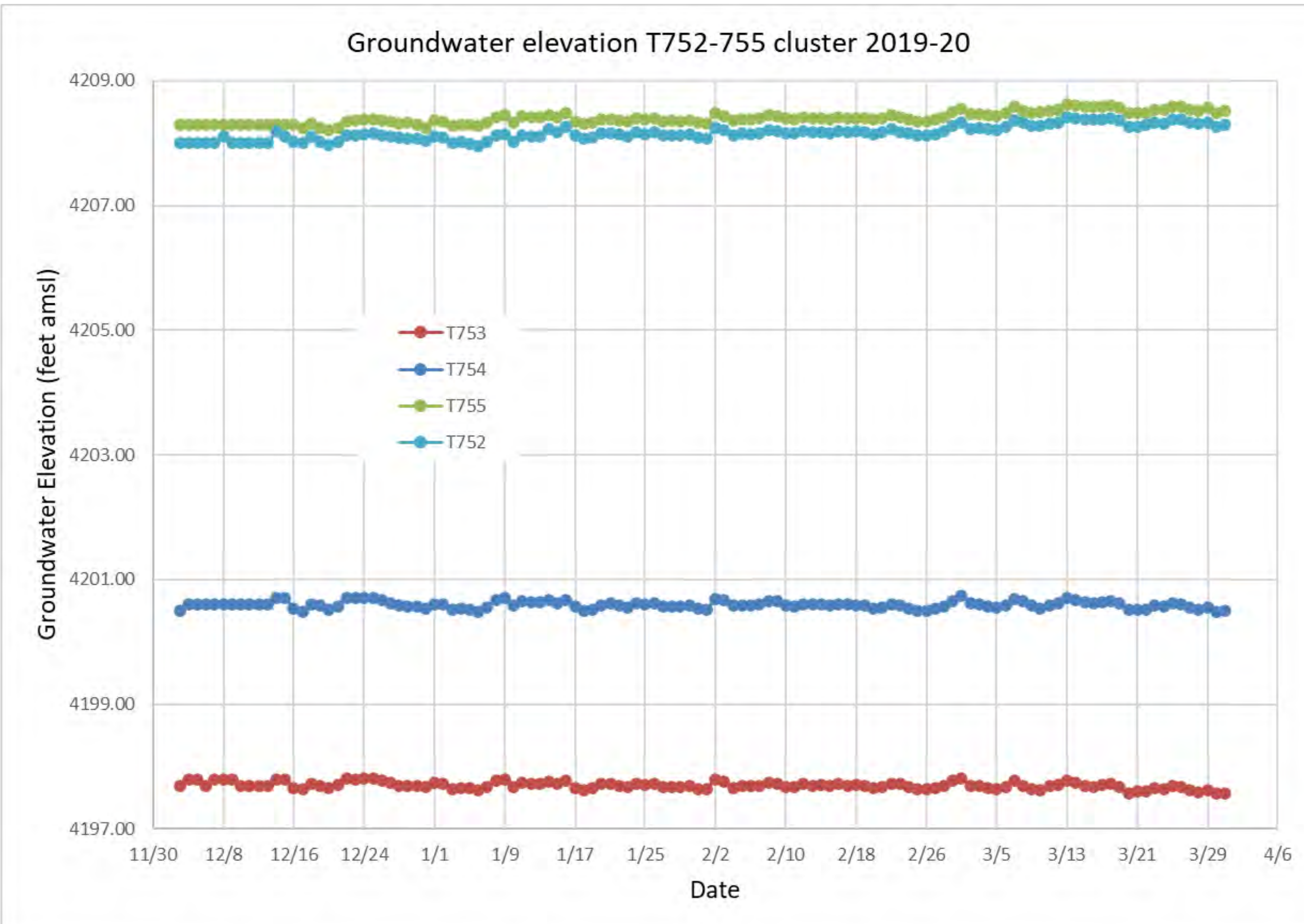
*Figure 18: Goundwater levels changes in T704, W386, T733 cluster during 2019/20 pumping*


*Note: Screen intervals from deepest to shallow are T733, W386, T704.*

On the north side of the Owens River at wells T704 (shallow), W386 (deep, pumped zone), and T733 (deepest zone) there was a deep-to-shallow gradient before W385 pumping initiated with T733 having the highest groundwater elevation (appx 4154.5'), then W386 (4154') and finally T704 (4143.6'; Figure 18). The positive vertical gradient was approximately 10'. Within 1 day of pumping, this gradient had reversed, with T704 GWE at 4143.6' and W386 GWE at 4140.5'. By then end of the test, W386 GWE had dropped to 4136.4' with T704 at 4142.8' and T733 at 4145.1'. The flow gradient during the test was from the shallow towards the deeper W386 aquifer unit; and the gradient from the deepest aquifer remained upward to the pumped unit.

On the north side of the Owens River to the west of W385 at the T752-755 cluster, the vertical gradient before, during and after the test remained upwards from deep to shallow (Figure 19). Groundwater levels across all subsurface units or depths were unchanged throughout the W385 test.

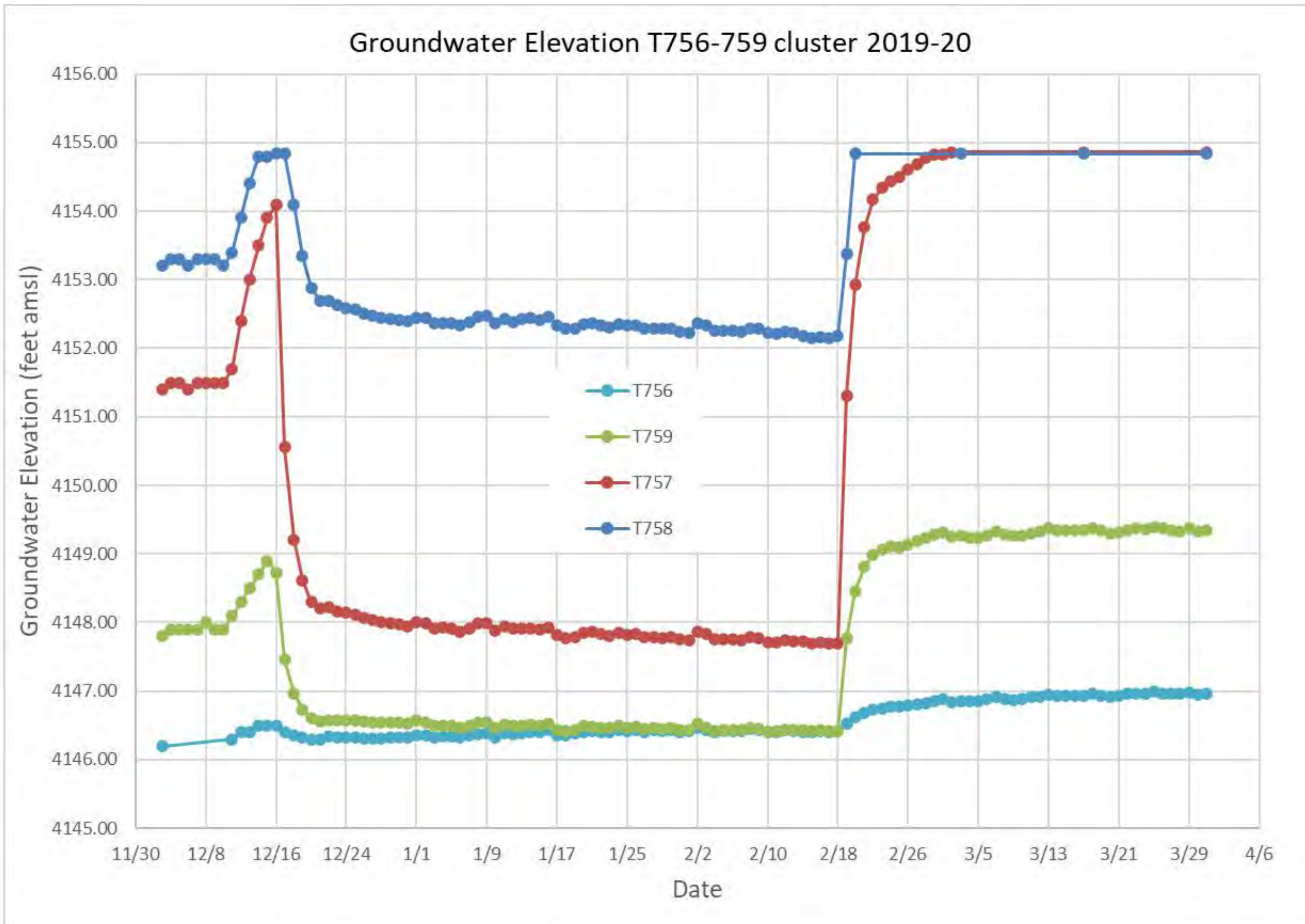
*Figure 19: Goundwater levels changes in T752-T755 cluster during 2019/20 pumping*




*Note: Screen intervals from deepest to shallow are T752, T755, T754, T753.*

On the south side of the Owens River at the T756-759 cluster, the gradient before, during and after the test remained upwards from deepest to shallowest zone (Figure 20). However, the difference in upward gradient was reduced greatly in the two screened zones immediately beneath the shallow aquifer. T756 is completed in the shallow aquifer and there was 0.1' of water level decline during the test. T759 is completed in the Bishop Tuff immediately below the shallow aquifer and had 2.4' of drawdown. T757 is completed below T759 in the same zone that W385 pumps from and had 6.8' of drawdown. T758 is the deepest of the cluster, screened below the W385 pumping zone and had 2.7' of drawdown. T758 is completed beneath an approximate 20' thick low resistivity zone described as clayey sand in the lithologic log; there is likely some localized confinement between the W385 pumping zone reflected by T757 drawdown and T758's deeper zone (see Geochemical Analysis of Groundwater section for more detail). The fact that an upward gradient was maintained on the south side of the river may partially explain why little or no drawdown was observed in the shallow aquifer wells.

*Figure 20: Goundwater level changes in T756-T759 cluster during 2019/20 pumping*




*Note: Screen intervals from deepest to shallow are T758, T757, T759, T756.*

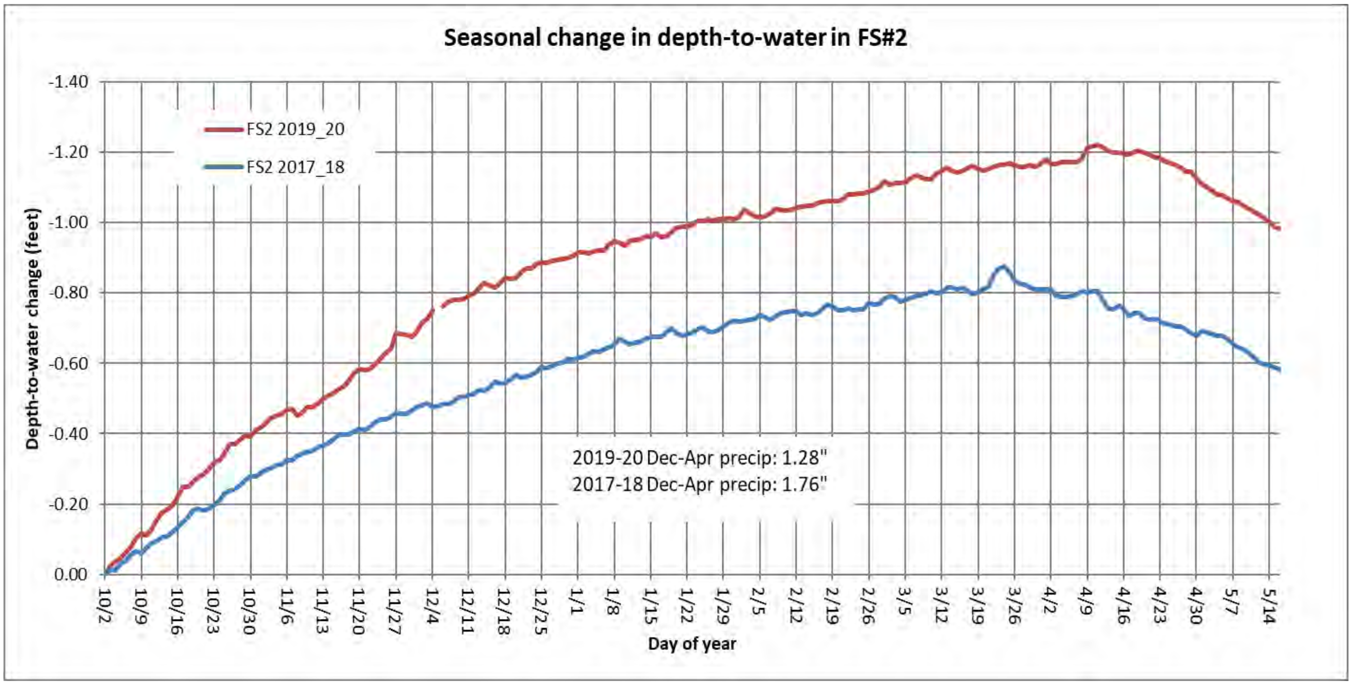
## *Fish Slough Response to Pumping*

The Private Well, located at the mouth of Fish Slough and completed in the Bishop Tuff exhibited drawdown of approximately 2.2 feet during the test (Table 3).

The Private well is 0.6 miles north of W385. The next closest Fish Slough monitoring wells are the FS#3 shallow and deep cluster, located 2.8 miles north of W385 and drilled in fall 2019 preceding the test. In addition to these two wells, Zack and T397 are deep monitoring wells completed in the Bishop Tuff. These wells are 4-7 miles north of W385. Because of the distance from W385 and short period of record for newer wells, any pumping effects were anticipated to be difficult to discern from background trends. Given the sensitivity of the Fish Slough habitat, additional analysis was required to confirm whether drawdown from the test occurred. For central and northern Fish Slough (Zack, FS#2, T397 and FS#1), long-term data exists to which comparisons between 2019/20 and previous winters can be made. Data from the recent 2017/18 winter (which had similar amount and timing of winter precipitation) was compared with 2019/20 data from these wells (Figure 21). Note in Figures 21 and 22, the y-axis is “depth-to-water change (feet)” with negative values representing increasing recovery (shallowing groundwater).

Groundwater levels in FS#2 typically exhibit an ET decline in the spring through summer, and a similar curved recovery from fall through winter. This recovery relationship is somewhat variable, but typically logarithmic in shape and, therefore, significant drawdown related to pumping should be discernable as a change in slope or a reduced winter recovery. The Zack well exhibits a similar seasonal recovery pattern as FS#2 only overlain on a long-term downward trend.

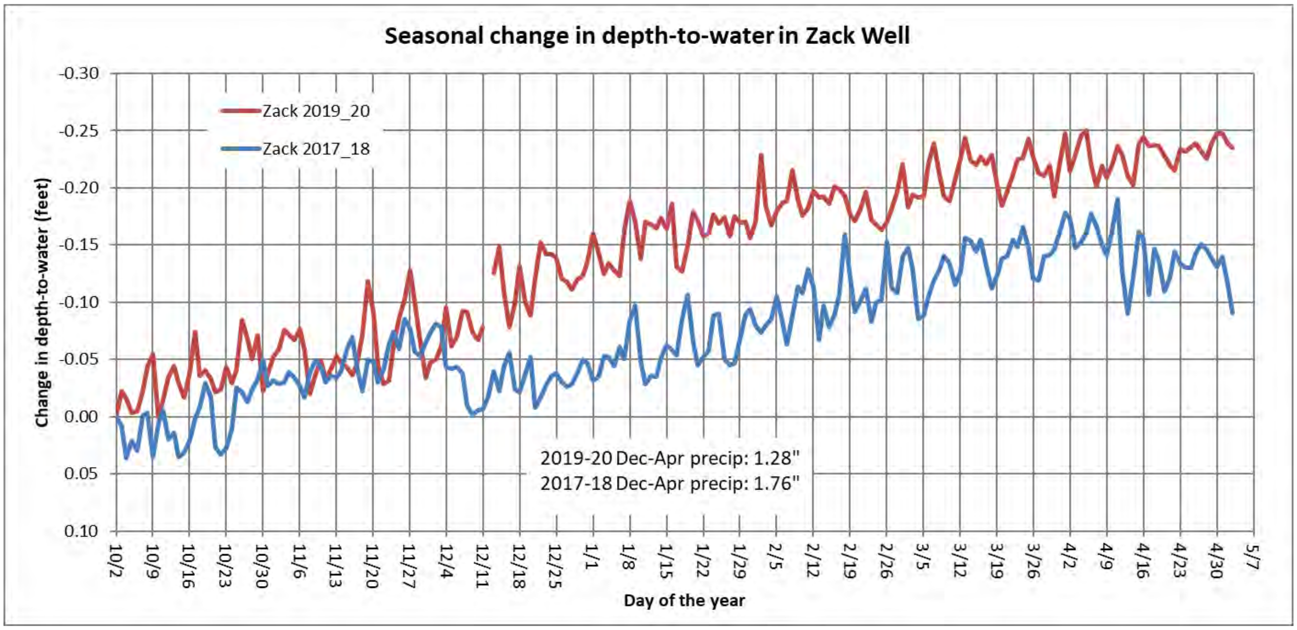
*Figure 21: Groundwater level change at FS#2 from October to April in 2017/29 and 2019/20*




Both winters had less than average precipitation (as recorded at the Bishop Airport) from December through February (2017/18 0.14”, 2019/20 0.21”). Both winters had average or above precipitation in March and April (2017/8 1.62”, 2019/20 1.07”). In 2019/20 the total winter precipitation from December through April was 27% less than 2017/18 (1.28” vs. 1.76”).

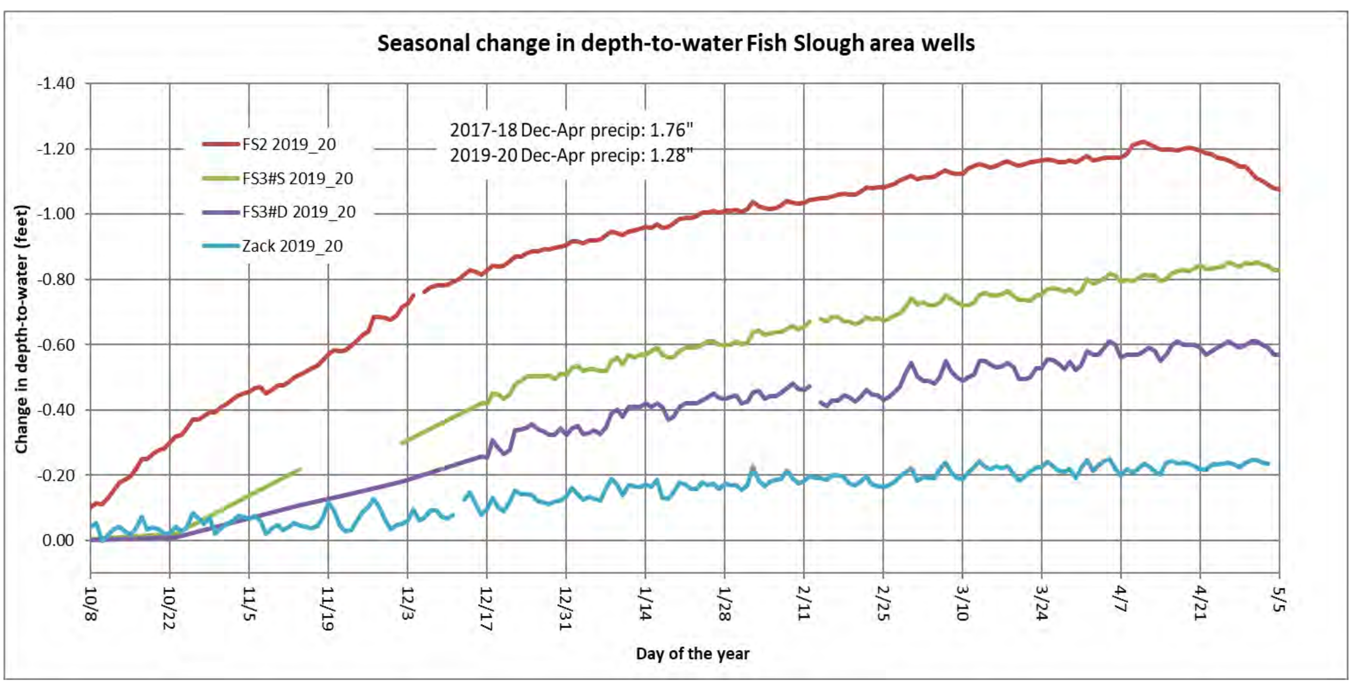
Despite less winter precipitation, the annual winter DTW recovery (October through April 2020) in FS#2 and Zack wells were greater than in 2017/8 (Figure 22). In 2019-20, throughout the pumping test and the ensuing months the absolute recovery in both wells was greater as were both the slope and sustained trend of the recovery. The same relationships were observed further north in T397 and FS#1.

*Figure 22: Groundwater level change at Zack well from October to April in 2017/29 and 2019/20*




For the FS#3 cluster, only one season of data exists so trends in FS#3 shallow and deep wells were compared with Zack and FS#2 (Figure 23). Winter recovery in FS#3 shallow and deep wells was intermediate between FS#2's and Zack. The two FS#3 wells had parallel trends throughout October-April with FS#3shallow recovering approximately 0.8 feet and FS#3deep recovering approximately 0.6 feet. With the exception of 2/13/20 when both FS#3 wells were purged (pumped) for the purpose of collecting a groundwater sample for geochemical analysis, recoveries in both wells are similar to FS#2 and Zack in both 2019/20 (pumping) and 2017/18 (no pumping). No significant flattening or downward trends attributable to pumping were noted in any Fish Slough well.

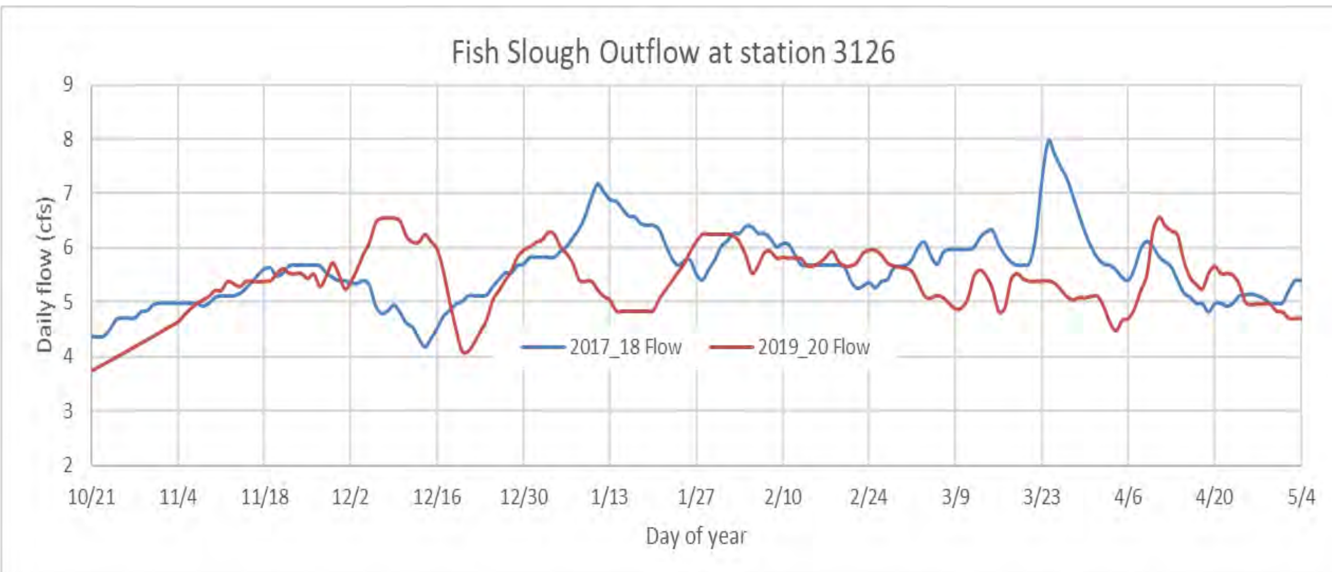
*Figure 23: Groundwater level change at Fish Slough wells from October-April 2019/20*



There appears to be no drawdown from W385 in the Fish Slough wells based on the comparison with Zack and FS#2 as surrogates for expected seasonal trends, but it would be prudent to collect data during at least one "baseline" winter from the FS#3 wells without pumping stress from W385 or W386 to aid future analyses.

Finally, surface water flow exiting Fish Slough was measured at Station 3216 before, during and after W385 pumping (Figure 24). Data for this station exists back to the 1970s, and like the older Fish Slough monitoring wells, there has been a long-term continuing decline in outflow (Figure 6 above). Comparisons were made for winters 2017/18 and 2019/20 based on similar rationale for the monitoring wells. There was a decline in the seasonal average flow rate from the December through April period in 2019/20 (5.51 cfs) versus 2017/18 (5.73 cfs) of approximately 0.2 cfs, approximately a 4% reduction in average flow rate. Based on the precipitation data from the Bishop Airport, precipitation in 2019/20 was 27% less than 2017/18. A minor reduction in Fish Slough surface outflow would be expected. In summary, no significant or notable changes in Fish Slough outflow were observed in 2019/20 during the test.

*Figure 24: Fish Slough outflow at 3216 in 2017/18 and 2019/20.*



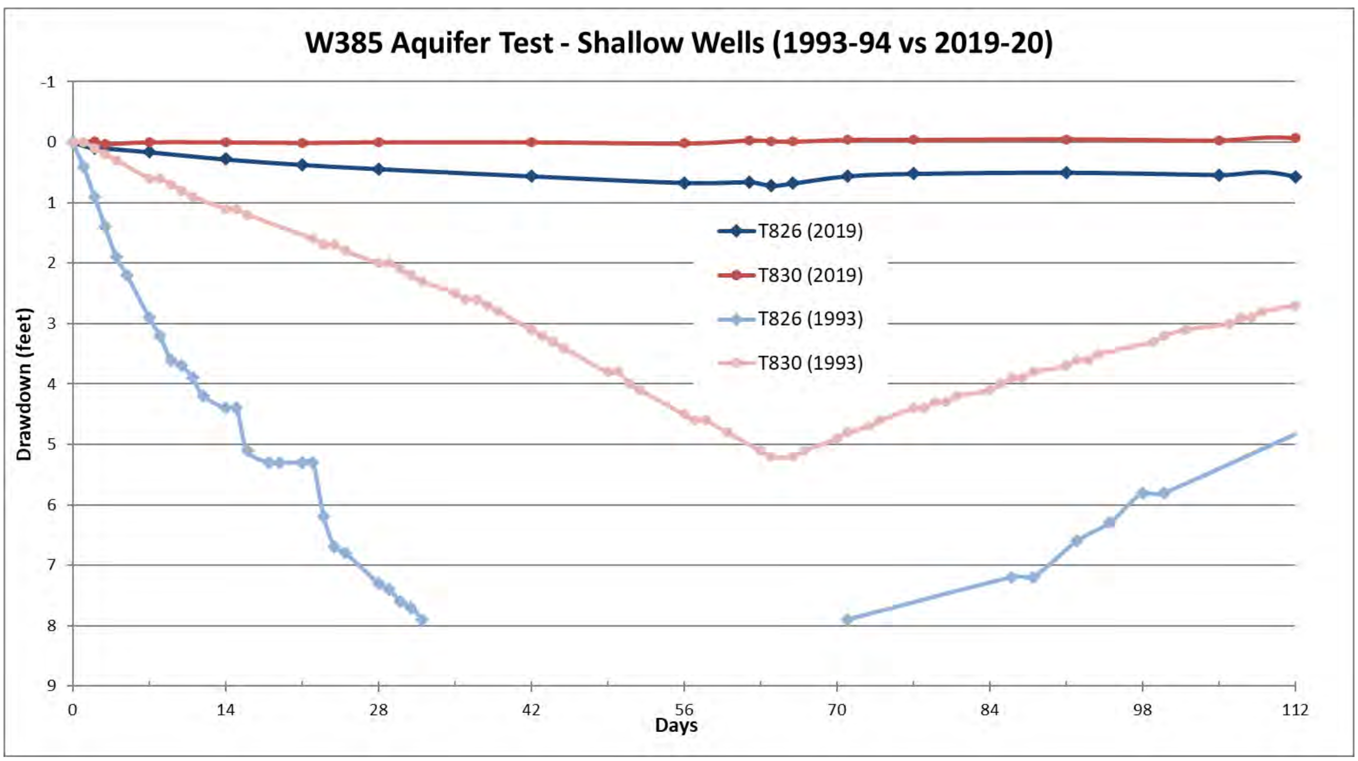

<u>*Comparative Response to Pumping 2019/20 Versus 1993/94*</u>

As discussed in the preceding sections, there was a notable difference in response to pumping in the deep and shallow aquifer zones during the 2019/20 test when compared to the 1993/94 test. This was expected for two reasons. The upper 320 feet of W385 screen was sealed in 2014 focusing pumping stress in the deep aquifer unit compared to 1993/94 when both W385 and W386 were screened to both shallow and deeper zones. The well modification also reduced W385's pumping rate to 3.7 cfs and a total of 463 AF of groundwater was pumped during the 2019/20 test. During the 1993/94 test both W385 and W386 were pumped simultaneously at a combined rate of 16.3 cfs for a total of 2,095 AF. To properly determine the comparative effects of the reduced pumping amount and screen modification on drawdown, the Bishop-Laws groundwater model will need to be calibrated to observed drawdown from the 2019/20 test with hydrological parameters updated; then the model can run comparative simulations between the two tests (1993/94 and 2019/20) and their differing well characteristics (pumping amounts, screen intervals). This work is currently in progress along with several updates being completed on the Bishop-Laws model.

Due to the significant stress of groundwater pumping (16.3 cfs) during the combined operation of W385 and W386, drawdown in the shallow and deep aquifers did not reach steady-state and the AOI continued to grow throughout the 1993/4 test. However, in the 2019-20 test, due to the smaller pumping stress (3.7 cfs) hydrographs indicate the deeper aquifer zone reached a steady-state condition (T757-759, T733, Private well). In 2019/20, the shallow aquifer neared but did not reach steady state in the vicinity of pumping (T826, T704), but drawdown was less than 1 foot north of the Owens River and was not measurable south of the river in the majority of monitoring wells during the test. This comparison indicates that drawdown from pumping in the W385 area is sensitive to the cumulative groundwater withdrawal rate of area wells.

Several observations can be made from the monitoring data collected during the test. First, there was a substantial reduction in drawdown in both the shallow and deep aquifers in 2019/20 compared with the 1993/4 test. This was expected.

*Figure 25: Comparison of drawdown in the shallow aquifer 1993/94 versus 2019/20.*

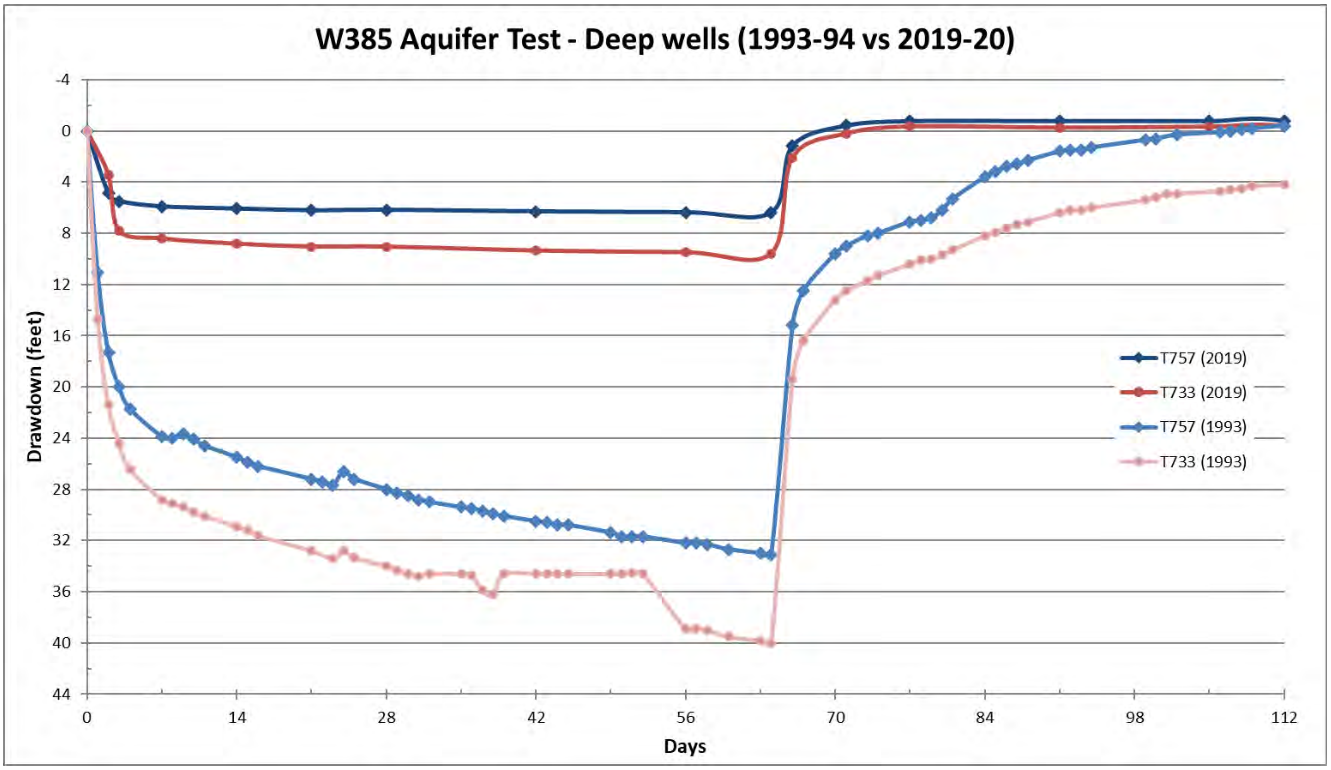



*Note: Groundwater levels dropped below T826's maximum depth at day 32 of the previous test.*

As shown in Figure 25, in the shallow aquifer drawdown north of the river at T826 was less than a foot in 2020 versus more than 8 feet in 1994. On the south side of the river T830 had no measurable drawdown in 2020 versus approximately 5 feet of drawdown in 1994. In the deeper aquifer drawdown north of the river at T733 was approximately 9.5' in 2020 versus 40' in 1994 (Figure 26). On the south side of the river, drawdown in T757 was approximately 6.4' in 2020 versus 33' in 1994.

One method to determine the effect that modifying W385's screen interval had on groundwater changes is to compare drawdown in the various aquifer zones from 2019/20 to the 1993/94 test. The ratio of 2019/20 pumping to 1993/94 pumping is 22% (approximately 1/5th). If sealing W385 out of the shallow aquifer had no hydrologic effect and the only difference between the two tests was the reduced pumping rate, then one would predict a reduction in the amount of drawdown in the vicinity of pumping proportional to the reduction in pumping rate. In other words, one-fifth the pumping rate would lead to one-fifth the drawdown in both shallow and deeper aquifer zones. Although this is a simplification and not strictly applicable because of the screen modification (reducing screen length and increasing screen depth) the comparison can still provide insight on the strategy of restricting pumping to deeper aquifers in this area.

*Figure 26: Comparison of drawdown in the deeper aquifer 1993/94 versus 2019/20*




In the shallow aquifer after 28 days of pumping during each test, the ratio of drawdown from 2019/20 to 1993/94 was: T704 4%, T826 6%, T830 0%, and T438 38%. The 28-day mark was used because data was available from multiple wells during both tests and drawdown rates were relatively stable. With the exception of T438, there was much less drawdown in 2019/20 than predicted by the reduced (22%) pumping rate alone. This indicates that either the deeper screen interval and/or partial confinement between aquifer zones had some effect on shallow drawdown in the short term. On the south side of the Owens River a combination of deeper screen interval, partial confinement, reduced pumping rate, and surface water seepage from the Owens River may have all contributed to the limited drawdown. A similar comparison was made at Day 62 of both tests (Table 3) and the ratios remain similar.

As noted earlier, T438 exhibits greater than expected drawdown in the initial stages of the 2019/20 test, and then recovers due to water transfer from gravel pit eastward towards the well. There is insufficient data to draw conclusions as to the cause of T438's initial rate of decline but possible explanations include: continued drainage from the lowered McNally or Owens River flows, greater degree of hydrologic communication with W385 due to subsurface materials or faulting, drawdown associated with W249 pumping, or undocumented gravel management actions.

*Table 3 Bishop-Laws Model predicted drawdown for 2019-20 test and comparison of 2019-20 drawdown with 1993-94 at end of test.*

| Monitoring Well | Total Depth or Screen interval of well (ft) | Distance from W385 (ft) | 1993/94 Maximum Observed Drawdown (ft) | Predicted Drawdown at 2.8 cfs rate using 2012 Bishop-Laws Model (ft)* | 2019-20 Actual Drawdown (ft) | 22% of 1993/94 Drawdown (ft) |
|---|---|---|---|---|---|---|
| T704 | 32 | 570 | 16.5 | 1.4 | 0.8 | 3.6 |
| T825 | 27 | 1,410 | 10.4 | 1.2 | 1.0 | 2.3 |
| T826 | 17 | 1,880 | >12.2 (dry at day 32)** | 1.1 | 0.7 | 2.7** |
| T827 | 16 | 2,200 | 8.4 | 1.0 | 0.5 | 1.9 |
| T828 | 15 | 2,680 | 3.8 | 1.0 | 0.1 | 0.8 |
| T829 | 17 | 3,090 | 4.4 | 0.8 | 0.0 | 1.0 |
| T830 | 14 | 2,920 | 5.2 | 0.9 | 0.0 | 1.1 |
| T756 | 45 | 3,560 | 6.4 | 0.8 | 0.1 | 1.4 |
| T757 | 310 | 3,560 | 33.0 | NA | 6.4 | 7.3 |
| T758 | 575 | 3,560 | 27.1 | NA | 2.7 | 6.0 |
| T733 | 674 | 585 | 39.8 | NA | 9.4 | 8.8 |
| Private Well | 160 | 3,400 | 12.0 | NA | 2.2 | 2.6 |

*Predicted drawdown developed from 2012 Bishop MODFLOW Model with modified W385 well-screen spanning model layers 2 and 3, and pumping rate is 2.8 cfs for two months (Source: LADWP 2017 CEQA Neg. Dec.)*

** - Actual average pumping rate of W385 in 2019/20 was 3.7 cfs, and actual pumping rate of 1993/94 was 16.3 cfs (3.7 cfs/16.3 cfs = 22%)*

*** - T826 went dry at day 32, 1993/94 observed drawdown was estimated by extrapolating the rate of decline in T826 to the end of the test*

In the deep aquifer zone, where W385 now preferentially draws water, the difference in drawdown between 1993/94 and 2019/20 are closer to the proportional reduction in pumping rate. For example, after 28 days of pumping in each year, the ratio of drawdown from 2019/20 to 1993/94 were as follows: T733 27%, T757 22%, T758 16%, and Private Well 21%; approximately what was expected if the assumption was valid.

<u>*Actual Hydrologic Response Compared to Modeled Predictions*</u>

A three-dimensional finite-difference MODFLOW groundwater model was developed by MWH Americas Consulting Co in 2006 for the Bishop-Laws area, including the W385 area. In 2018-19, model parameters and inputs were significantly revised, updated with recent data, and calibrated to observed water levels by Stantec. As part of the 2017 CEQA Negative Declaration for the W385 pumping test, LADWP predicted potential drawdown during the test (Table 3). Using a pumping rate of 2.8 cfs (which is less than the actual rate of 3.7 cfs), in the shallow aquifer the model predicted drawdown on the north side of the Owens River of 1-2 feet compared to the observed 0-1 feet of actual drawdown. Predicted drawdown on the south side of the river was approximately 0.75-1 foot compared to the no change or rising water levels that were observed. The model over-predicted the actual drawdown, but generally model performance was acceptable because conservative modeling results are more protective of sensitive receptors. Data collected from the two-month pumping test on W385 will be used to update and recalibrate the Bishop/Laws groundwater flow model before using it to simulate potential long-term operation of this well.

*Geochemical Analysis of Groundwater*

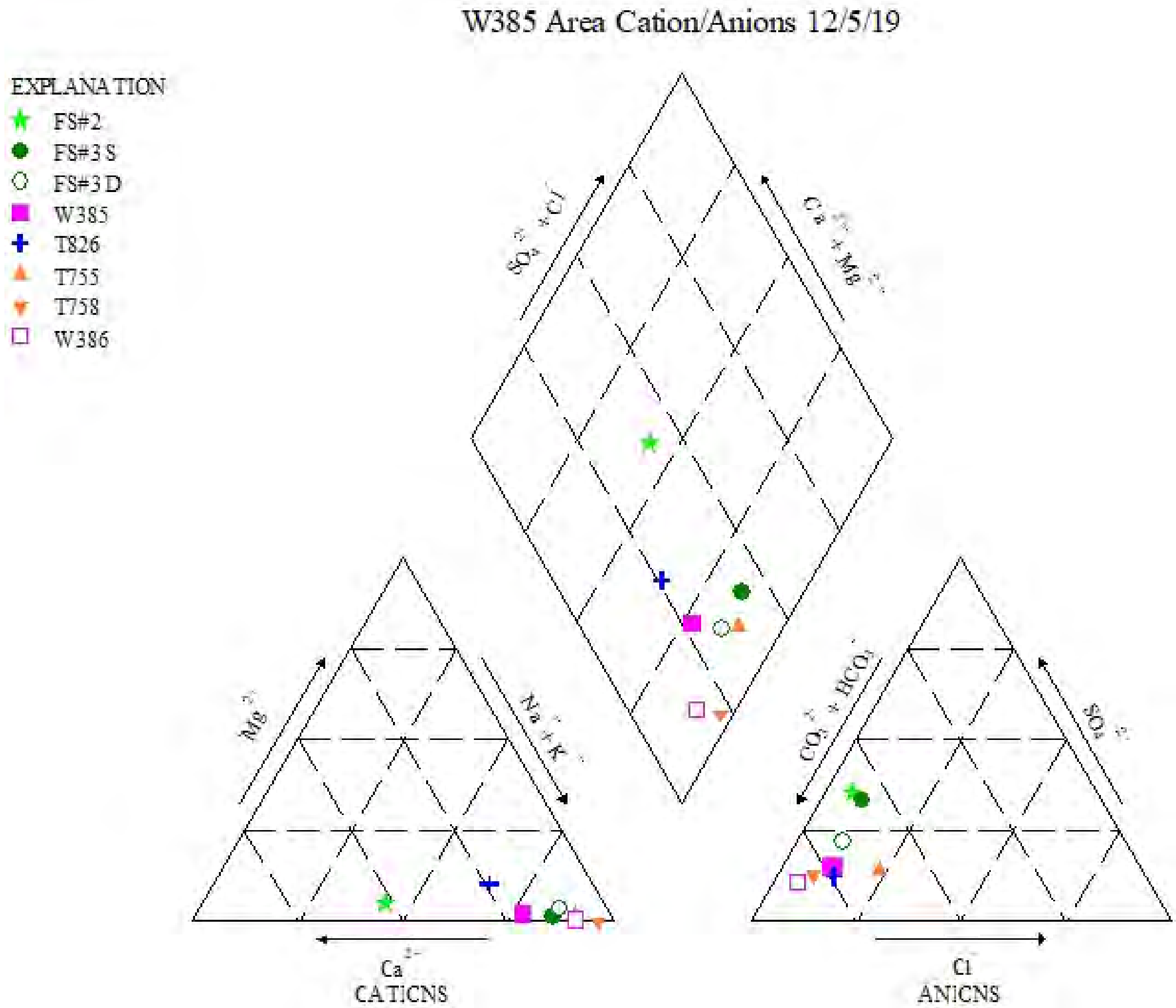
As part of the monitoring program for the W385 test, two geochemical sampling events were conducted at selected wells. An initial sampling occurred at seven wells on December 5, 2019, before W385 pumping began. A second sampling event occurred at the same seven wells and also W386 on February 13, 2020, 58 days into pumping just before the end of the test. Table 4 presents groundwater field parameters measured immediately before to sample collection. The purpose of these sampling events was to characterize the chemistry and isotopic signatures of waters in the Fish Slough and W385 area, to compare waters from the shallow and deeper aquifer zones, and to place local groundwaters in a regional context. The sampling events also attempted to identify groundwater flow and source information during the pumping itself and test whether changes to groundwater composition were caused by pumping (i.e. the sampling results differ before and at the end of the test).

As recharge infiltrates the subsurface, chemical reactions allow groundwater to dissolve some of the materials it flows through, leaving characteristic concentrations of dissolved constituents that can potentially differentiate groundwaters with varying source areas and flows paths. Table 6 presents laboratory analytical data for major constituents (cations and anions) and trace metals and major cation and anion compositional make-up in Piper (trilinear) diagrams from before and during the test are shown in Figure 26 and Figure 27.

Several observations can be made based on the cation/anion and trace mineral composition of sampled groundwater from the W385 test. Cation/anion compositional make-up in area wells did not change significantly between pre-pumping and late pumping sampling (Figures 27 and 28) with a couple of exceptions.

Groundwater in T826, screened in the shallow aquifer on the north side of the Owens River, had a notable decrease in salinity from December to February (reduced cation/anion concentrations and conductivity). The change in the isotopic signature of T826 also suggested a “fresher” composition. This well is screened in transmissive sediments adjacent to the West Pit/pond and its elevated salinity (and other trace metal concentrations) are likely the result of evaporative surface water from the West Pit/pond during summer and fall providing the primary source of groundwater to the well. With the lowered evaporation rate during winter, pond recharge from non-saline direct precipitation, or possibly a greater portion of Owens River water seepage supplying groundwater flow to the well are likely causes of the lowered salinity observed in February 2020.

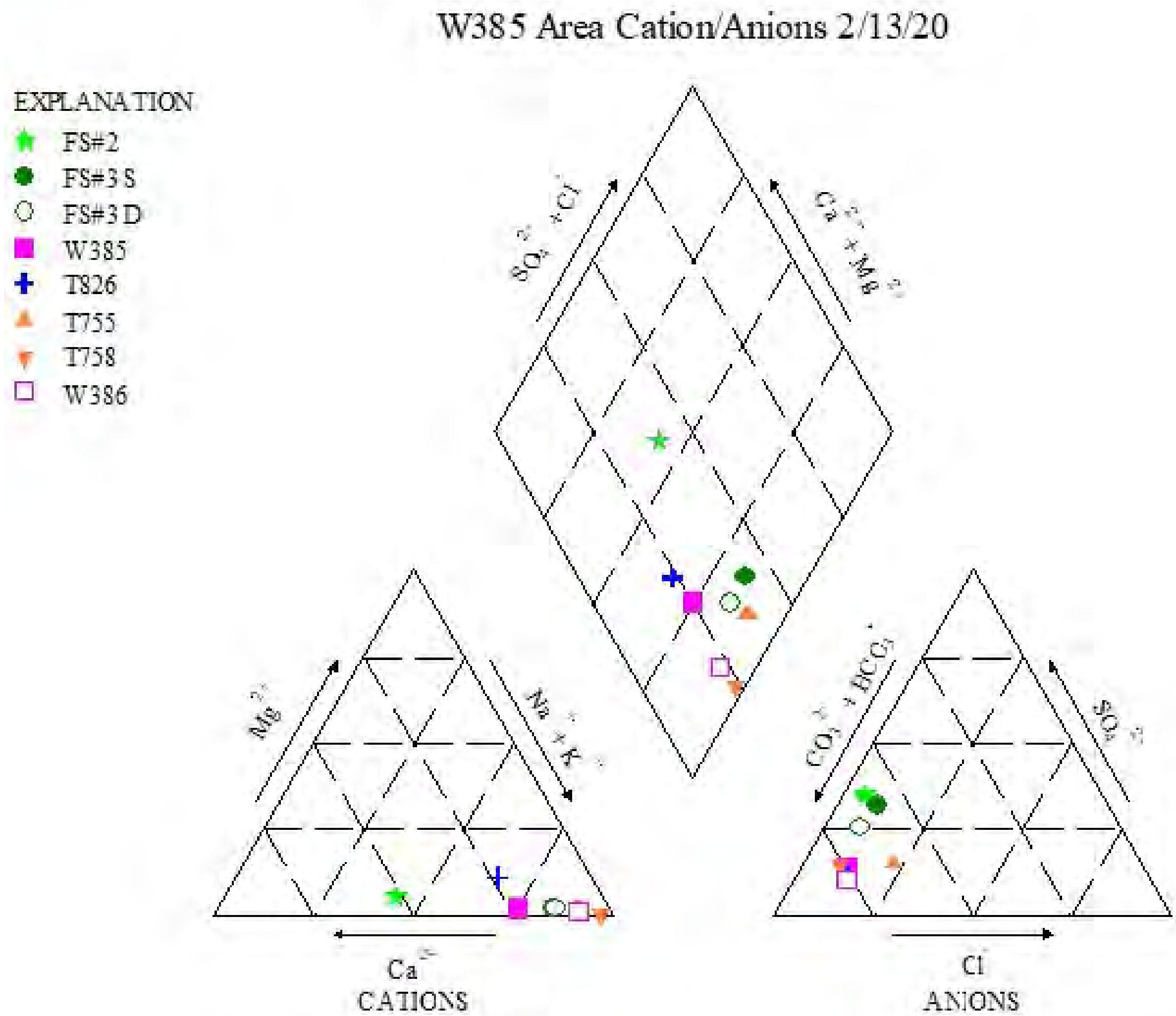
*Figure 27: Cation/Anion compositional precentages before 2019/20 pumping*




Seven of the eight groundwaters sampled had a similar sodium-bicarbonate geochemical signature. However, the northern most location, FS#2, had significantly more calcium than the other waters representing a mixed or calcic-bicarbonate water. This result is consistent with recent regional studies which demonstrated that the northern Fish Slough waters (based on samples from wells and springs) have increased calcium compositions and are more chemically similar to Hammil and Chalfant groundwaters. T826 and W385 both had elevated concentrations of calcium compared to the other wells (excluding FS#2). The two FS#3 wells (shallow and deep) had similar composition.

Groundwater from T758 is significantly less saline than other waters sampled. The total dissolved solids of T758 is approximately 175 mg/L, whereas the other groundwaters samples range between 300-400 mg/L. Although T758 is screened in the deepest aquifer zone of the sampled wells, it is the only well sampled south of the Owens River and may reflect a greater portion of recharge from the less saline waters of the Bishop Creek area.

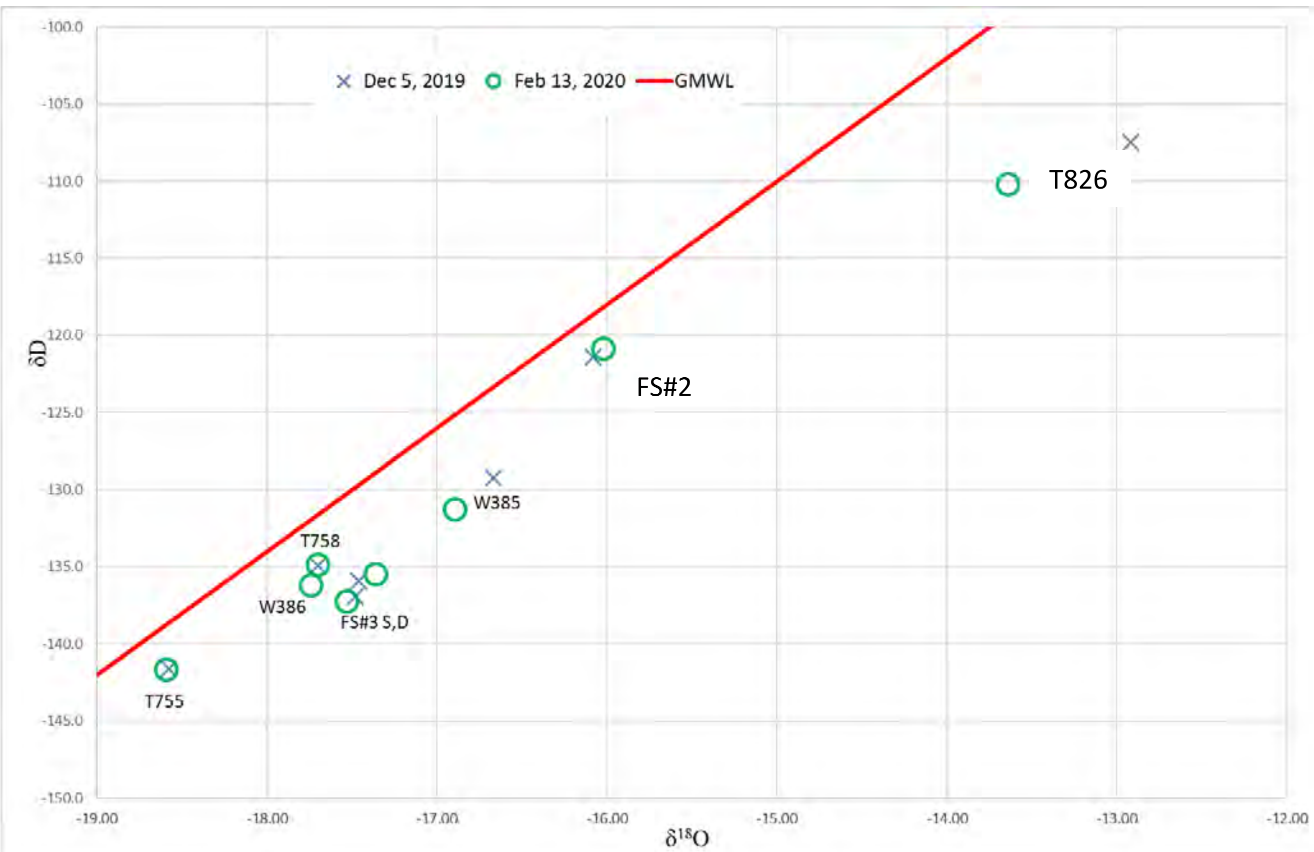
*Figure 28: Cation/Anion compositional precentages after 58 days of pumping*




Stable and unstable isotopes were also analyzed in area groundwater samples. Table 5 presents hydrogen, tritium and oxygen isotopic data, Figure 29 displays the stable isotope ratios from before and during the test. These isotopic tracers are properties of the water molecule itself and primarily reflect the characteristics of the source of recharge (snow-melt, precipitation, surface water seepage, etc.) and any post-depositional changes (e.g. evaporation, mineral exchange, etc.). The unstable hydrogen isotope, Tritium, is produced naturally in the atmosphere and also anthropogenically from above ground nuclear testing in the 1960s. It decays quickly with a short-half life (12.5 years); therefore, samples with higher Tritium concentrations indicate young groundwater sources. As expected, T826 had elevated Tritium concentrations during both sampling events compared to the other samples, indicative of young groundwater. No other well had detectable Tritium concentrations in December 2019. In February 2020, both FS#3d and W385 had Tritium concentrations that were above but near the laboratory's detection limit. Because the results from December and February appear to straddle the laboratory detection capabilities, it would be speculative to conclude that pumping caused younger water from the shallow aquifer to recharge the deeper aquifer. A more defensible interpretation is simply that T826 groundwater is substantially younger than other area wells.

Stable oxygen and hydrogen isotopes, Deuterium (D) and Oxygen-18 ($O^{18}$), contain one and two additional neutrons, respectively, than their more common counterparts (H and $O^{16}$). Due to these weight differences, water molecules can undergo fractionation during evaporation and precipitation events. Isotopic ratios for groundwater samples are expressed in δ "del" ratios of D/H and $O^{18}/O^{16}$ normalized to non-fractionated waters (standard mean oceanic water). The more negative the δD and $\delta O^{18}$ values are, the isotopically "lighter" the sample. The results can also be referenced to the average meteoric water composition (GMWL) and inferences made based on the degree of fractionation observed. The GMWL represents the "average" isotopic ratios between deuterium and $O^{18}$ in precipitation (snow or rain) from around the world. In general precipitation derived from colder, more northern, more inland, or higher elevation storms have a lighter isotopic ratio (more negative values) as compared to warmer, sea-ward, lower latitude and elevation precipitation (less negative values). Departures from this line can also indicate which prevailing fractionation process is at work on the surface (e.g. evaporation or condensation) or in the subsurface (e.g. mineral or hydrogen sulfide exchange).

*Figure 29: Stable isotope values (δD and $\delta O^{18}$) for W385 area groundwater samples*

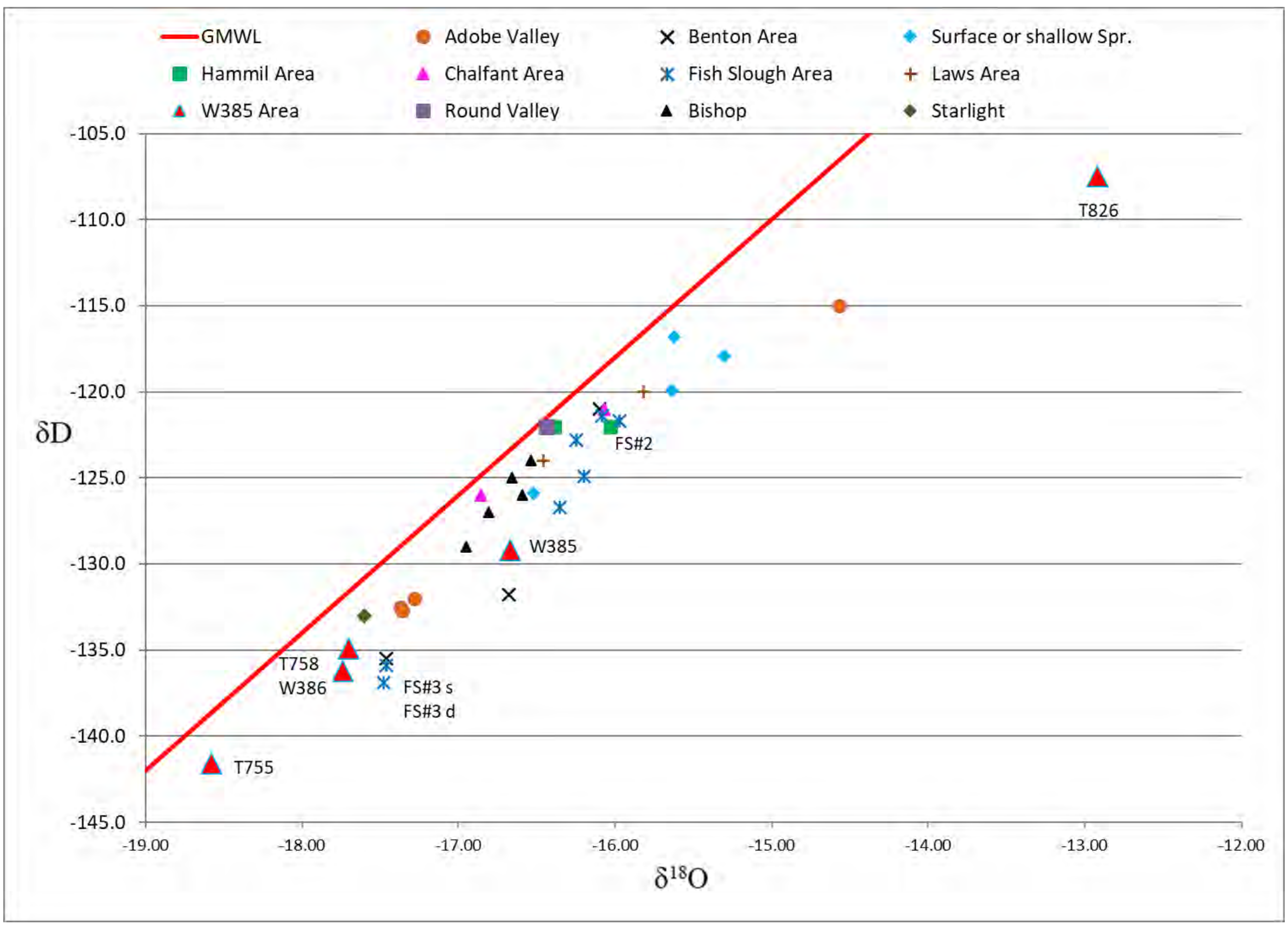



Groundwater from T826 was significantly heavier than other groundwater samples, indicating an evaporated source of recharge to this well (Figure 29). T826 samples also had a significant isotopic change from the December to February sampling, moving to an isotopically lighter source in February suggesting a water source less affected by evaporation and consistent with the dissolved constituent data. FS#2 samples were lighter than T826 but heavier than groundwater from the deeper wells and did not change composition during the test. FS#3s, FS#3d, W386 and T758 were similar isotopically and did not change composition during the pumping test (W386 was not sampled in December). T755 represented the isotopically lightest waters and combined with elevated chloride and fluoride concentrations, appears to differ from the other deep groundwaters; no isotopic change was observed in T755 during the pumping test.

W385 has isotopic waters that are the heaviest of the deeper aquifer zone; the isotopic composition became slightly lighter during the pumping but remained distinct from the other deep wells.

Isotopic data from this test were also compared with similar data collected in the area (Figure 30)to place results of this study in a regional context Map 7, including a recent study in the northeastern Owens and Adobe Valley area (Zdon, 2019) and USGS GAMA wells (Densmore, 2006). The evaporative influence on T826 is distinct when compared to other regional waters. The 2019/20 isotope ratios at FS#2 are very similar to the Zdon (2019) results. Wells W386, T758, T755, and both FS#3 wells appear to source water from highly fractionated precipitation, likely recharge from higher-altitude precipitation, colder storms. W385 groundwater differs from the neighboring deep groundwaters and may represent a mixture of deep and shallow aquifer water from its immediate vicinity or a mixture between the local deep aquifer waters and waters from the Bishop or Fish Slough area.

*Figure 30: Stable isotope values (δD and δO$^{18}$) for regional groundwater samples*



There is increasing sodic content as water moves south through Fish Slough combined with a lighter isotopic trend.  Shallow wells FS#2 and T826 have groundwaters that are chemically distinct from each other and from the deeper aquifer zones. Deeper water from T758, W386, and FS#3 are isotopically and chemically similar. T755 is isotopically distinct from the other deep wells (lightest) and contains higher chloride and fluoride concentrations. FS#3 shallow and deep waters are nearly identical chemically and have similar groundwater temperature. Given the initial similarity in hydrographs and similar chemistry and fugitive data from drilling, these two wells are likely in hydrologic communication with the same groundwater and hydrostratigraphic unit. W385 water differs slightly from adjacent deep wells both chemically and isotopically and may be influenced either by overlying shallow aquifer waters or greater hydrologic communication with either Bishop or Fish Slough waters.

## Conclusions

Based on hydrologic and geochemical data collected during the two-month pumping test of W385, ICWD has reached the following conclusions.

- The pumping test complied with the relevant CEQA, Technical Group and Standing Committee plans, and settlement agreements reached between LADWP and various parties. No groundwater drawdown triggers were exceeded during the test.
- The groundwater model used to predict pumping impacts proved to be conservative, i.e. the model predicted slightly greater drawdown than was observed during the test despite a higher actual pumping rate.
- The water-table remained within the 6.5’ (2-meter) rooting zone of meadow vegetation in the area of the test wells at the Five Bridges Mitigation Site and in Fish Slough.
- In the deep aquifers, pumping of W385 affected groundwater from the Private Well in the north and in T757-T759 in the south.  The wells in the deeper aquifer west of W385 (T752 and T755) in Fish Slough at FS#3 or further north were not affected by the pumping. Results were inconclusive to determine the eastern extent of drawdown.
- The test caused less drawdown in the shallow aquifer than observed in 1993/4 test largely due to the reduced pumping rate, but some effect of the well-modification or subsurface confinement was evident. The drawdown observed in the deeper aquifer was proportional to the reduced 2019/20 pumping rate when compared to 1993/94 test.
- In the shallow aquifer zones, pumping W385 affected groundwater north of the Owens River in the vicinity of the gravel pit by less than 1 foot, but did not affect water levels west at T752-755, east at V875, or in the majority of wells south of the Owens River.
- The observed water level changes in both the shallow and deep aquifer zones suggest that the area has partial or leaky vertical confinement between subsurface zones. Some hydrologic communication between the deeper aquifer which W385 is screened in and the shallow, water-table aquifer was evident (the shallow aquifer was affected but not greatly).
- Geochemical data indicates that groundwater in the shallow aquifer is of a different age and isotopic composition than deeper zones. The shallow and more northern groundwaters of Fish

Slough are chemically and isotopically different from shallow and deep groundwater near W385.
- Data collected during the test should be used to update the Bishop-Laws groundwater model, and to further inform the regional geochemistry of subsurface waters.
- Across the W385 area there are substantial differences in subsurface lithology (offsets or discontinuous units), in groundwater temperature and chemistry, and in the complex structural (faulting) and geomorphic features (floodplain environment with active and chaotic erosional and depositional forces over time).

Preliminary observations which could benefit from additional data analysis or collection include:

- The Fish Slough fault zone running north-south parallel to the C-Drain potentially impedes lateral flow from west to east in deeper aquifer zones.
- W385 geochemical signature differs slightly from neighboring deep aquifer wells and may represent a mixing of either shallow aquifer or deeper water flowing from the north or south.
- Although not the focus of the W385 pumping test, data from December 2019 and April 2020 appear to indicate that W410 has a small but measurable effect on shallow and deep aquifer zones in the Five Bridges area. The effects of W410 should be further examined and taken into consideration when assessing the cumulative impacts of any potential W385 or W386 pumping.

## Recommendations

Based on hydrologic and geochemical data collect during the two-month pumping test of W385, ICWD makes the following recommendations.

- Currently, the Private Well (an active domestic supply well) provides valuable data on pumping at the mouth of Fish Slough. Monitoring in this location should be replaced with a dedicated cluster pair of shallow and deep wells installed by LADWP. This will allow for consistent monitoring without in-well pumping effects and/or access issues.
- The area of influence of W385 pumping in the deeper aquifer zone was identified in wells located south, west, and north of W385; however, there was insufficient monitoring data to the east. A single deep monitoring well or a shallow/deep pair should be added in the vicinity of T438 and V875 to better constrain the hydrologic properties of the Fish Slough fault zone in this area and the eastern edge of the AOI.
- FS#3 shallow and deep monitoring wells should be accurately surveyed and, if possible, a survey elevation should be made to the east at the Fish Slough itself to allow a comparison between groundwater levels and surface water elevation in this area.
- During any additional pumping tests proposed by LADWP, W410 and W249 should remain off for several weeks (more than 6) before, during, and after W385 or W386 pumping to avoid confounding the test results.

- Additional pre-test data (3 or more weeks) should be collected at the West Pit and Owens river staff gauges to more thoroughly capture pre/post-test surface water trends.
- Geochemical sampling and analysis proved informative during the W385 test. If additional pumping tests are proposed by LADWP, a geochemical component should once again be included.
- Due to the heterogeneous hydrogeologic make-up of the W385 area, any additional pumping proposals should be evaluated cautiously and recognize that differing pumping stresses (amounts of pumping, production wells pumped, or seasonal timing) could produce unexpected hydrologic responses in the shallow and deep aquifer zones.

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*Table 4 Field Parameters W385 Pumping Test*

| Parameter | Unit | FS #2 | | FS #3D | | FS #3S | | T755 | | T758 | | T826 | | W385 | | W386 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 |
| Dissolved Oxygen Concentration | mg/L | 4 | 5.50 | 1.6 | 1.60 | 4.7 | 4.30 | 1.1 | 2.60 | 5.5 | - | 1.6 | 1.00 | 2.2 | 1.90 | - | 0.9 |
| Dissolved Oxygen Saturation | % | 44 | 59 | 19 | 20 | 54 | 54 | 14 | 30 | 63 | - | 18 | 11 | 34 | 29 | - | 11 |
| Fluid Turbidity | NTU | 4.44 | 0.47 | 19 | 2.6 | 3.92 | 9.12 | 0.52 | 0.26 | 0.64 | 0.46 | 0.95 | 1.2 | 2.77 | 0.25 | - | 1.44 |
| General Appearance | - | 1 | - | 4 | 2 | 1 | - | 1 | - | 1 | - | 3 | - | 1 | - | | - |
| Odor | - | 1 | - | 4 | 3 | 1 | - | 3 | - | 1 | - | 1 | - | 1 | - | - | - |
| pH | - | 7.8 | 7.88 | 8.43 | 7.84 | 8.08 | 7.96 | 7.88 | 8.21 | 8.6 | 7.16 | 7.12 | 7.21 | 7.84 | 7.77 | - | 8.35 |
| Specific Conductance | µS/cm | 447 | 433 | 511 | 527 | 515 | 520 | 455 | 465 | 227 | 535 | 625 | 530 | 543 | 536 | - | 354 |
| Temperature | °C | 13.3 | 11 | 17.5 | 17.6 | 18.2 | 17.4 | 15.2 | 27.9 | 15.2 | 17.2 | 15 | 13.8 | 31.8 | 28.9 | - | 19.6 |

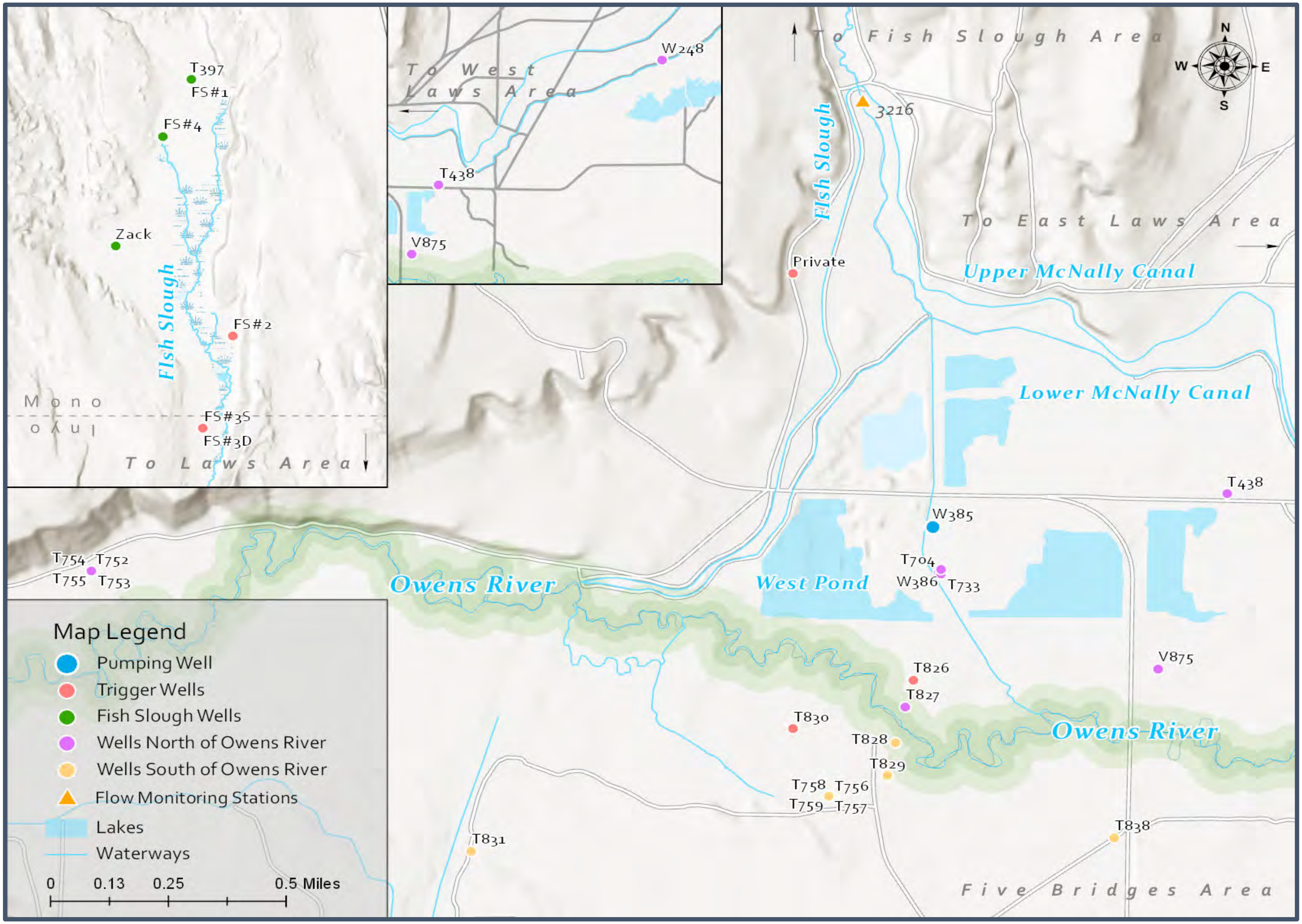
*Table 5. Hydrogen and Oxygen Isotopes, W385 Pumping Test*

| Parameter | Unit | FS #2 | | FS #3D | | FS #3S | | T755 | | T758 | | T826 | | W385 | | W386 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 |
| Oxygen-18 | % | -16.08 | -16.02 | -17.48 | -17.53 | -17.46 | -17.36 | -18.58 | -18.59 | -17.7 | -17.7 | -12.92 | -13.64 | -16.67 | -16.89 | - | -17.74 |
| Deuterium | % | -121.4 | -120.9 | -136.9 | -137.3 | -135.9 | -135.5 | -141.6 | -141.7 | -134.9 | -134.9 | -107.5 | -110.2 | -129.2 | -131.3 | - | -136.2 |
| Tritium | TU | < 0.52 | TBD | < 0.65 | TBD | < 0.54 | TBD | < 0.45 | TBD | < 0.41 | TBD | 2.23 ± 0.2 | TBD | < 0.51 | TBD | - | TBD |

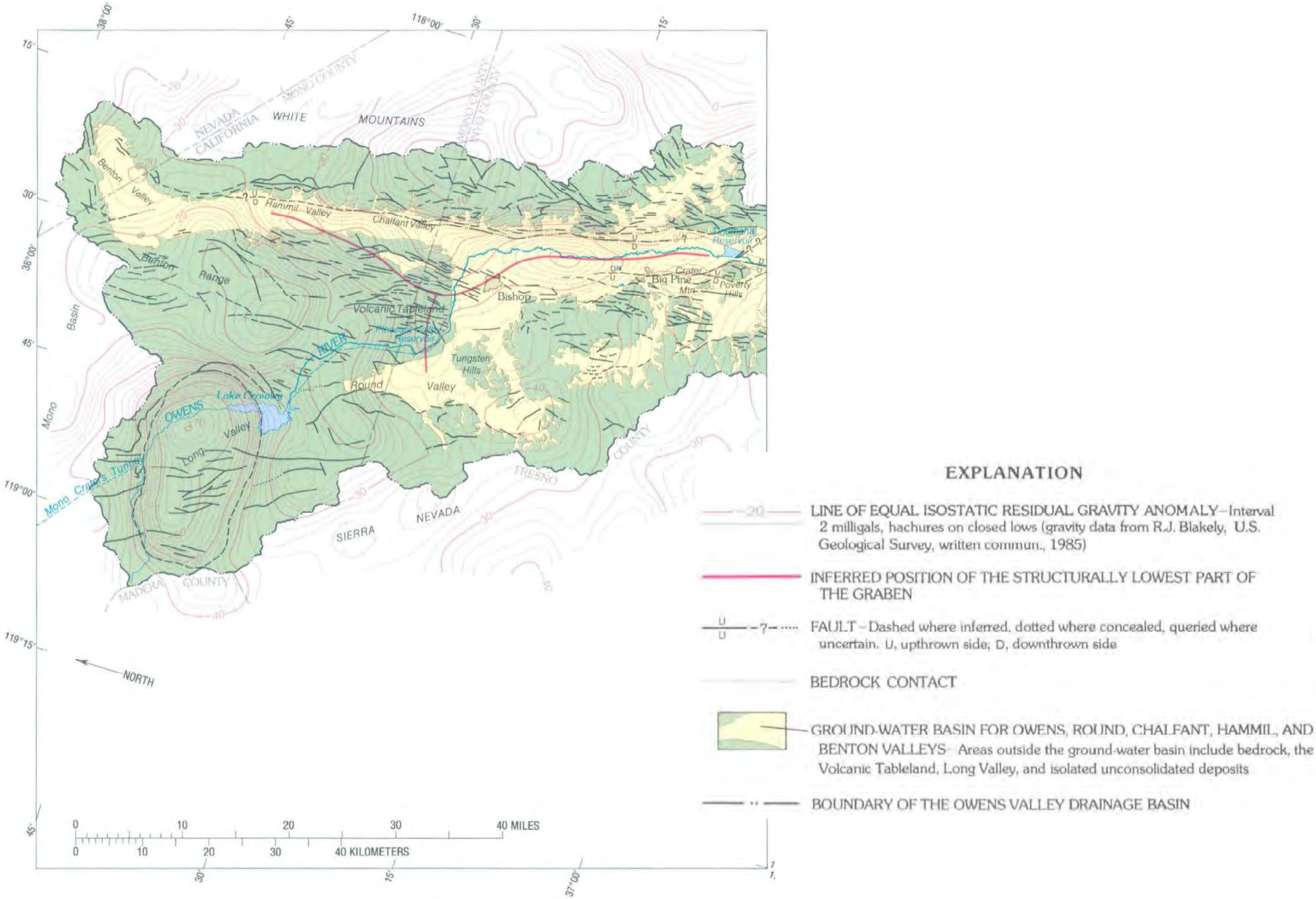
*Table 6 General chemistry (cations, anions, trace metals) W385 Pumping Test*

| Parameter | Unit | FS #2 | | FS #3D | | FS #3S | | T755 | | T758 | | T826 | | W385 | | W386 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 |
| Aluminum | ug/L | 43.9 | ND | 419 | 44.6 | 217 | 2680 | ND | ND | ND | ND | 14.3 | 21.2 | ND | ND | - | ND |
| Antimony | ug/L | 14.1 | 7.9 | ND | ND | ND | ND | ND | ND | ND | ND | 3.2 | 3.8 | ND | ND | - | ND |
| Arsenic | ug/L | 8.2 | 7.9 | 1.4 | 1.5 | 12.9 | 13.8 | 19.9 | 21.7 | 13.4 | 13.5 | 46.3 | 45.9 | 7.3 | 7.6 | - | 14.1 |
| Barium | ug/L | 14.2 | 13.6 | ND | ND | ND | 21.4 | 78.5 | 84.8 | 31.1 | 14.0 | 39.0 | 33.3 | 21.6 | 17.4 | - | 25.5 |
| Beryllium | ug/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | - | ND |
| Bicarbonate (HCO3), H2SO4 Titration | mg/L | - | 158 | - | 194 | - | 173 | - | 153 | - | 86.5 | - | 251 | - | 228 | - | 164 |
| Bicarbonate Alkalinity, Total (as CaCO3) | mg/L | - | 130 | - | 159 | - | 142 | - | 126 | - | 83.6 | - | 206 | - | 187 | | 138 |
| Boron | ug/L | 140 | 161 | 354 | 344 | 369 | 372 | 419 | 436 | ND | 148 | 1080 | 1090 | 436 | 469 | - | 305 |
| Bromide, Ion-Chromatography | mg/L | 0.0329 | 0.0322 | 0.0672 | 0.0567 | 0.0547 | 0.0567 | 0.0386 | 0.0438 | ND | ND | 0.0913 | 0.0764 | 0.0623 | 0.102 | - | 0.0324 |
| Cadmium | ug/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | - | ND |
| Calcium | mg/L | 46.4 | 45.2 | 11.3 | 13.3 | 13.6 | 14.5 | 7.29 | 6.89 | 1.49 | 1.26 | 31.3 | 26.8 | 21.8 | 23.2 | - | 6.02 |
| Chloride, Ion-Chromatography | mg/L | 9.92 | 8.85 | 19.4 | 16.4 | 16.7 | 17.4 | 32.6 | 32.8 | 6.70 | 6.38 | 31.4 | 25.0 | 22.2 | 21.1 | - | 16.9 |
| Chromium | ug/L | 1.0 | ND | 2.3 | ND | ND | 4.5 | ND | ND | ND | ND | ND | ND | ND | ND | - | ND |
| Copper | ug/L | 3.5 | ND | 4.7 | ND | ND | 4.3 | ND | ND | ND | ND | 12.9 | 5.2 | 22.9 | ND | - | ND |
| Fluoride, Ion-Chromatography | mg/L | 0.858 | 0.908 | 2.50 | 2.58 | 2.54 | 2.57 | 7.54 | 7.75 | 1.91 | 1.92 | 1.51 | 1.55 | 2.14 | 2.28 | - | 2.09 |
| Lead | ug/L | 1.7 | ND | 0.52 | ND | ND | 1.7 | ND | ND | 5.4 | 1.3 | ND | ND | 5.8 | 0.88 | - | ND |
| Magnesium | mg/L | 2.90 | 2.80 | 2.30 | 1.65 | 0.799 | 1.31 | 0.951 | 0.896 | ND | ND | 8.17 | 6.83 | 1.09 | 1.10 | - | 0.246 |
| Manganese | ug/L | 2.6 | ND | 45.6 | 62.0 | ND | 60.6 | 20.5 | 21.5 | ND | ND | 283 | 276 | 128 | ND | - | 18.7 |
| Nickel | ug/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 12.9 | 12.9 | ND | ND | - | ND |
| Nitrate (as N), Ion-Chromatrography | mg/L | 0.366 | 0.360 | ND | ND | 0.170 | 0.158 | ND | ND | ND | ND | ND | 4.96 | 0.213 | 0.136 | - | ND |
| Potassium | mg/L | 2.16 | 1.64 | 6.37 | 4.95 | 3.69 | 4.34 | 3.65 | 3.17 | 1.66 | 1.37 | 7.51 | 6.00 | 6.33 | 5.76 | - | 3.63 |
| Selenium | ug/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | - | ND |
| Silica, ICP-OES | mg/L | 89.8 | 88.1 | 66.2 | 83.5 | 97.6 | 102 | 88.0 | 86.1 | 79.8 | 79.9 | 43.5 | 38.9 | 110 | 106 | - | 77.5 |
| Silver | ug/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | - | ND |
| Sodium | mg/L | 43.5 | 42.1 | 97.1 | 93.5 | 94.1 | 94.7 | 86.6 | 84.0 | 49.1 | 47.8 | 91.7 | 80.1 | 90.2 | 84.1 | - | 73.1 |
| Sulfate, Ion-Chromatography | mg/L | 75.7 | 72.4 | 53.3 | 59.3 | 76.6 | 75.4 | 26.7 | 27.4 | 13.3 | 12.9 | 36.7 | 28.0 | 36.8 | 32.9 | - | 16.5 |
| Thallium | ug/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | - | ND |
| Phosphorus, Total (as P), Colorimetry | mg/L | 0.040 | ND | 0.211 | 0.10 | 0.045 | 0.066 | 0.053 | 0.046 | 0.064 | 0.058 | 0.145 | 0.11 | 0.029 | NA | - | 0.036 |
| Phosphorus, Total (as PO4), Colorimetry | mg/L | 0.123 | - | 0.647 | - | 0.138 | - | 0.162 | - | 0.196 | - | 0.445 | - | 0.089 | - | - | - |
| Uranium | ug/L | 27.2 | 22.2 | ND | ND | 2.3 | 2.8 | ND | ND | ND | ND | 86.1 | 71.9 | 7.8 | 8.5 | - | ND |
| Vanadium | ug/L | 6.1 | 6.5 | ND | ND | ND | ND | ND | ND | ND | ND | 3.3 | 3.2 | ND | ND | - | ND |
| Zinc | ug/L | 21.8 | 12.2 | 34.2 | ND | ND | ND | 17.7 | ND | ND | ND | ND | ND | ND | ND | - | ND |

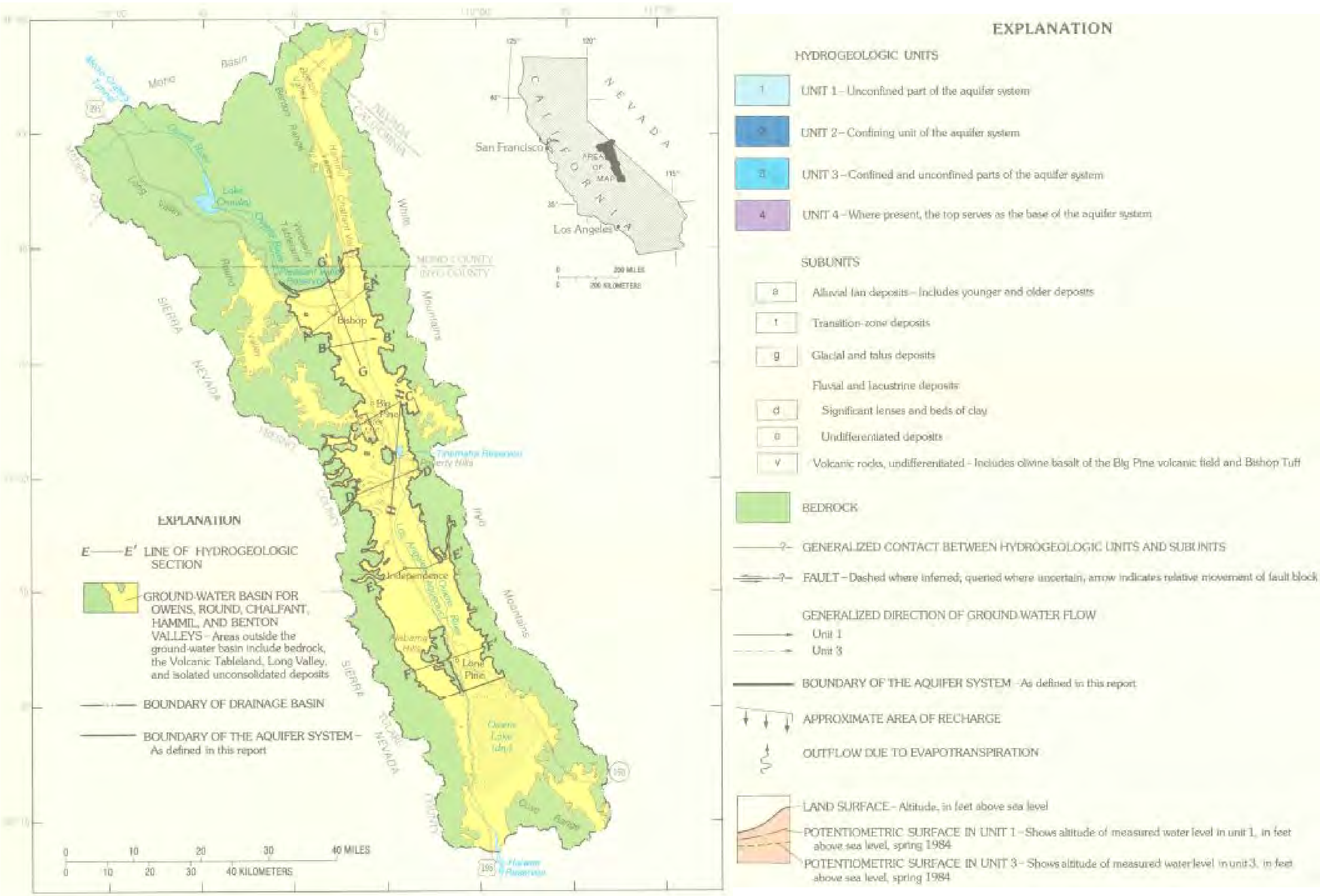
*Map 1 LADWP 2020*

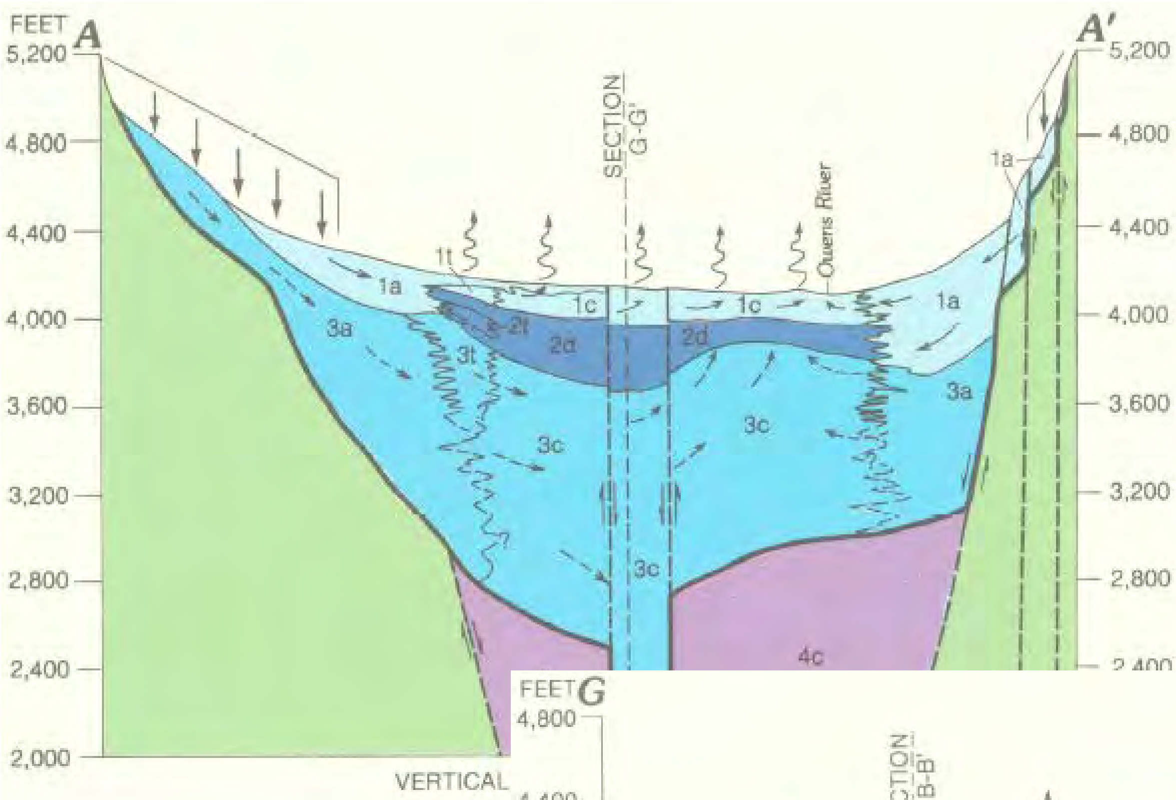


*Map 2 Hollet 1991, Figure 10*



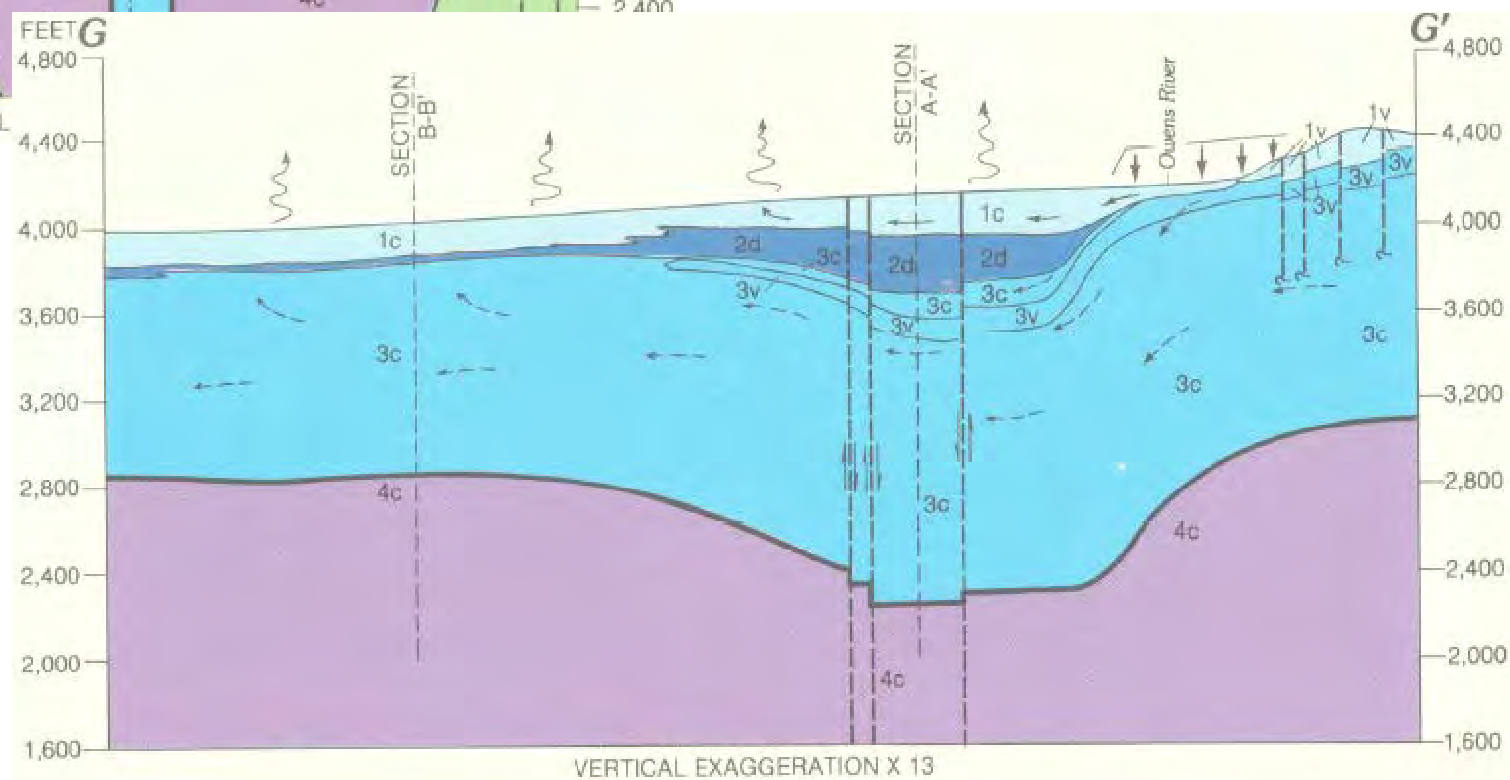
*Map 3 Hollet 1991, Plate 2, Cross Section A-A' and G-G'*






*Map 3. Continued:*

*Hollet 1991, Plate 2, Cross Section A-A' and G-G'*



*Map 4 Danskin 1998, Figure 4*

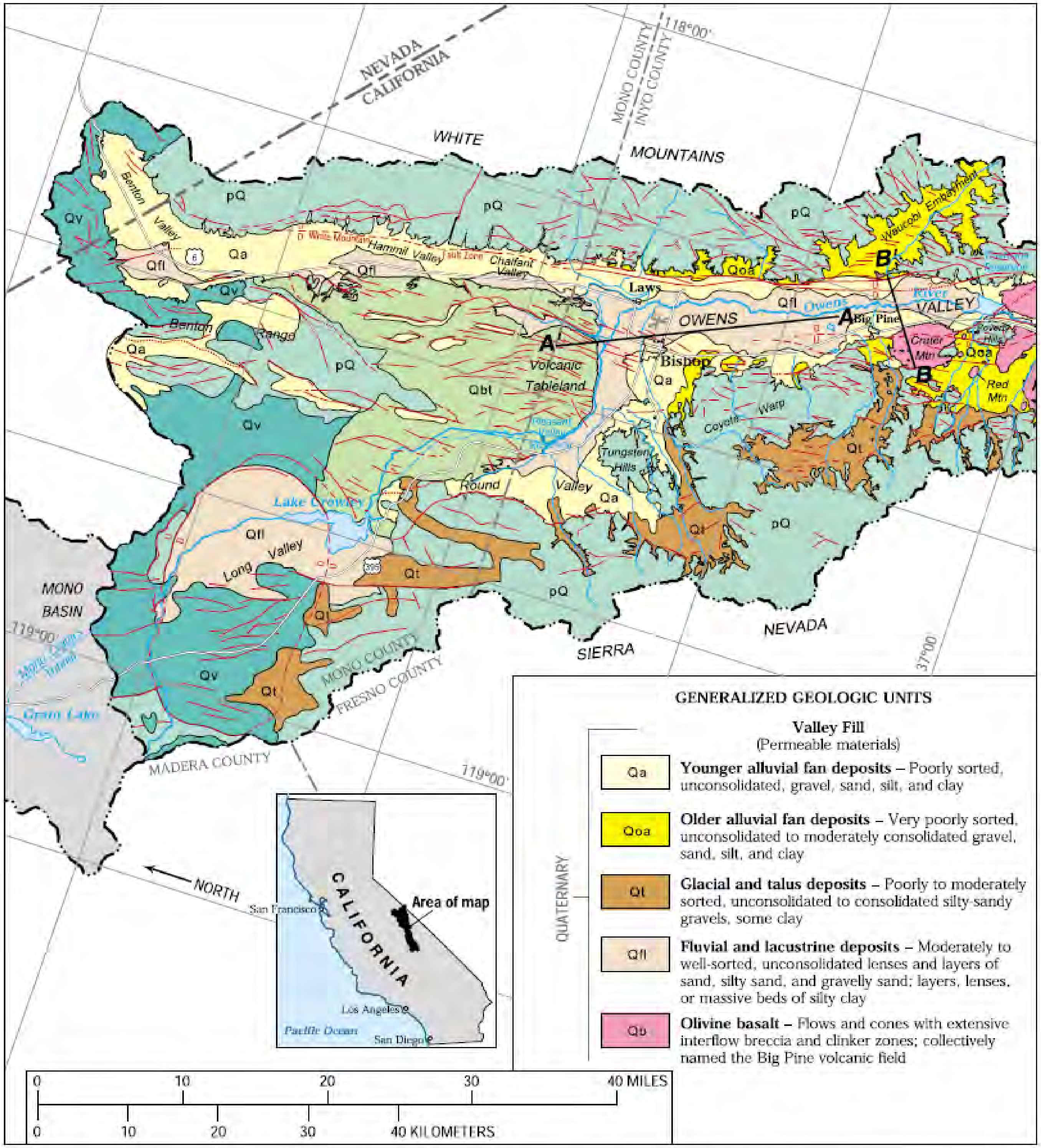



**Figure 4.** Generalized surficial geology of the Owens Valley drainage basin, California (modified from Hollett and others, 1991).

*Map 5 Danskin 1998, Figure 5*

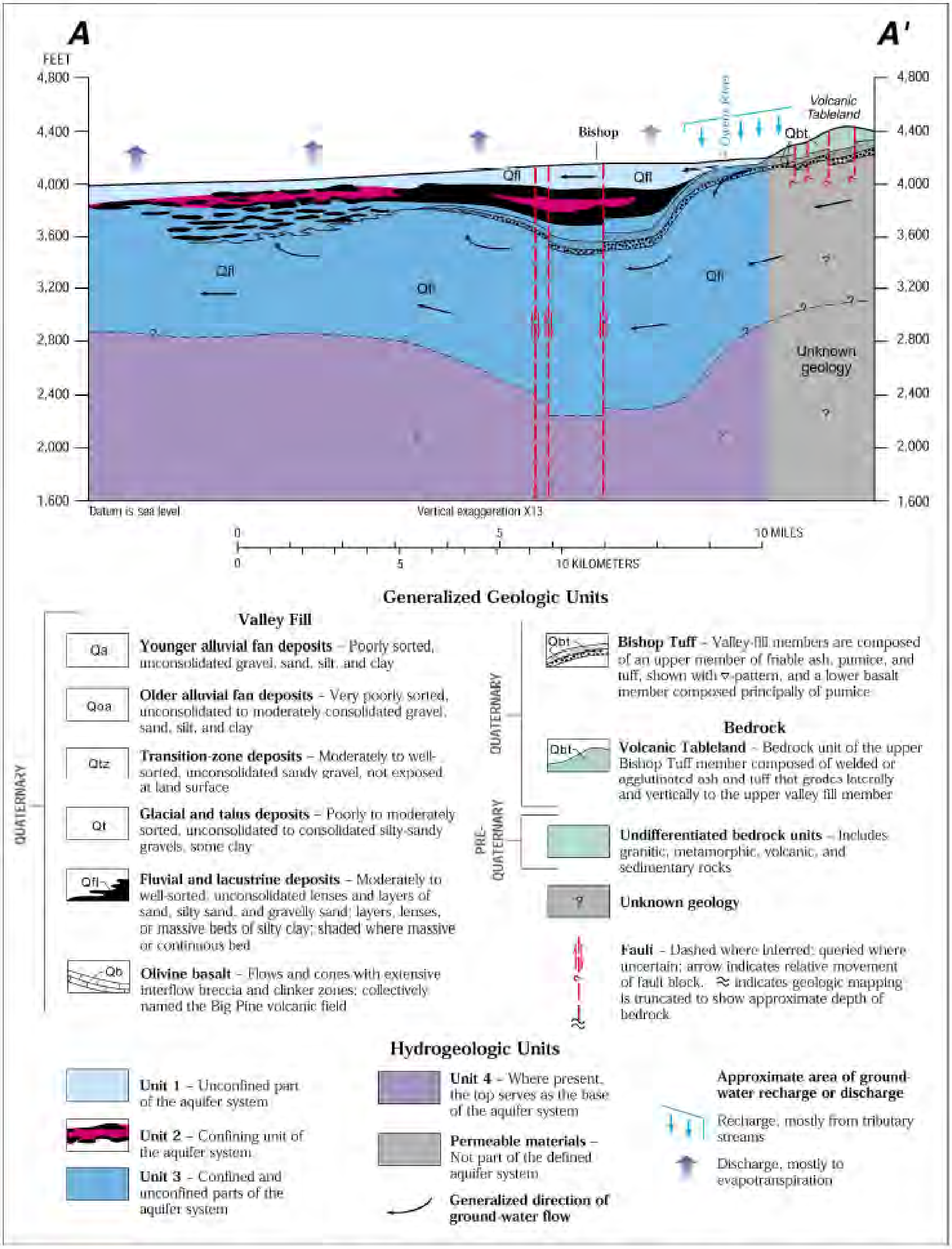



**Figure 5.** Typical hydrogeologic sections of the Owens Valley, California (modified from Hollett and others, 1991, plates 1 and 2). Sections located on figure 4.

*Map 6 Bateman 1965, Figure 64*

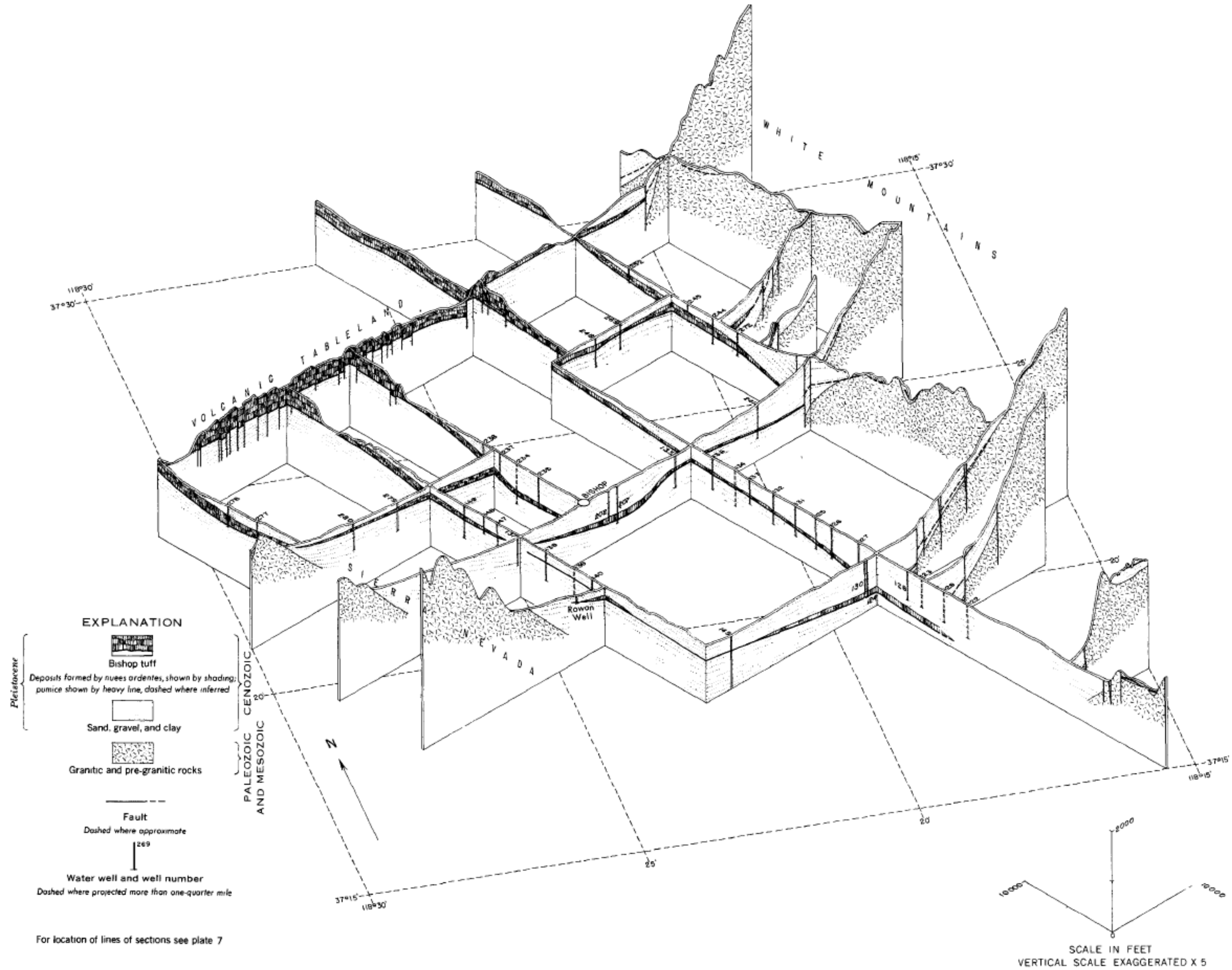
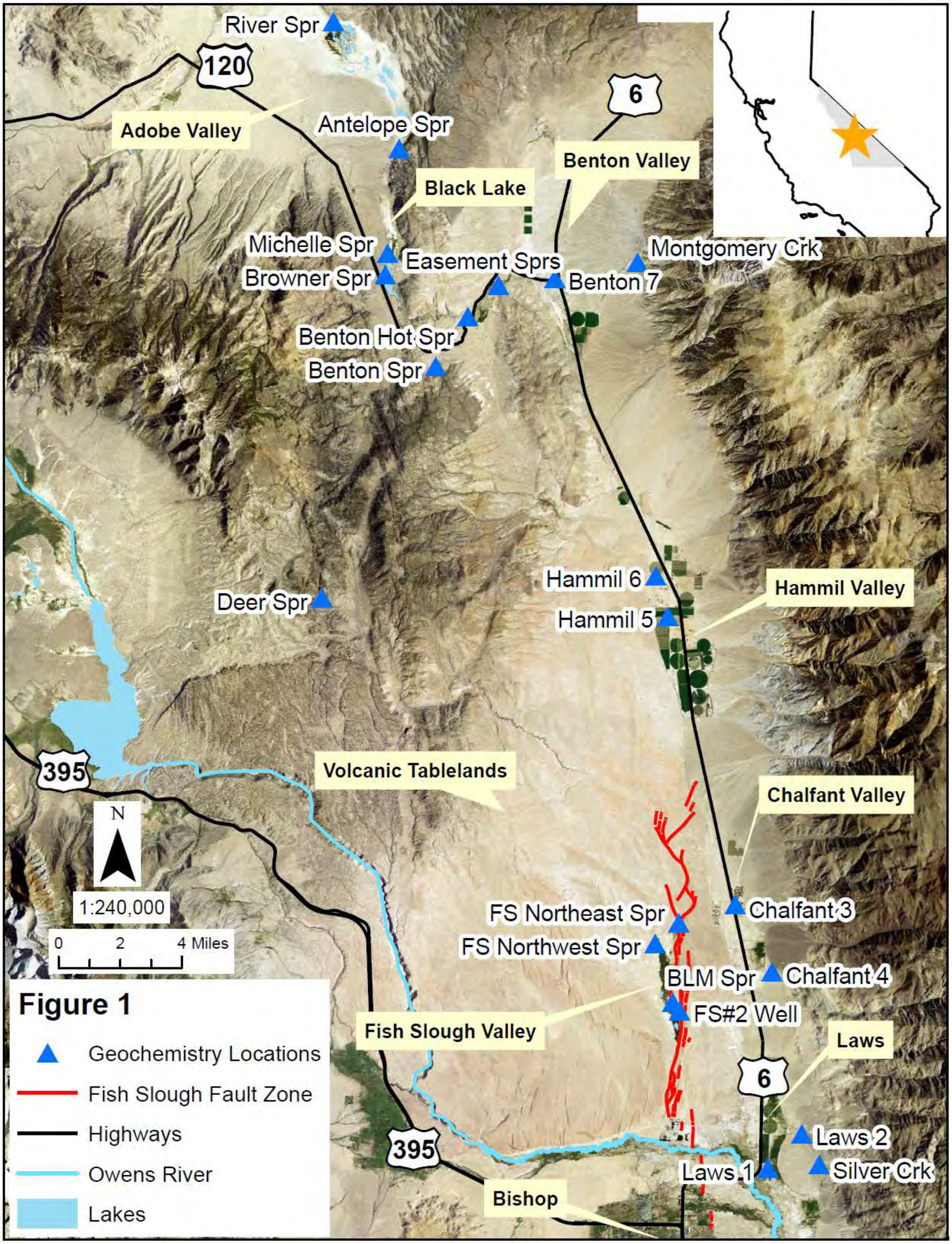



**Figure 64.—Fence diagram showing the distribution of the Bishop tuff in the Bishop quadrangle.**

*Map 7 Zdon 2018. Figure 1*



# Appendix A

## Production Well W385 in Laws Wellfield

## Two-Month Pumping Test

## April 2020

# Production Well W385 in Laws Wellfield

## Two-Month Pumping Test

April, 2020

Inyo County Water Department

Los Angeles Department of water and Power

## Executive Summary

The Los Angeles Department of Water and Power (LADWP) conducted a two-month pumping test in Well W385, located in the Laws Wellfield during the winter of 2019-20. The test was conducted in accordance with the Inyo/LA W385 Settlement Agreement and the amended Monitoring and Mitigation Plan approved by the Technical Group on December 13, 2019. The purpose of this report is to present the data collected during the pumping test. Groundwater levels within the potential area of influence were monitored to evaluate potential impacts to groundwater-dependent vegetation, a nearby private well, or the Fish Slough wetland due to the operation of W385. While groundwater level declines were observed in the vicinity of W385, there were no significant effects to sensitive resources during the pumping test based on measurements collected at 29 nearby monitoring wells.

Groundwater level changes in shallow monitoring wells north of Owens River during the pumping test varied from 1.1 feet rise to 0.8 feet decline. Groundwater levels in the shallow monitoring wells south of Owens River rose up to 1 foot. Groundwater level changes in the deeper monitoring wells varied between 9.5 feet of drawdown close to W385 and 0.2 foot of rise further away. In Fish Slough, groundwater levels rose in all monitoring wells during the pumping test at their typical seasonal trend.

No trigger groundwater levels were reached in any of the trigger wells selected to protect nearby resources during the pumping test. Groundwater quality samples were collected from 7 nearby wells (including W385) prior to pumping and at 8 wells near the conclusion of the pumping test. Based on general chemistry and isotope analyses of the samples, there were no significant changes in the groundwater quality as a result of the pumping test. All groundwater measurements collected during the pumping and recovery phases of the pumping test have been made available to relevant stakeholders. As of March 30, 2020, groundwater levels in the deep aquifer have recovered to pre-pumping levels. Shallow groundwater levels rose slightly following cessation of pumping and are expected to recover further as the stage of the Owens River rises due to higher spring flows. Finally, the groundwater level declines observed in the shallow aquifer were largely consistent with predictions made by the revised Bishop/Laws Groundwater Flow Model and contained in the Initial Study for the test.

# Background

## Original Design

LADWP installed wells W385 and W386 in Laws Wellfield to help dewater the shallow aquifer in the area surrounding a gravel mining operation. W385 was originally screened from 40 to 550 feet through the shallow and deep aquifers and W386 was originally screened from 50 to 550 feet. W385 and W386 were operated simultaneously from October 1987 to April 1989 for a total volume of 8,801 acre-feet. Due to pumping W385 and W386, groundwater levels in the shallow aquifer had lowered in the vicinity of these wells and, surprisingly, on the south side of Owens River. As a result, approximately 300 acres of groundwater dependent vegetation mostly south of the Owens River, known as Five Bridges Area, were impacted. Consequently, LADWP stopped operating W385 and W386.

## 1993-94 Pumping Test

Following the signing of the Inyo County/Los Angeles Water Agreement (Water Agreement), ICWD and LADWP conducted a two-month pumping test of W385 and W386 during the winter of 1993-94.[1] Both wells were pumped simultaneously at a combined pumping rate of 16.3 cfs. Groundwater levels were monitored at monitoring wells north and south of the Owens River. As shown on the hydrographs in **Figure 1**, pumping W385 and W386 affected groundwater levels in all monitoring wells on both sides of the Owens River in both the deep and shallow aquifers.

## Construction Modification

In 2014, LADWP modified W385 and W386 by sealing the portions of the wells screened to the shallow aquifer.[2] The upper approximately 330 feet and 360 feet were sealed in W385 and W386, respectively. This resulted in a substantial reduction in the pumping capacity of these wells (from 10.1 cfs to 2.8 cfs in W385 and from 6.2 cfs to 2.8 cfs in W386). A comparison of the original and modified W385 designs is presented in **Figure 2**. W386 original and modified designs were similar to that of W385.

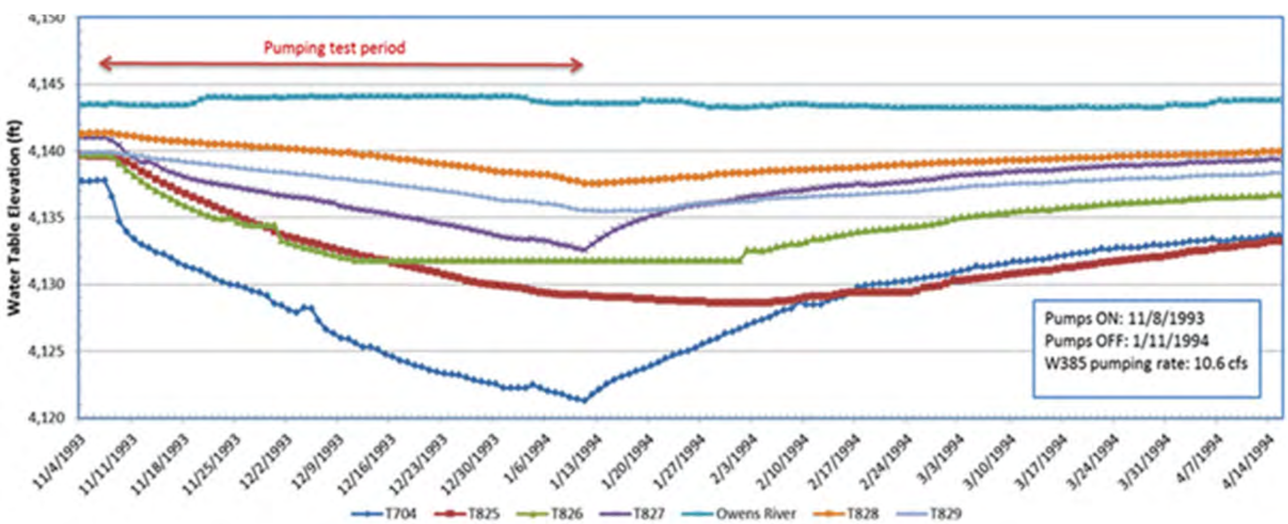



**Figure 1 – Groundwater Hydrographs during W385 and W386 Pumping Tests in 1993-94**

Original Modified

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[1] ICWD. *Draft Report 94-1* (1994).
[2] LADWP. *Owens Valley Well Modification Project* (2015).

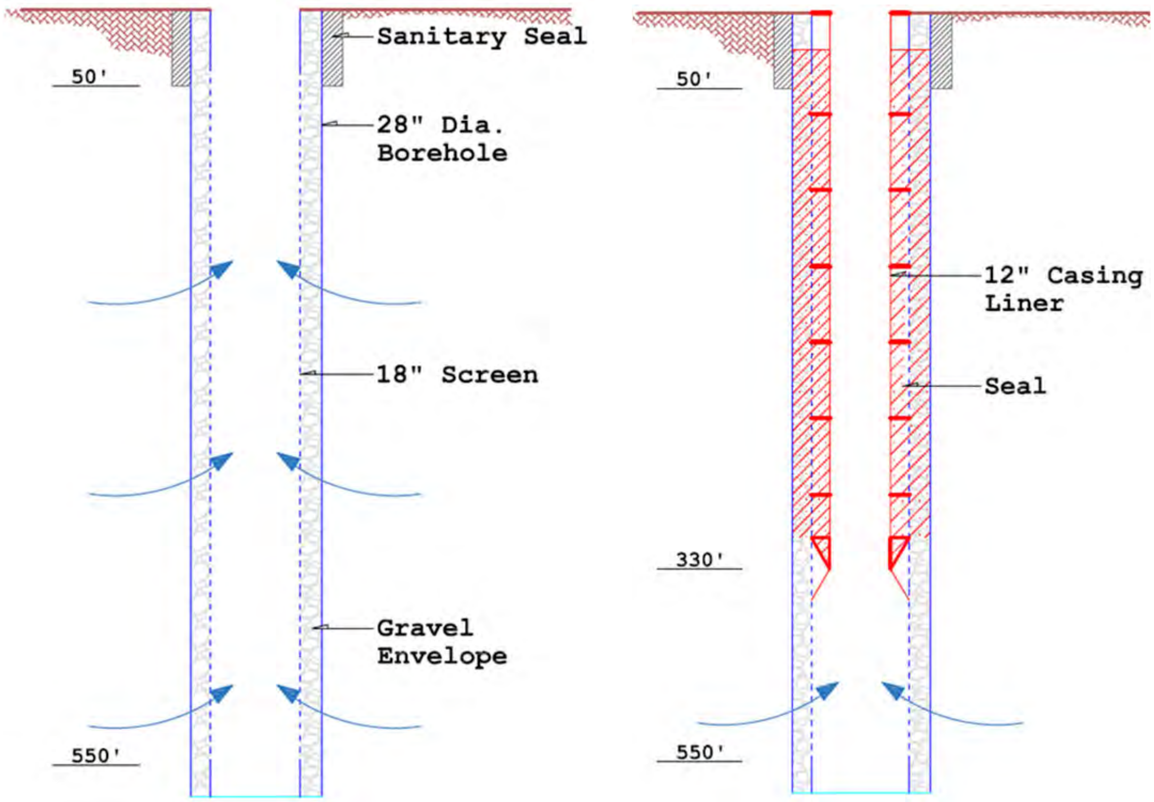



Figure 2 – Comparison of Original and Modified W385 Designs

After sealing the shallow portion of the screen, LADWP contractors conducted 24-hour pumping tests at W385 and W386, which exhibited no effects on shallow groundwater levels (**Figure 3).** Thus, LADWP started the process of activating wells W385 and W386.

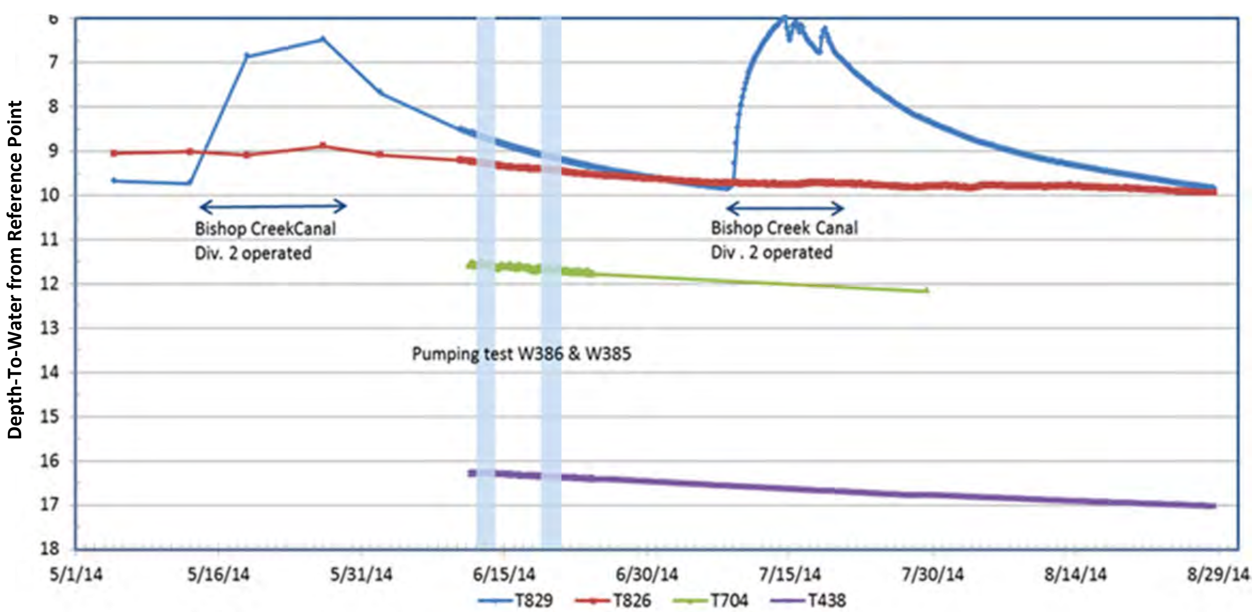



Figure 3 – W385 and W386 Pumping Tests in 2014

## Pumping Test

Following concerns expressed regarding the potential effects of pumping the modified wells, LADWP decided to treat W385 and W386 as “new” wells and follow the new well activation process outlined in the Inyo-LA Long Term Water Agreement. While the “new” wells are located at the same locations as the original W385 and W386, the characteristics of these wells have significantly changed:

- W385 and W386 now extract water primarily from the deep aquifer.
- The combined pumping capacity of W385 (during 2-month test) and W386 (during 24-hour test) was significantly reduced and is now approximately 6.5 cfs, compared with 16.3 cfs (a 60% reduction).

As part of operational pumping of W385 and W386, LADWP prepared CEQA documentation, which evaluated potential impacts of operating W385 and W386 on environmental resources. Following settlement of litigation over the CEQA documentation, LADWP conducted a two-month pumping test of W385 (without operating W386) over the winter period of 2019-20 in accordance with a Monitoring and Mitigation Plan adopted by the Technical Group. The test design was similar to the 1993-94 pumping test, and monitored the groundwater levels at nearby wells jointly selected by ICWD and LADWP, which included additional shallow and deep monitoring wells in Fish Slough Area installed at the request of California Department of Fish and Wildlife (CDFW). The 2019-20 pumping test of W385 was conducted to provide the following:

- To document the effectiveness of modifying W385 in minimizing the impact of pumping these wells on shallow groundwater levels nearby,
- To compare the groundwater level measurements from the 1993-94 and 2019-20 tests and groundwater models which provide a good indication of the effect of operating W385 on shallow groundwater level and, consequently, the nearby resources,
- To utilize data from the pumping test to recalibrate the Bishop/Laws groundwater flow model in the area near W385 and to utilize the model to simulate the long-term operation of this well.

# Hydrologic Monitoring

## Timeline

Pumping at W385 commenced at 10:00 am on December 16, 2019 and continued for 64 days, terminating on February 18, 2020 (“pumping phase”). The pumping rate was measured using a flow meter. The average pumping rate for the entire period of pumping was approximately 3.7 cfs and the total volume pumped during the test was approximately 463 acre-feet. Groundwater levels at wells in the surrounding area and the stage (surface water elevation) of nearby surface water features were also monitored before, during, and after the pumping phase of the test.

After completion of pumping phase of the test, surface and groundwater monitoring continued until the end of March 2020 (“recovery phase”). A timeline of the pumping test is presented in **Figure 4**.

## Surface Water Hydrology

Since early 2000, LADWP has diverted water from Diversion #2 of the Bishop Creek Canal three times per year to promote vegetation recovery in the Five Bridges Area. The operation of this diversion raises groundwater levels in the Five Bridges Area south of Owens River (see T829 data in **Figure 2**). In order to isolate any influence on groundwater levels due to W385 pumping from that of this diversion operation, LADWP stopped releasing water from this diversion during the course of the pumping test.

Fish Slough, located north of W385 (location map in **Figure 5**), is another surface water feature that supplies water to Fish Slough Ditch, which flows south to Owens River. Flow out of Fish Slough, measured at monitoring station 3216, demonstrates a seasonal characteristic (**Figure 6**). Annual flows range between 1.4 cfs in the summer and 11 cfs in the winter since April 2001. Flow from Fish Slough is recorded daily by LADWP and has been declining over the past several decades.

McNally Canals, which divert water from the Owens River, are used to carry out spreading and irrigation in the Laws area. To isolate any effects on groundwater levels due to W385 pumping from that of operating McNally Canals, LADWP ceased operation of the canals in October 2019.

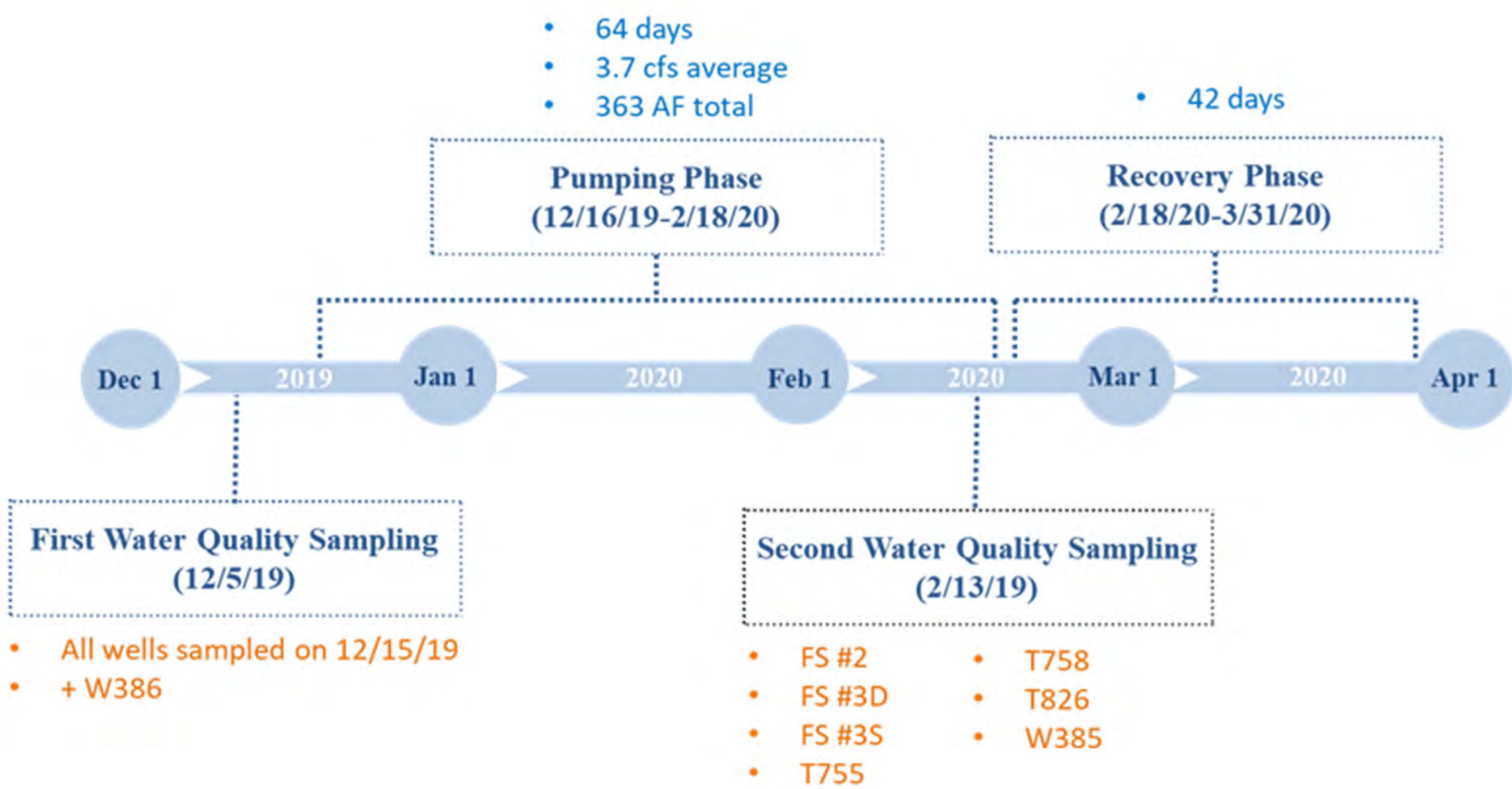



**Figure 4 - W385 Two-Month Pumping Test Timeline**

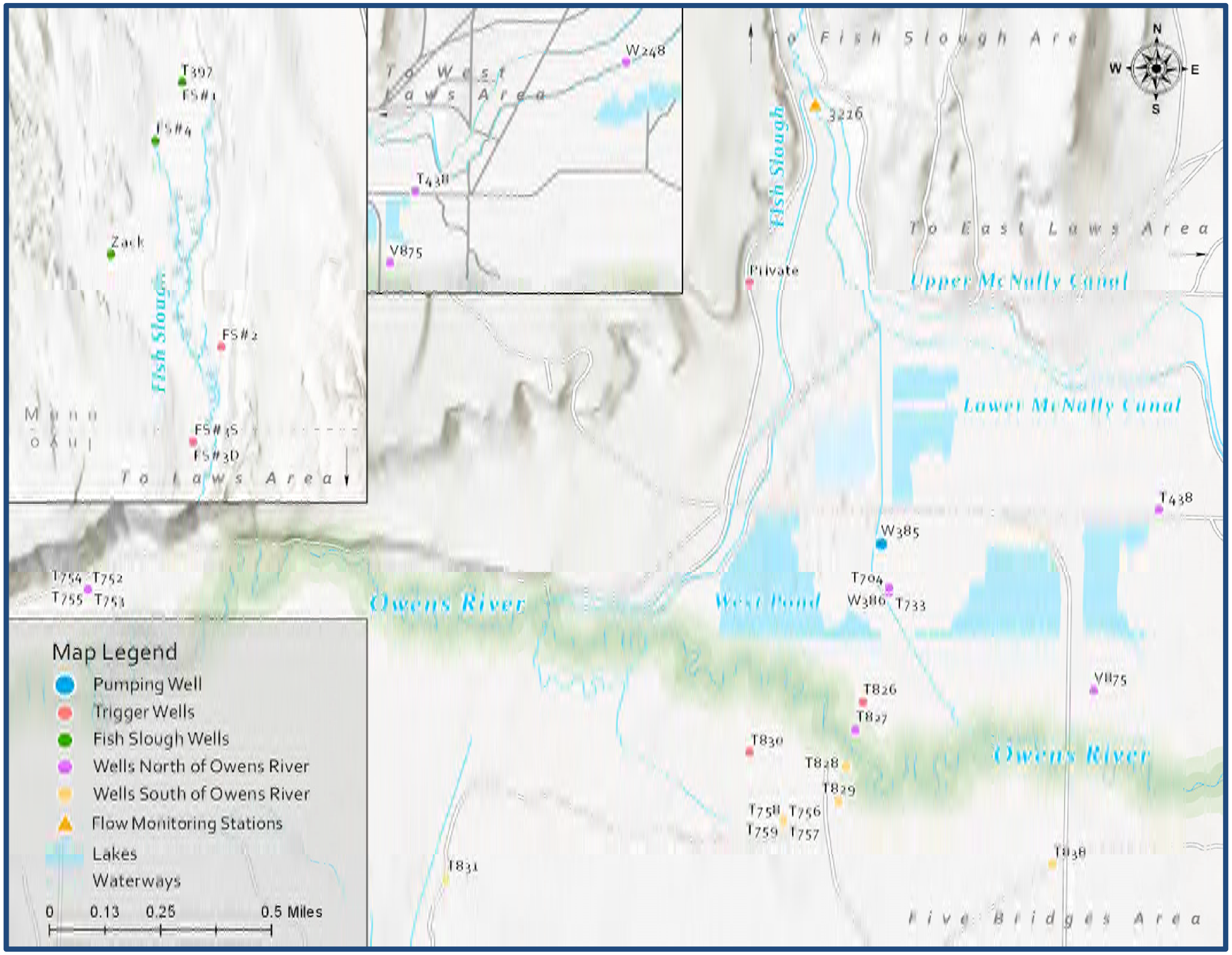



**Figure 5 - Map of Laws and Fish Slough Areas**

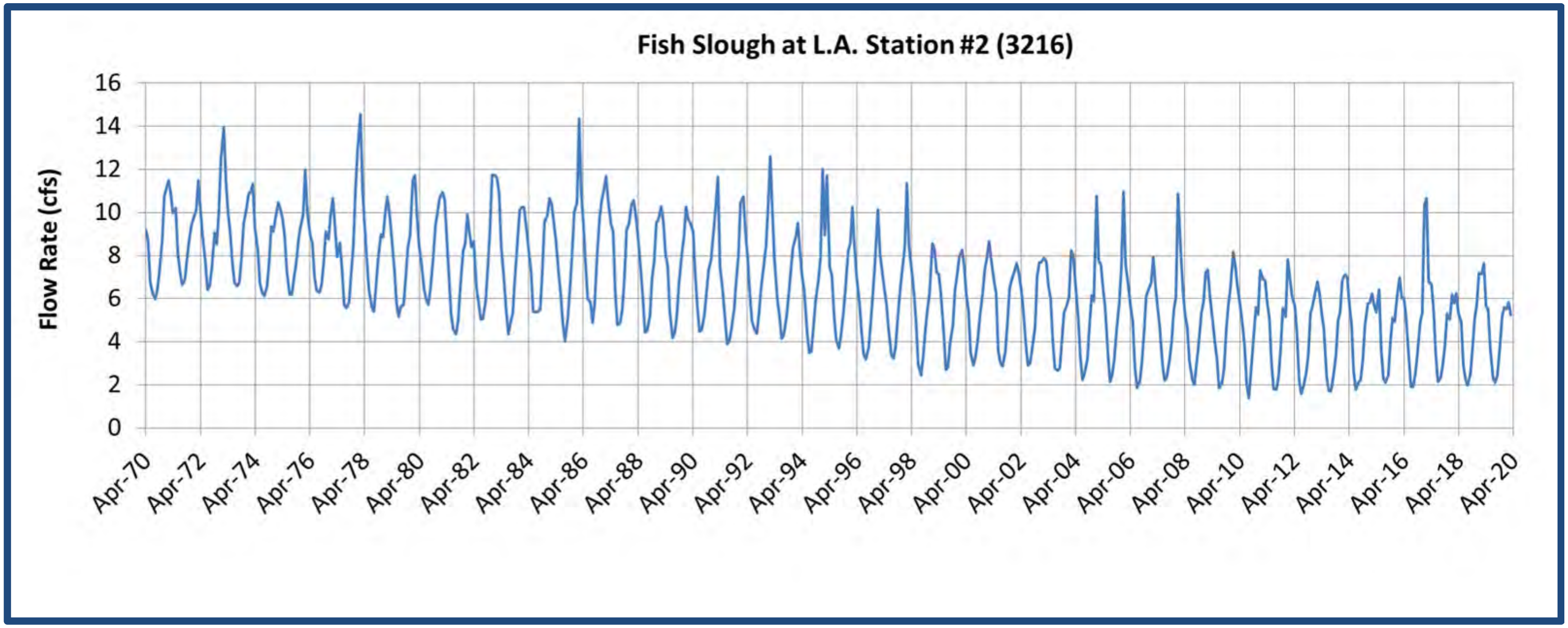



**Figure 6 – Historical Flow Out of Fish Slough at Monitoring Station 3216**

To measure and separate the effect of changes in the stage of surface water features from the effect of groundwater pumping on groundwater levels in the shallow aquifer, LADWP maintained the outflow from Pleasant Valley Reservoir at approximately 150 cfs from November 15, 2020 to March 2, 2020, and monitored stage at both the Owens River and the gravel pit's West Pond throughout the course of the pumping test. After March 2, 2020, outflow from Pleasant Valley Reservoir reduced to 125 cfs, due to forecasting a dryer than normal runoff year. LADWP personnel installed a staff gauge along a transect connecting monitoring wells T827 and T828 to monitor stage in Owens River. The water level in West Pond, located west of W385, was monitored using a staff gauge installed in the pond. Both staff gauges measured stage daily throughout the pumping test. The locations of Owens River and West Pond are indicated on the map in **Figure 5**.

## Groundwater Level Monitoring

To evaluate the effect of pumping W385, ICWD and LADWP personnel monitored groundwater levels at 29 wells located north and south of Owens River. The locations of these monitoring wells are displayed in **Figure 5**.

The groundwater levels at most monitoring wells were monitored by LADWP. ICWD monitored the groundwater levels at select wells in the Fish Slough area (Private Well, Zack Well, and all FS Wells). Most monitoring wells (except Private Well, FS#4, and W248) were equipped with pressure transducers that recorded groundwater levels every hour. The other wells were measured manually with an electric sounder on weekly and bi-weekly bases. A list of the measurement reference points (RPs), depths, and distances from W385 of each well is presented in **Table 1**. Reference points are presented as offsets above ground surface and elevations above mean sea level.

Data from the transducers were downloaded at approximately 10:00 am on days 3, 7, 14, 21, 28, 42, and 60 of the pumping phase, and on days 14, 28, and 56 of the recovery phase. They were transmitted to ICWD and CDFW after performing QA/QC.

## Trigger Levels

To ensure that pumping W385 during the test will not impact nearby resources, six wells were selected as trigger wells with assigned trigger levels. Based on ICWD and LADWP's Monitoring Plan,[3] if the groundwater in any of the trigger wells were to reach their respective trigger levels, the pumping phase of the test would stop and recovery data will be collected. ICWD, CDFW, and LADWP assigned groundwater "trigger levels" to wells T830, T826, Private Well, FS #2, FS #3S, and FS #3D located in areas with groundwater dependent vegetation approximately one

[3] LADWP. Pumping Test of W385R in the Laws Wellfield Monitoring Plan (2016).

week before the start of the pumping test (**Table 2**). An additional trigger level was assigned to the Private Well to protect its use as a domestic supply well. No trigger levels were reached during the pumping test.

**Table 1 – Characteristics of Wells Monitored during the Pumping Test of W385**

| Well | Total Depth (ft) | RP Offset from Ground (ft) | RP Elevation (ft-amsl) | Distance from W385 (mi) |
|---|---|---|---|---|
| FS #1 | 61 | 1.82 | 4201.82* | 7.1 |
| FS #2 | 46 | 1.80 | 4185.25 | 4.0 |
| FS #3D | 145 | 2.59 | 4194.84 | 2.8 |
| FS #3S | 35 | 2.76 | 4194.22 | 2.8 |
| FS #4 | 8 | 1.98 | 4221.98* | 6.4 |
| Private Well | 160 | 1.00 | 4186.00* | 0.6 |
| T397 | 180 | 1.87 | 4230.07 | 7.1 |
| T438 | 37 | 3.21 | 4142.11 | 0.6 |
| T704 | 32 | 2.33 | 4150.63 | 0.1 |
| T733 | 674 | 1.44 | 4151.24 | 0.1 |
| T752 | 680 | 2.97 | 4200.17 | 1.8 |
| T753 | 100 | 1.97 | 4199.17 | 1.8 |
| T754 | 210 | 3.82 | 4201.02 | 1.8 |
| T755 | 490 | 2.99 | 4200.19 | 1.8 |
| T756 | 45 | 2.00 | 4154.60 | 0.7 |
| T757 | 310 | 2.26 | 4154.86 | 0.7 |
| T758 | 575 | 2.24 | 4154.84 | 0.7 |
| T759 | 210 | 1.78 | 4154.38 | 0.7 |
| T826 | 17 | 0.94 | 4148.54 | 0.4 |
| T827 | 16 | 0.25 | 4147.95 | 0.4 |
| T828 | 15 | 0.98 | 4147.68 | 1.0 |
| T829 | 17 | 1.98 | 4149.68 | 0.6 |
| T830 | 14 | 1.05 | 4154.25 | 0.6 |
| T831 | 10 | 0.99 | 4176.49 | 1.2 |
| T838 | 37 | 1.89 | 4137.29 | 0.8 |
| V875 | 21 | 1.84 | 4132.85 | 0.6 |
| W248 | 602 | 0.28 | 4141.98 | 2.0 |
| W385 | 560 | -0.19 | | - |
| W386 | 560 | 3.64 | 4153.44 | 0.1 |
| Zack | 257 | 1.18 | 4227.18* | 5.2 |

*Ground surface elevation (ft-amsl) was estimated using Google Earth, which provided the highest resolution imagery among other elevation databases.

**Table 2 – Trigger Wells and Trigger Levels during W385 Pumping Test**

| Well | Trigger Level from RP (ft) | Trigger Level AMSL (ft) |
|---|---|---|
| T830 | 6.10 | 4148.15 |
| T826 | 7.60 | 4140.94 |
| Private Well | 21.40 | 4164.60 |
| FS #2 | 4.70 | 4180.55 |
| FS #3S | 15.30 | 4178.92 |
| FS #3D | 16.00 | 4178.84 |

# Pumping Phase

## Groundwater Levels

Wells measured during the pumping test, except W385, were grouped as Trigger, Fish Slough, North of Owens River, and South of Owens River monitoring wells. Trigger Wells are located in sensitive areas. The other categories are based on the geographical locations of the wells in the Laws area. The weekly groundwater level measurements at the wells of each category during the pumping phase are presented in **Table 3.** Daily data is presented in **Table A-1** in **Appendix A.** All groundwater level data entries are measured as a distance (ft) below Reference Point (RP). Negative numbers indicate a head above RP. The values presented are in the same format presented to relevant stakeholders during the course of the pumping test.

## Surface Water Elevations

Monitoring data from staff gauge elevation data at West Pond and Owens River are also presented in **Table 3**. All data entries are presented as elevations above mean sea level (ft-amsl). All data entries presented are preliminary and subject to revision and were recorded at approximately 10:00 am each day.

## Water Table Cross-Section

The changes in the shallow groundwater table and surface water elevations from the commencement to the end of the pumping phase in the Laws area are presented in **Figure 7**. Shallow groundwater level data at wells included from south to north are T756, T829, T828, T827, T826, T704, and T438. The stage of Owens River is included and located between T828 and T827. Groundwater and surface water level data are presented in ft-amsl. The position (on the x-axis) of each well is presented as a reference distance (ft) from T756. A satellite view of the cross section is presented in **Figure 8**.


**Figure 8– Satellite View of Laws Area Cross-Section**

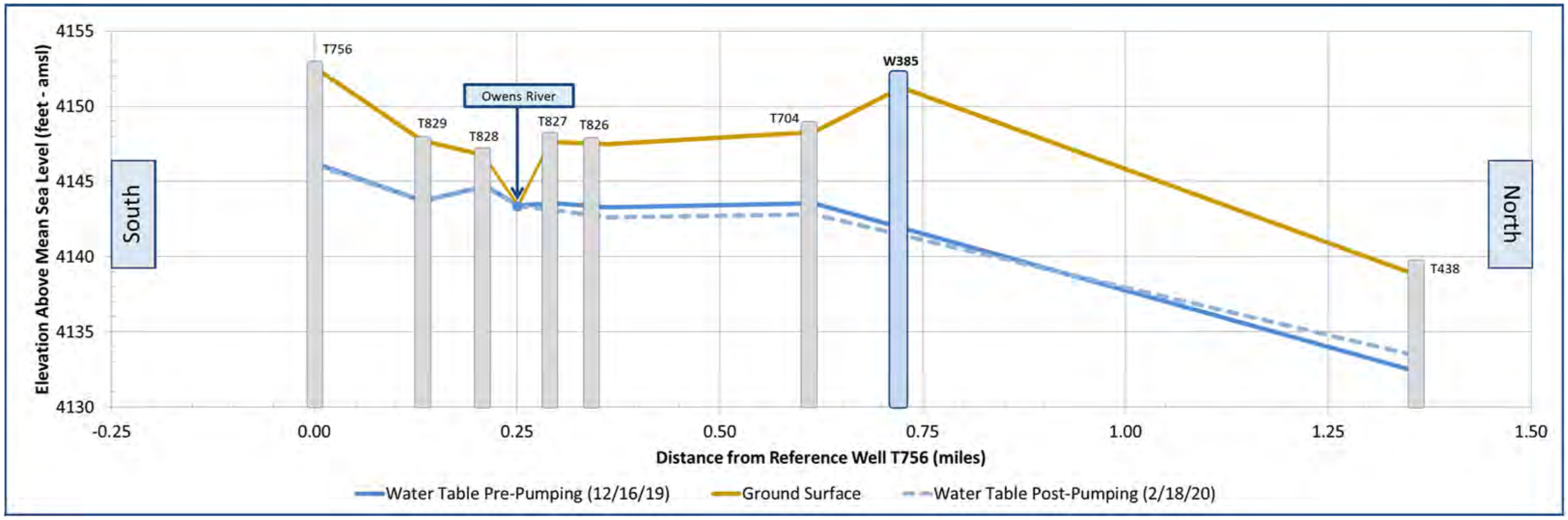



**Figure 7 – Laws Area Water Table Cross-Section for Pumping Phase**

## Table 3 – Pumping Phase Weekly Groundwater Level and Stage Measurements

| Week | Date | Depth to Groundwater from Reference Point | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pumping Well | Trigger Monitoring Wells | | | | | | Fish Slough Monitoring Wells | | | |
| | | W385 | T826 | T830 | Private | FS#2 | FS#3S | FS#3D | T397 | Zack | FS#1 | FS#4 |
| 0 | 12/16/19 | Flowing | 5.14 | 4.32 | 11.18 | 4.25 | 14.53 | 14.10 | 29.46 | 25.29 | 28.66 | Dry |
| 1 | 12/23/19 | 100.24 | 5.28 | 4.30 | 12.38 | 4.20 | 14.46 | 14.02 | 29.44 | 25.22 | 28.64 | Dry |
| 2 | 12/30/19 | 107.18 | 5.41 | 4.33 | 12.65 | 4.17 | 14.44 | 14.02 | 29.41 | 25.24 | 28.63 | Dry |
| 3 | 01/06/20 | 107.18 | 5.51 | 4.33 | 12.85 | 4.15 | 14.43 | 14.03 | 29.41 | 25.25 | 28.64 | Dry |
| 4 | 01/13/20 | 108.33 | 5.58 | 4.33 | 12.86 | 4.11 | 14.38 | 13.95 | 29.41 | 25.21 | 28.61 | Dry |
| 5 | 01/20/20 | - | 5.63 | 4.31 | - | - | 14.37 | 13.95 | 29.42 | - | - | - |
| 6 | 01/27/20 | 110.63 | 5.69 | 4.31 | 13.12 | 4.07 | 14.35 | 13.92 | 29.43 | 25.22 | 28.64 | Dry |
| 7 | 02/03/20 | - | 5.73 | 4.31 | - | - | 14.31 | 13.90 | 29.42 | - | - | - |
| 8 | 02/10/20 | 107.18 | 5.78 | 4.32 | 13.40 | 4.04 | 14.30 | 13.90 | 29.42 | 25.21 | 28.63 | Dry |
| 9 | 02/16/20 | - | 5.79 | 4.29 | - | - | 14.27 | 13.93 | 29.41 | - | - | - |
| - | 02/18/20 | 107.18 | 5.81 | 4.32 | 13.35 | 4.01 | 14.28 | 13.92 | 29.42 | 25.19 | 28.63 | Dry |
| Week | Date | W385 | T826 | T830 | Private | FS#2 | FS#3S | FS#3D | T397 | Zack | FS#1 | FS#4 |

| Week | Date | Depth to Groundwater from Reference Point | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | North of Owens River Monitoring Wells | | | | | | | | | | |
| | | T438 | T704 | T733 | T752 | T753 | T754 | T755 | T827 | V875 | W248 | W386 |
| 0 | 12/16/19 | 9.67 | 7.07 | -3.31 | -7.85 | 1.51 | 0.49 | -8.10 | 4.29 | 4.81 | - | 7.81 |
| 1 | 12/23/19 | 9.71 | 7.13 | - | -7.96 | 1.37 | 0.32 | -8.17 | 4.43 | 4.27 | 20.51 | 15.88 |
| 2 | 12/30/19 | 9.83 | 7.32 | 5.42 | -7.90 | 1.48 | 0.45 | -8.10 | 4.52 | 4.29 | 27.44 | 16.20 |
| 3 | 01/06/20 | 9.97 | 7.43 | 5.65 | -7.79 | 1.55 | 0.54 | -8.09 | 4.58 | 4.24 | 27.44 | 16.51 |
| 4 | 01/13/20 | 10.00 | 7.48 | 5.64 | -7.94 | 1.44 | 0.38 | -8.22 | 4.63 | 4.20 | 27.44 | 16.53 |
| 5 | 01/20/20 | 10.11 | 7.55 | 5.77 | -7.99 | 1.45 | 0.43 | -8.20 | 4.64 | 4.14 | - | 16.73 |
| 6 | 01/27/20 | 10.17 | 7.62 | 5.89 | -7.95 | 1.50 | 0.45 | -8.16 | 4.69 | 4.15 | 28.60 | 16.87 |
| 7 | 02/03/20 | 10.21 | 7.61 | 5.85 | -8.03 | 1.41 | 0.34 | -8.24 | 4.71 | 4.12 | - | 16.83 |
| 8 | 02/10/20 | 9.80 | 7.74 | 6.07 | -7.99 | 1.49 | 0.44 | -8.20 | 4.75 | 4.11 | 27.44 | 17.01 |
| 9 | 02/16/20 | 8.90 | 7.79 | 6.11 | -8.02 | 1.45 | 0.42 | -8.23 | 4.76 | 4.05 | - | 17.04 |
| - | 02/18/20 | 8.60 | 7.81 | 6.13 | -8.01 | 1.46 | 0.43 | -8.21 | 4.76 | 4.06 | 27.44 | 17.06 |
| Week | Date | T438 | T704 | T733 | T752 | T753 | T754 | T755 | T827 | V875 | W248 | W386 |

| Week | Date | Depth to Groundwater from Reference Point | | | | | | | | Staff Gauge Elevations Above Sea Level | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | South of Owens River Monitoring Wells | | | | | | | | | |
| | | T756 | T757 | T758 | T759 | T828 | T829 | T831 | T838 | West Pond | Owens River |
| 0 | 12/16/19 | 8.10 | 0.77 | 0.00 | 5.65 | 2.96 | 5.95 | 4.20 | 3.61 | 4149.25 | 4143.42 |
| 1 | 12/23/19 | 8.28 | 6.70 | 2.21 | 7.80 | 2.93 | 5.96 | 3.92 | 3.43 | 4149.12 | 4143.43 |
| 2 | 12/30/19 | 8.28 | 6.88 | 2.43 | 7.84 | 3.02 | 6.01 | 3.79 | 3.44 | 4148.97 | 4143.37 |
| 3 | 01/06/20 | 8.28 | 6.99 | 2.51 | 7.92 | 3.07 | 6.01 | 3.71 | 3.42 | 4148.91 | 4143.37 |
| 4 | 01/13/20 | 8.21 | 6.95 | 2.41 | 7.89 | 3.06 | 5.98 | 3.58 | 3.38 | 4148.67 | 4143.34 |
| 5 | 01/20/20 | 8.19 | 7.01 | 2.49 | 7.89 | 2.87 | 5.95 | 3.47 | 3.30 | 4148.52 | 4143.38 |
| 6 | 01/27/20 | 8.19 | 7.07 | 2.55 | 7.93 | 2.99 | 5.95 | 3.41 | 3.31 | 4148.40 | 4143.33 |
| 7 | 02/03/20 | 8.17 | 7.03 | 2.50 | 7.91 | 3.00 | 5.93 | 3.35 | 3.28 | 4148.23 | 4143.32 |
| 8 | 02/10/20 | 8.19 | 7.15 | 2.62 | 7.97 | 3.05 | 5.95 | 3.30 | 3.27 | 4148.09 | 4143.37 |
| 9 | 02/16/20 | 8.18 | 7.15 | 2.68 | 7.95 | 2.96 | 5.92 | 3.26 | 3.19 | 4147.96 | 4143.37 |
| - | 02/18/20 | 8.18 | 7.16 | 2.66 | 7.96 | 3.04 | 5.94 | 3.26 | 3.20 | 4147.92 | 4143.37 |
| Week | Date | T756 | T757 | T758 | T759 | T828 | T829 | T831 | T838 | West Pond | Owens River |

All data entries were recorded at approximately 10:00 am each day

# Recovery Phase

## Groundwater and Surface Water Levels

Weekly groundwater level and staff gauge elevations measured during the recovery phase are presented in **Table 4**. Daily data is presented in **Table A-2** in the **Appendix A.** All groundwater level data entries are measured as a distance (ft) below RP. Any negative number entries indicate a head above RP. The values presented are in the same format presented to relevant stakeholders during the course of the pumping test. All stage entries are presented as elevations above mean sea level (ft-amsl). All data entries are also preliminary and subject to revision and were recorded at approximately 10:00 am each day.

## Water Table

The diagram presented in **Figure 9** covers the same cross-section presented in **Figure 7** except it presents the changes in shallow groundwater table and surface water elevation from the beginning to the end of the recovery phase. Groundwater and surface water level data is presented in ft-amsl. The position (on the x-axis) of each well is presented as a reference distance (ft) from T756.

### Table 4 – Recovery Phase Weekly Groundwater Level and Stage Measurements

| Week | Date | Depth to Groundwater from Reference Point | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Pumping Well | Trigger Monitoring Wells | | | | | | Fish Slough Monitoring Wells | | | |
| | | W385 | T826 | T830 | Private | FS#2 | FS#3S | FS#3D | T397 | Zack | FS#1 | FS#4 |
| 0 | 02/18/20 | 107.18 | 5.81 | 4.32 | 13.35 | 4.01 | 14.28 | 13.92 | 29.42 | 25.19 | 28.63 | Dry |
| 1 | 02/25/20 | - | 5.68 | 4.28 | - | - | 14.28 | 13.93 | 29.43 | - | - | - |
| 2 | 03/03/20 | 64.44 | 5.63 | 4.27 | 11.60 | 3.97 | 14.22 | 13.87 | 29.42 | 25.20 | 28.62 | Dry |
| 3 | 03/10/20 | - | 5.66 | 4.29 | - | - | 14.23 | 13.87 | 29.42 | - | - | - |
| 4 | 03/17/20 | Flowing | 5.62 | 4.25 | - | 3.95 | 14.20 | 13.82 | 29.40 | 25.16 | 28.63 | Dry |
| 5 | 03/24/20 | - | 5.64 | 4.27 | - | - | 14.20 | 13.83 | 29.41 | - | - | - |
| 6 | 03/31/20 | Flowing | 5.67 | 4.28 | - | 3.92 | 14.19 | 13.82 | 29.41 | 25.20 | 28.63 | Dry |
| Week | Date | W385 | T826 | T830 | Private | FS#2 | FS#3S | FS#3D | T397 | Zack | FS#1 | FS#4 |

| Week | Date | Depth to Groundwater from Reference Point | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | North of Owens River Monitoring Wells | | | | | | | | | | |
| | | T438 | T704 | T733 | T752 | T753 | T754 | T755 | T827 | V875 | W248 | W386 |
| 0 | 02/18/20 | 8.60 | 7.81 | 6.13 | -8.01 | 1.46 | 0.43 | -8.21 | 4.76 | 4.06 | 27.44 | 17.06 |
| 1 | 02/25/20 | 7.85 | 7.68 | -2.74 | -7.95 | 1.53 | 0.52 | -8.16 | 4.56 | 4.03 | - | - |
| 2 | 03/03/20 | 7.34 | 7.72 | -3.32 | -8.07 | 1.48 | 0.42 | -8.28 | 4.54 | 3.98 | 25.13 | -0.67 |
| 3 | 03/10/20 | 6.99 | 7.81 | -3.49 | -8.10 | 1.55 | 0.48 | -8.30 | 4.60 | 3.98 | - | - |
| 4 | 03/17/20 | 6.80 | 7.80 | -3.70 | -8.23 | 1.46 | 0.38 | -8.41 | 4.56 | 3.92 | 26.29 | Flowing |
| 5 | 03/24/20 | 6.88 | 7.88 | -3.76 | -8.14 | 1.53 | 0.45 | -8.35 | 4.57 | 3.89 | - | - |
| 6 | 03/31/20 | 7.16 | 7.92 | -3.76 | -8.12 | 1.59 | 0.52 | -8.32 | 4.58 | 3.93 | 27.44 | Flowing |
| Week | Date | T438 | T704 | T733 | T752 | T753 | T754 | T755 | T827 | V875 | W248 | W386 |

| Week | Date | Depth to Groundwater from Reference Point | | | | | | | | Staff Gage Elevations Above Sea Level | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | South of Owens River Monitoring Wells | | | | | | | | | |
| | | T756 | T757 | T758 | T759 | T828 | T829 | T831 | T838 | West Pond | Owens River |
| 0 | 02/18/20 | 8.18 | 7.16 | 2.66 | 7.96 | 3.04 | 5.94 | 3.26 | 3.20 | 4147.92 | 4143.37 |
| 1 | 02/25/20 | 7.82 | 0.36 | - | 5.28 | 2.96 | 5.87 | 3.16 | 3.23 | 4147.86 | 4143.37 |
| 2 | 03/03/20 | 7.74 | - | -2.63 | 5.12 | 2.98 | 5.82 | 3.09 | 3.19 | 4147.77 | 4143.37 |
| 3 | 03/10/20 | 7.72 | - | - | 5.12 | 3.06 | 5.84 | 3.08 | 3.12 | 4147.75 | 4143.21 |
| 4 | 03/17/20 | 7.66 | Flowing | Flowing | 5.03 | 2.88 | 5.78 | 2.96 | 2.98 | 4147.72 | 4143.15 |
| 5 | 03/24/20 | 7.63 | - | - | 5.02 | 2.97 | 5.78 | 2.96 | 3.09 | - | - |
| 6 | 03/31/20 | 7.63 | Flowing | Flowing | 5.03 | 2.97 | 5.80 | 2.96 | 3.09 | 4147.64 | 4143.24 |
| Week | Date | T756 | T757 | T758 | T759 | T828 | T829 | T831 | T838 | West Pond | Owens River |

All data entries were recorded at approximately 10:00 am each day

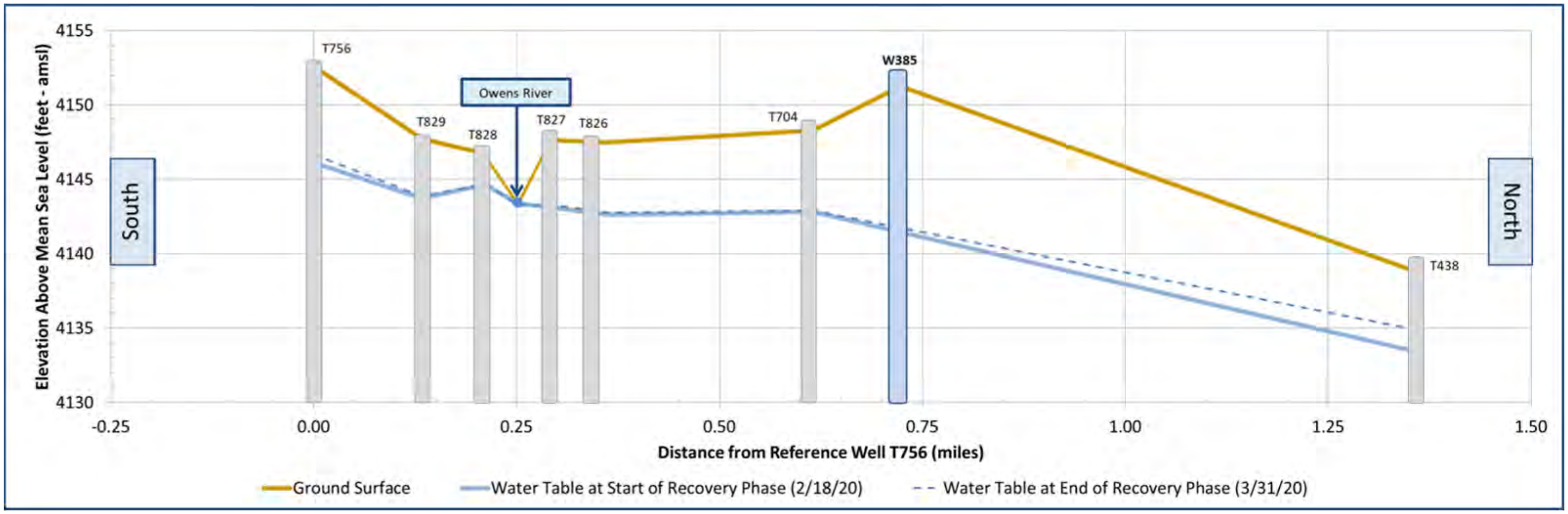



**Figure 9 – Laws Area Water Table Cross-Section for Recovery Phase**

# Select Hydrographs

## Pumping and Recovery Phase Hydrographs

Along with a spreadsheet of groundwater level and stage measurements, LADWP submitted select hydrographs of the groundwater levels at W385 and the six trigger monitoring wells to ICWD and CDFW. Hydrographs show changes in groundwater levels during both the pumping and the recovery phases. The hydrographs of W385, T826, T830, Private Well, FS #2, FS#3S, and FS#3D are presented in **Figures 10 to 16**, respectively. Hydrographs of the rest of wells monitored during the pumping test are presented in **Appendix B**. A hydrograph of flow rate at monitoring station 3216 is presented in **Figure 17**.

The groundwater level and stage measurements at the start and end of the pumping phase and recovery phase are presented in **Table 5**. The groundwater level in this section is presented as a "distance from ground surface (feet)", where negative values indicate level below ground and positive values indicate level above ground. The hydrographs are presented in the same manner. Data is presented using Distance to Water instead of Depth to Water to reduce confusion regarding the datum.

**Table 5 – Pumping Test Groundwater Level and Stage Measurements**

| Date | Distance from Ground Surface (feet) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pumping Well | Trigger Monitoring Wells | | | | | | Fish Slough Monitoring Wells | | | |
| | W385 | T826 | T830 | Private | FS#2 | FS#3S | FS#3D | T397 | Zack | FS#1 | FS#4 |
| 12/16/19 | Flowing | -4.20 | -3.27 | -10.18 | -2.45 | -11.77 | -11.51 | -27.59 | -24.11 | -26.84 | Dry |
| 02/18/20 | 107.37 | -4.87 | -3.27 | -12.35 | -2.21 | -11.52 | -11.33 | -27.55 | -24.01 | -26.81 | Dry |
| 03/31/20 | Flowing | -4.73 | -3.23 | - | -2.12 | -11.43 | -11.23 | -27.54 | -24.02 | -26.81 | Dry |

| Date | Distance from Ground Surface (feet) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | North of Owens River Monitoring Wells | | | | | | | | | | |
| | T438 | T704 | T733 | T752 | T753 | T754 | T755 | T827 | V875 | W248 | W386 |
| 12/16/19 | -6.46 | -4.74 | 4.75 | 10.82 | 0.46 | 3.33 | 11.09 | -4.04 | -2.97 | - | -4.17 |
| 02/18/20 | -5.39 | -5.48 | -4.69 | 10.98 | 0.51 | 3.39 | 11.20 | -4.51 | -2.22 | -27.16 | -13.42 |
| 03/31/20 | -3.95 | -5.59 | 5.20 | 11.09 | 0.38 | 3.30 | 11.31 | -4.33 | -2.09 | -27.16 | Flowing |

| Date | Distance from Ground Surface (feet) | | | | | | | | Staff Gauge Elevations Above Sea Level (feet) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | South of Owens River Monitoring Wells | | | | | | | | | |
| | T756 | T757 | T758 | T759 | T828 | T829 | T831 | T838 | West Pond | Owens River |
| 12/16/19 | -6.10 | 1.49 | 2.24 | -3.87 | -1.98 | -3.97 | -3.21 | -1.72 | 4149.25 | 4143.42 |
| 02/18/20 | -6.18 | -4.90 | -0.42 | -6.18 | -2.06 | -3.96 | -2.27 | -1.31 | 4147.92 | 4143.37 |
| 03/31/20 | -5.63 | Flowing | Flowing | -3.25 | -1.99 | -3.82 | -1.97 | -1.20 | 4147.64 | 4143.24 |

All data entries were recorded at approximately 10:00 am each day

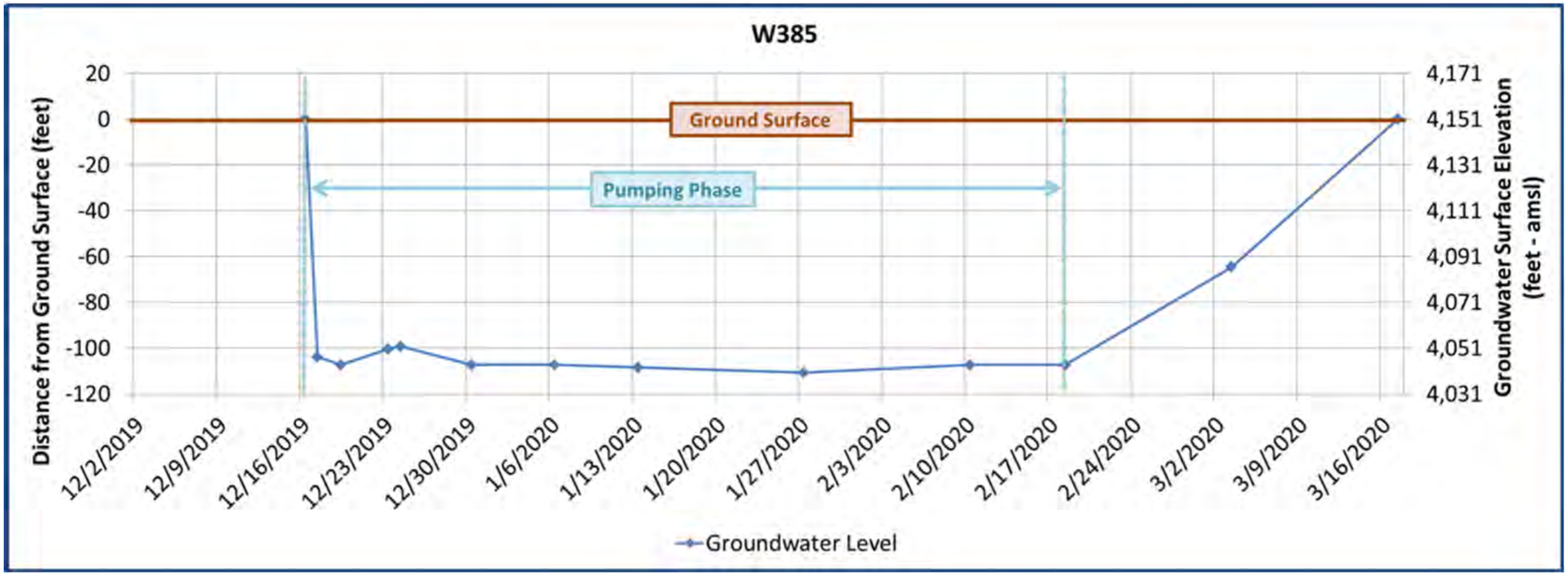



Figure 10

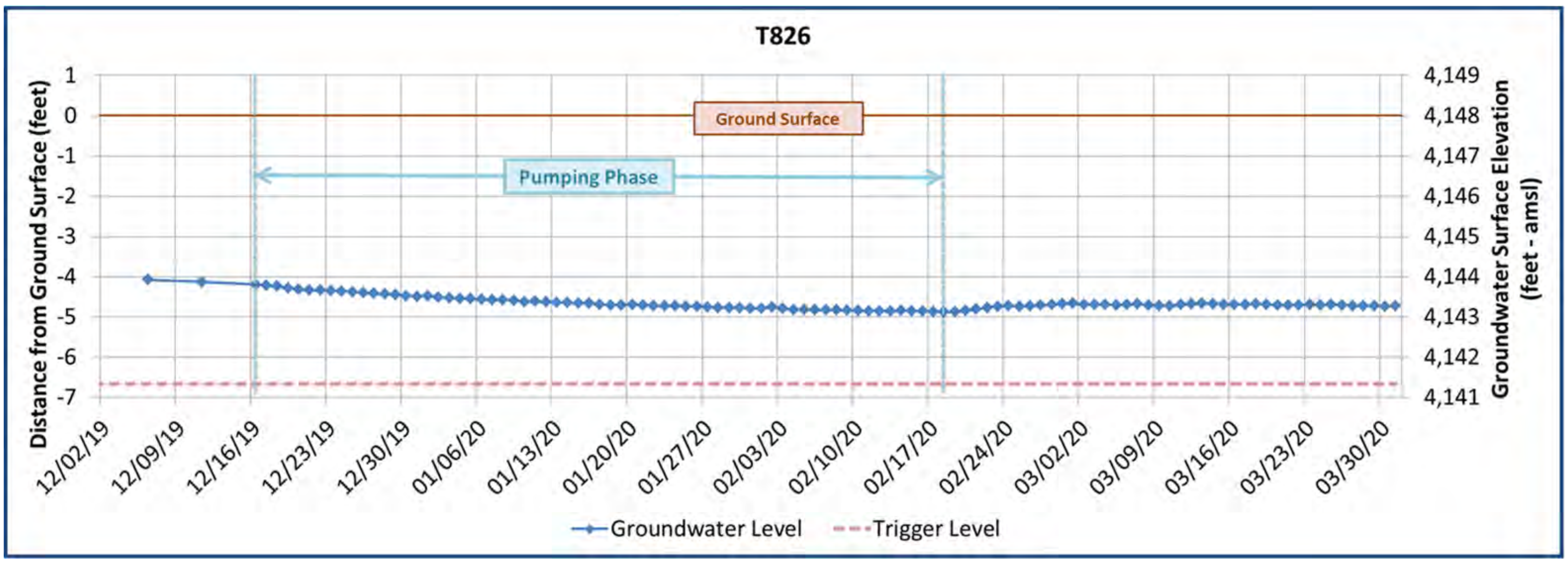



Figure 11

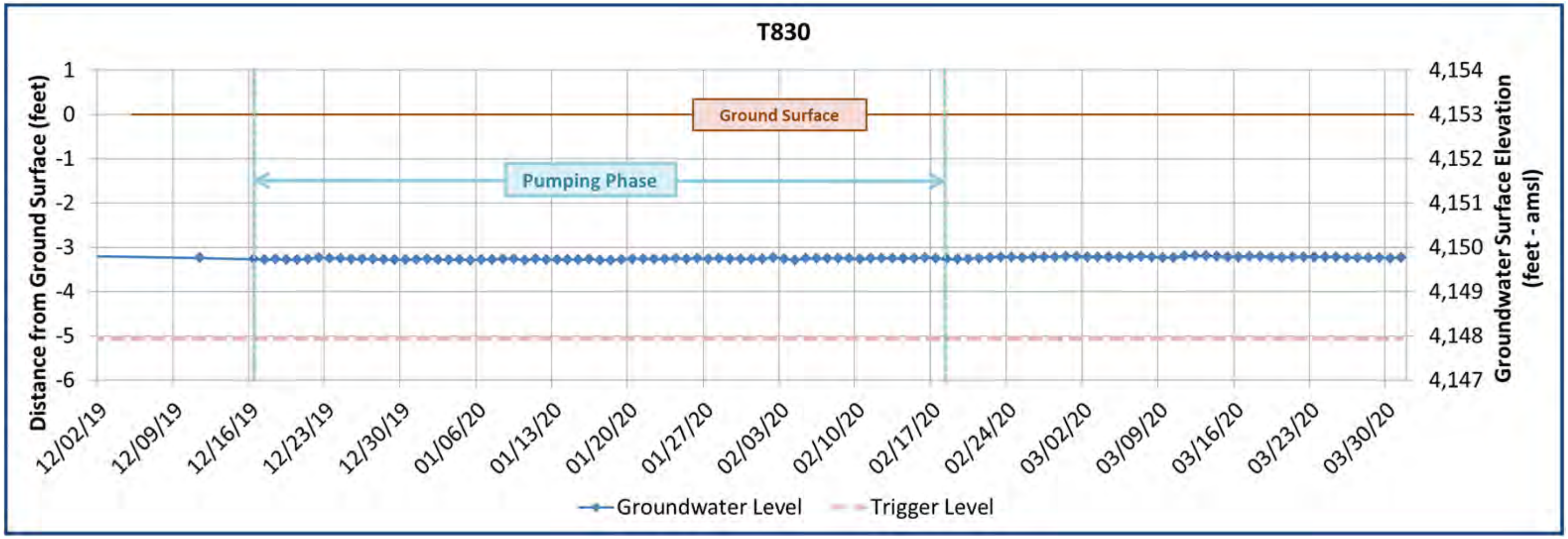



**Figure 12**

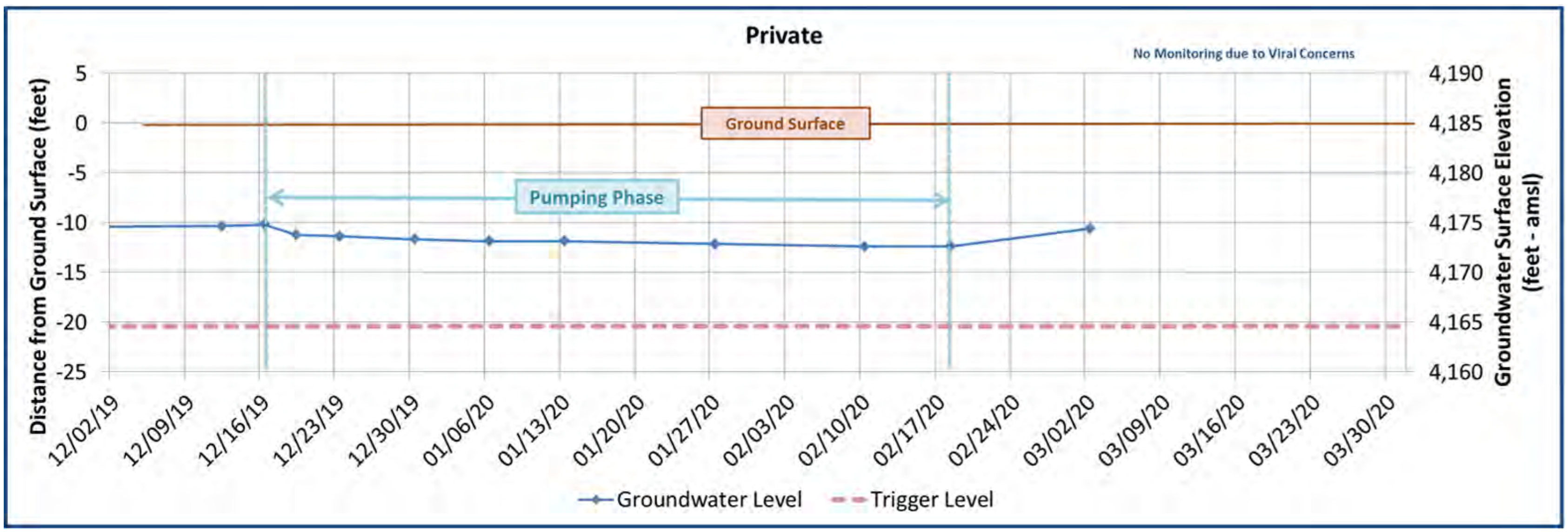



**Figure 13**

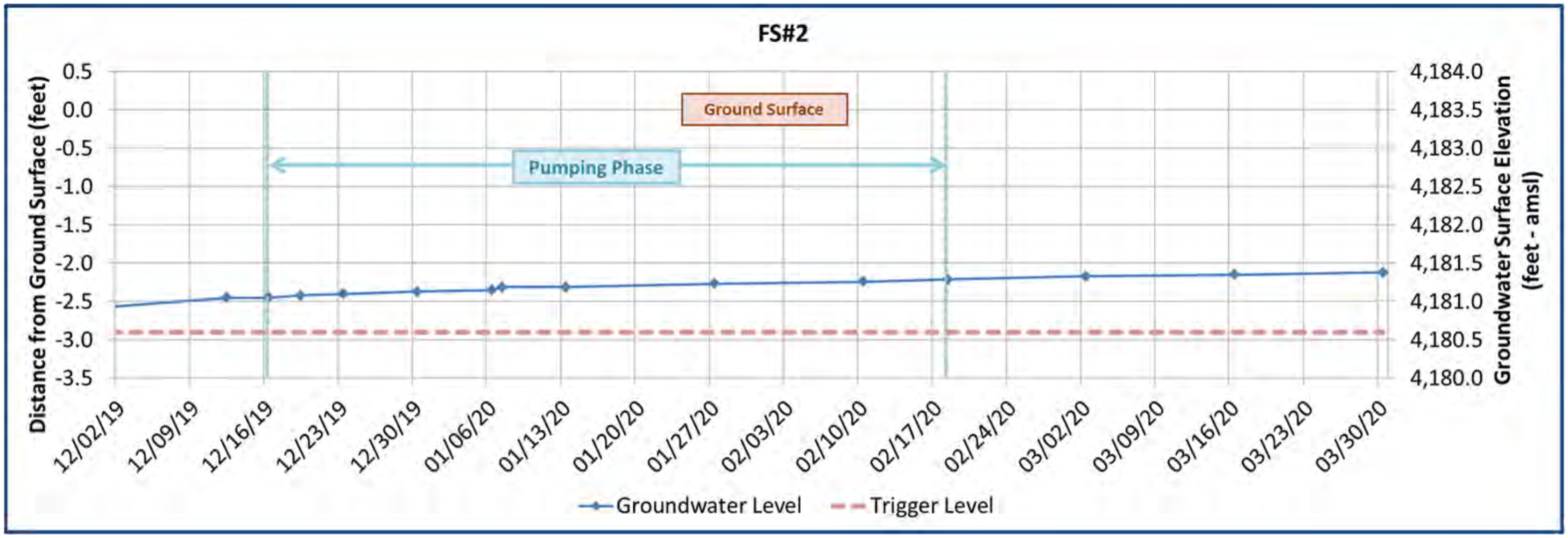



Figure 14

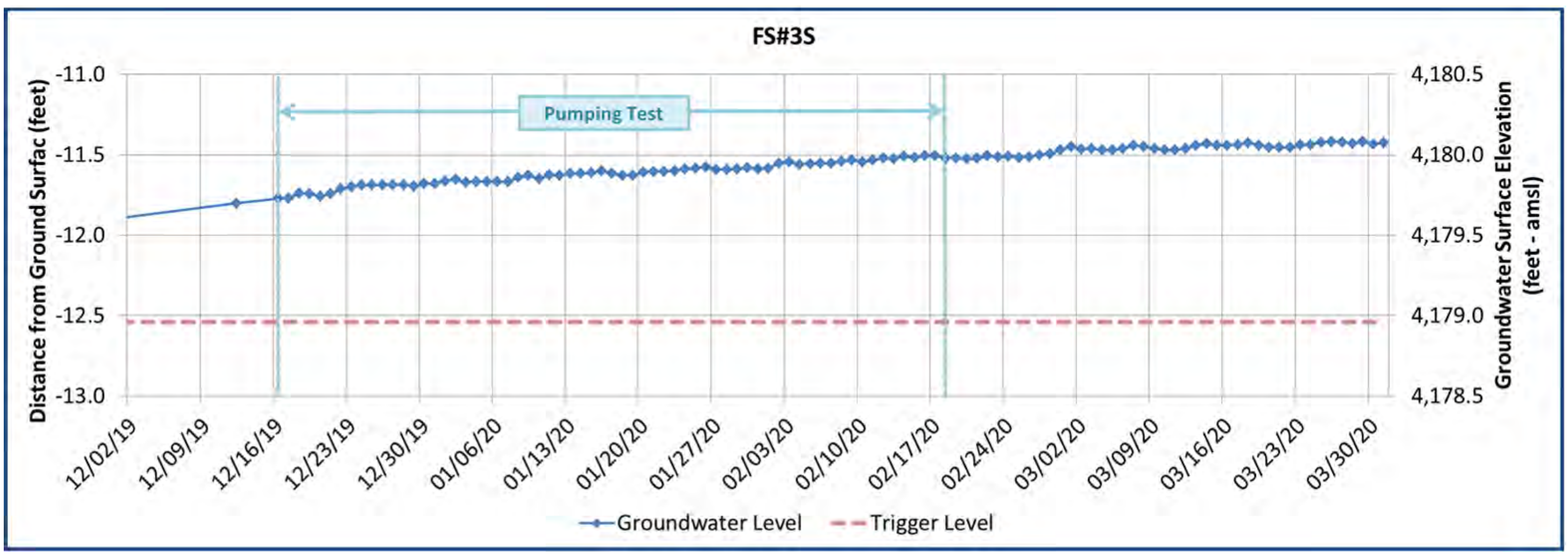



Figure 15

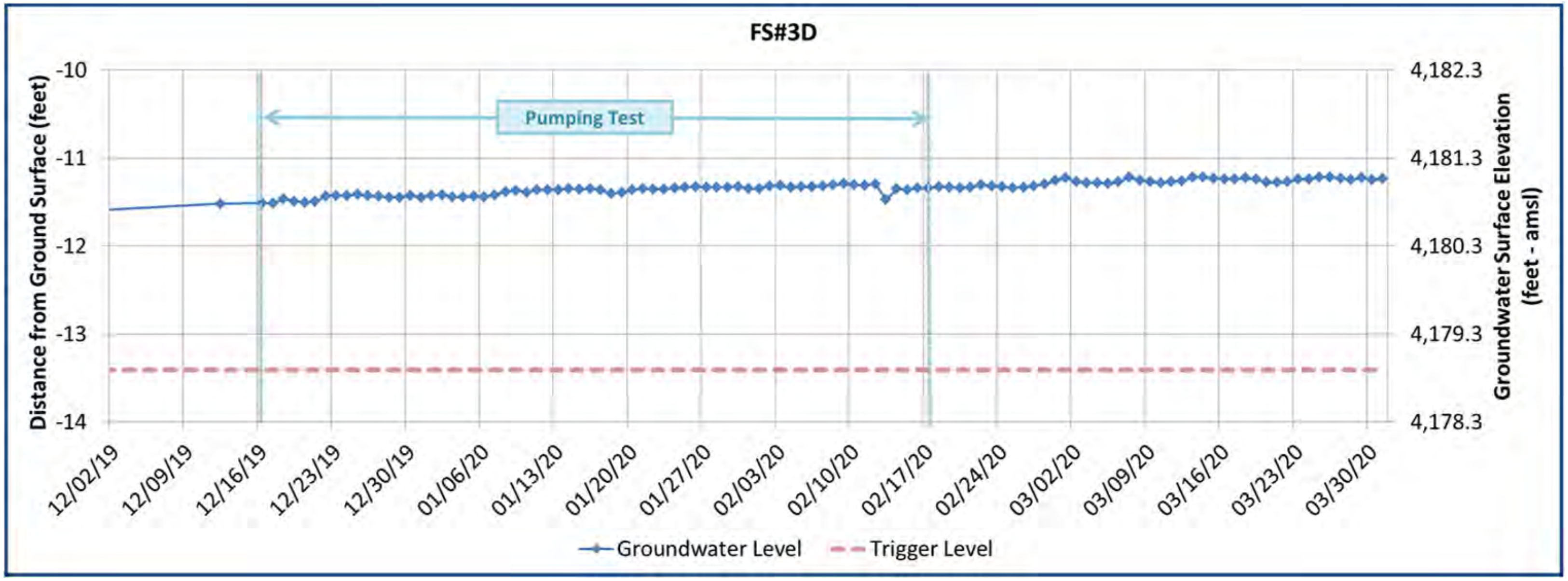



**Figure 16**

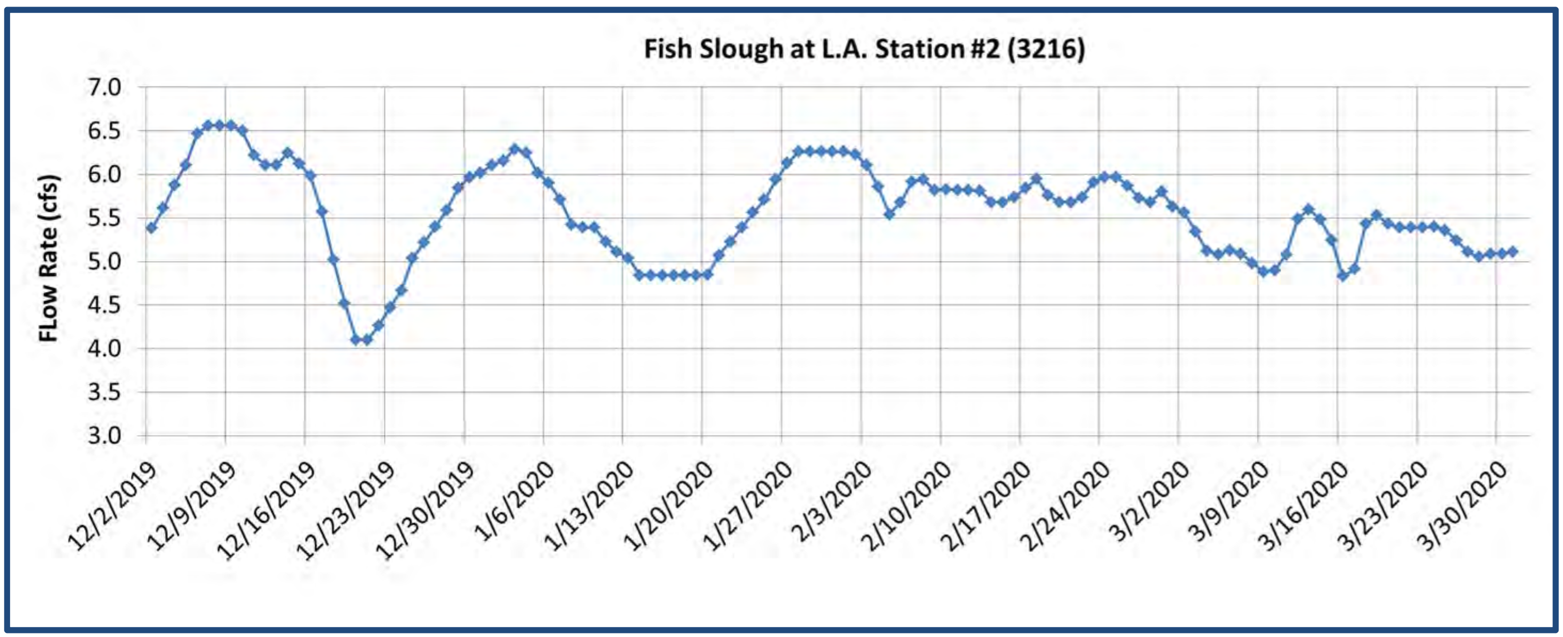



**Figure 17**

# Water Quality Sampling

### Water Quality and Isotope Sampling

LADWP collected groundwater samples from representative wells to document effects of pumping W385 on groundwater quality in the area around the well. The seven representative wells (FS #2, FS #3S, FS #3D, T755, T758, T826, and W385) were selected because they are distributed throughout the area of influence. Samples were taken at the wells 11 days prior to the commencement of the pumping phase and 5 days prior to the end of the pumping phase (60 days after the first water quality sampling). W386 was also sampled additionally to better understand the water quality of the aquifer at that location compared to the W385 location. Both sets of samples underwent field chemistry, general chemistry, and isotope analyses. All wells were sampled between 8:00 am and 2:00 pm.

The field chemistry parameters measured before and just before the end of the pumping test are presented in **Table 6**.

The general chemistry parameters measured before and towards the end of the pumping test are presented in **Table 7**.

## Isotope Chemistry

Isotope analyses were conducted by Isotech Laboratories, a third-party laboratory. The parameters measured were *tritium*, *deuterium*, and *oxygen-18*. Isotope measurements were conducted to determine if there were changes in the source of groundwater recharge for the water pumped from W385. The most common isotope measurements for determining recharge source are deuterium and oxygen-18. Tritium, a radioactive isotope, was also measured for relative age-dating of the groundwater.

The isotope chemistry parameters measured before and near the end of the pumping test are presented in **Table 8**. A plot comparing the percentages of Oxygen-18 and Deuterium relative to the Vienna Standard Mean Ocean Water (VSMOW) of representative wells in the Laws area, in addition to wells in areas along the same flow path (Fish Slough Area, Adobe Valley, White Mountain Creeks, and Tri-Valley), are presented in **Figure 18**. Supporting isotope data from the other regions are presented in **Table C-1** in **Appendix C**.[4]

[4] Zdon et. al. Identification of Source Water Mixing in the Fish Slough Spring Complex, Mono County, California, USA (2019).

## Table 6 – Field Chemistry Parameter Results

| Parameter | Unit | FS #2 | | FS #3D | | FS #3S | | T755 | | T758 | | T826 | | W385 | | W386 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 |
| Dissolved Oxygen Concentration | mg/L | 4 | 5.50 | 1.6 | 1.60 | 4.7 | 4.30 | 1.1 | 2.60 | 5.5 | - | 1.6 | 1.00 | 2.2 | 1.90 | - | 0.9 |
| Dissolved Oxygen Saturation | % | 44 | 59 | 19 | 20 | 54 | 54 | 14 | 30 | 63 | - | 18 | 11 | 34 | 29 | - | 11 |
| Fluid Turbidity | NTU | 4.44 | 0.47 | 19 | 2.6 | 3.92 | 9.12 | 0.52 | 0.26 | 0.64 | 0.46 | 0.95 | 1.2 | 2.77 | 0.25 | - | 1.44 |
| General Appearance | - | 1 | - | 4 | 2 | 1 | - | 1 | - | 1 | - | 3 | - | 1 | - | | - |
| Odor | - | 1 | - | 4 | 3 | 1 | - | 3 | - | 1 | - | 1 | - | 1 | - | - | - |
| pH | - | 7.8 | 7.88 | 8.43 | 7.84 | 8.08 | 7.96 | 7.88 | 8.21 | 8.6 | 7.16 | 7.12 | 7.21 | 7.84 | 7.77 | - | 8.35 |
| Specific Conductance | µS/cm | 447 | 433 | 511 | 527 | 515 | 520 | 455 | 465 | 227 | 535 | 625 | 530 | 543 | 536 | - | 354 |
| Temperature | °C | 13.3 | 11 | 17.5 | 17.6 | 18.2 | 17.4 | 15.2 | 27.9 | 15.2 | 17.2 | 15 | 13.8 | 31.8 | 28.9 | - | 19.6 |

## Table 8 – Isotope Chemistry Parameter Results

| Parameter | Unit | FS #2 | | FS #3D | | FS #3S | | T755 | | T758 | | T826 | | W385 | | W386 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 |
| Oxygen-18 | % | -16.08 | -16.02 | -17.48 | -17.53 | -17.46 | -17.36 | -18.58 | -18.59 | -17.7 | -17.7 | -12.92 | -13.64 | -16.67 | -16.89 | - | -17.74 |
| Deuterium | % | -121.4 | -120.9 | -136.9 | -137.3 | -135.9 | -135.5 | -141.6 | -141.7 | -134.9 | -134.9 | -107.5 | -110.2 | -129.2 | -131.3 | - | -136.2 |
| Tritium | TU | < 0.52 | TBD | < 0.65 | TBD | < 0.54 | TBD | < 0.45 | TBD | < 0.41 | TBD | .23 ± 0.2 | TBD | < 0.51 | TBD | - | TBD |

## Table 7 – General Chemistry Parameter Results

| Parameter | Unit | FS #2 | | FS #3D | | FS #3S | | T755 | | T758 | | T826 | | W385 | | W386 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 | 12/5/19 | 2/13/20 |
| Aluminum | ug/L | 43.9 | ND | 419 | 44.6 | 217 | 2680 | ND | ND | ND | ND | 14.3 | 21.2 | ND | ND | - | ND |
| Antimony | ug/L | 14.1 | 7.9 | ND | ND | ND | ND | ND | ND | ND | ND | 3.2 | 3.8 | ND | ND | - | ND |
| Arsenic | ug/L | 8.2 | 7.9 | 1.4 | 1.5 | 12.9 | 13.8 | 19.9 | 21.7 | 13.4 | 13.5 | 46.3 | 45.9 | 7.3 | 7.6 | - | 14.1 |
| Barium | ug/L | 14.2 | 13.6 | ND | ND | ND | 21.4 | 78.5 | 84.8 | 31.1 | 14.0 | 39.0 | 33.3 | 21.6 | 17.4 | - | 25.5 |
| Beryllium | ug/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | - | ND |
| Bicarbonate (HCO3), H2SO4 Titration | mg/L | - | 158 | - | 194 | - | 173 | - | 153 | - | 86.5 | - | 251 | - | 228 | - | 164 |
| Bicarbonate Alkalinity, Total (as CaCO3) | mg/L | - | 130 | - | 159 | - | 142 | - | 126 | - | 83.6 | - | 206 | - | 187 | | 138 |
| Boron | ug/L | 140 | 161 | 354 | 344 | 369 | 372 | 419 | 436 | ND | 148 | 1080 | 1090 | 436 | 469 | - | 305 |
| Bromide, Ion-Chromatography | mg/L | 0.0329 | 0.0322 | 0.0672 | 0.0567 | 0.0547 | 0.0567 | 0.0386 | 0.0438 | ND | ND | 0.0913 | 0.0764 | 0.0623 | 0.102 | - | 0.0324 |
| Cadmium | ug/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | - | ND |
| Calcium | mg/L | 46.4 | 45.2 | 11.3 | 13.3 | 13.6 | 14.5 | 7.29 | 6.89 | 1.49 | 1.26 | 31.3 | 26.8 | 21.8 | 23.2 | - | 6.02 |
| Chloride, Ion-Chromatography | mg/L | 9.92 | 8.85 | 19.4 | 16.4 | 16.7 | 17.4 | 32.6 | 32.8 | 6.70 | 6.38 | 31.4 | 25.0 | 22.2 | 21.1 | - | 16.9 |
| Chromium | ug/L | 1.0 | ND | 2.3 | ND | ND | 4.5 | ND | ND | ND | ND | ND | ND | ND | ND | - | ND |
| Copper | ug/L | 3.5 | ND | 4.7 | ND | ND | 4.3 | ND | ND | ND | ND | 12.9 | 5.2 | 22.9 | ND | - | ND |
| Fluoride, Ion-Chromatography | mg/L | 0.858 | 0.908 | 2.50 | 2.58 | 2.54 | 2.57 | 7.54 | 7.75 | 1.91 | 1.92 | 1.51 | 1.55 | 2.14 | 2.28 | - | 2.09 |
| Lead | ug/L | 1.7 | ND | 0.52 | ND | ND | 1.7 | ND | ND | 5.4 | 1.3 | ND | ND | 5.8 | 0.88 | - | ND |
| Magnesium | mg/L | 2.90 | 2.80 | 2.30 | 1.65 | 0.799 | 1.31 | 0.951 | 0.896 | ND | ND | 8.17 | 6.83 | 1.09 | 1.10 | - | 0.246 |
| Manganese | ug/L | 2.6 | ND | 45.6 | 62.0 | ND | 60.6 | 20.5 | 21.5 | ND | ND | 283 | 276 | 128 | ND | - | 18.7 |
| Nickel | ug/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | 12.9 | 12.9 | ND | ND | - | ND |
| Nitrate (as N), Ion-Chromatrography | mg/L | 0.366 | 0.360 | ND | ND | 0.170 | 0.158 | ND | ND | ND | ND | ND | 4.96 | 0.213 | 0.136 | - | ND |
| Potassium | mg/L | 2.16 | 1.64 | 6.37 | 4.95 | 3.69 | 4.34 | 3.65 | 3.17 | 1.66 | 1.37 | 7.51 | 6.00 | 6.33 | 5.76 | - | 3.63 |
| Selenium | ug/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | - | ND |
| Silica, ICP-OES | mg/L | 89.8 | 88.1 | 66.2 | 83.5 | 97.6 | 102 | 88.0 | 86.1 | 79.8 | 79.9 | 43.5 | 38.9 | 110 | 106 | - | 77.5 |
| Silver | ug/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | - | ND |
| Sodium | mg/L | 43.5 | 42.1 | 97.1 | 93.5 | 94.1 | 94.7 | 86.6 | 84.0 | 49.1 | 47.8 | 91.7 | 80.1 | 90.2 | 84.1 | - | 73.1 |
| Sulfate, Ion-Chromatography | mg/L | 75.7 | 72.4 | 53.3 | 59.3 | 76.6 | 75.4 | 26.7 | 27.4 | 13.3 | 12.9 | 36.7 | 28.0 | 36.8 | 32.9 | - | 16.5 |
| Thallium | ug/L | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | - | ND |
| Phosphorus, Total (as P), Colorimetry | mg/L | 0.040 | ND | 0.211 | 0.10 | 0.045 | 0.066 | 0.053 | 0.046 | 0.064 | 0.058 | 0.145 | 0.11 | 0.029 | NA | - | 0.036 |
| Phosphorus, Total (as PO4), Colorimetry | mg/L | 0.123 | - | 0.647 | - | 0.138 | - | 0.162 | - | 0.196 | - | 0.445 | - | 0.089 | - | - | - |
| Uranium | ug/L | 27.2 | 22.2 | ND | ND | 2.3 | 2.8 | ND | ND | ND | ND | 86.1 | 71.9 | 7.8 | 8.5 | - | ND |
| Vanadium | ug/L | 6.1 | 6.5 | ND | ND | ND | ND | ND | ND | ND | ND | 3.3 | 3.2 | ND | ND | - | ND |
| Zinc | ug/L | 21.8 | 12.2 | 34.2 | ND | ND | ND | 17.7 | ND | ND | ND | ND | ND | ND | ND | - | ND |

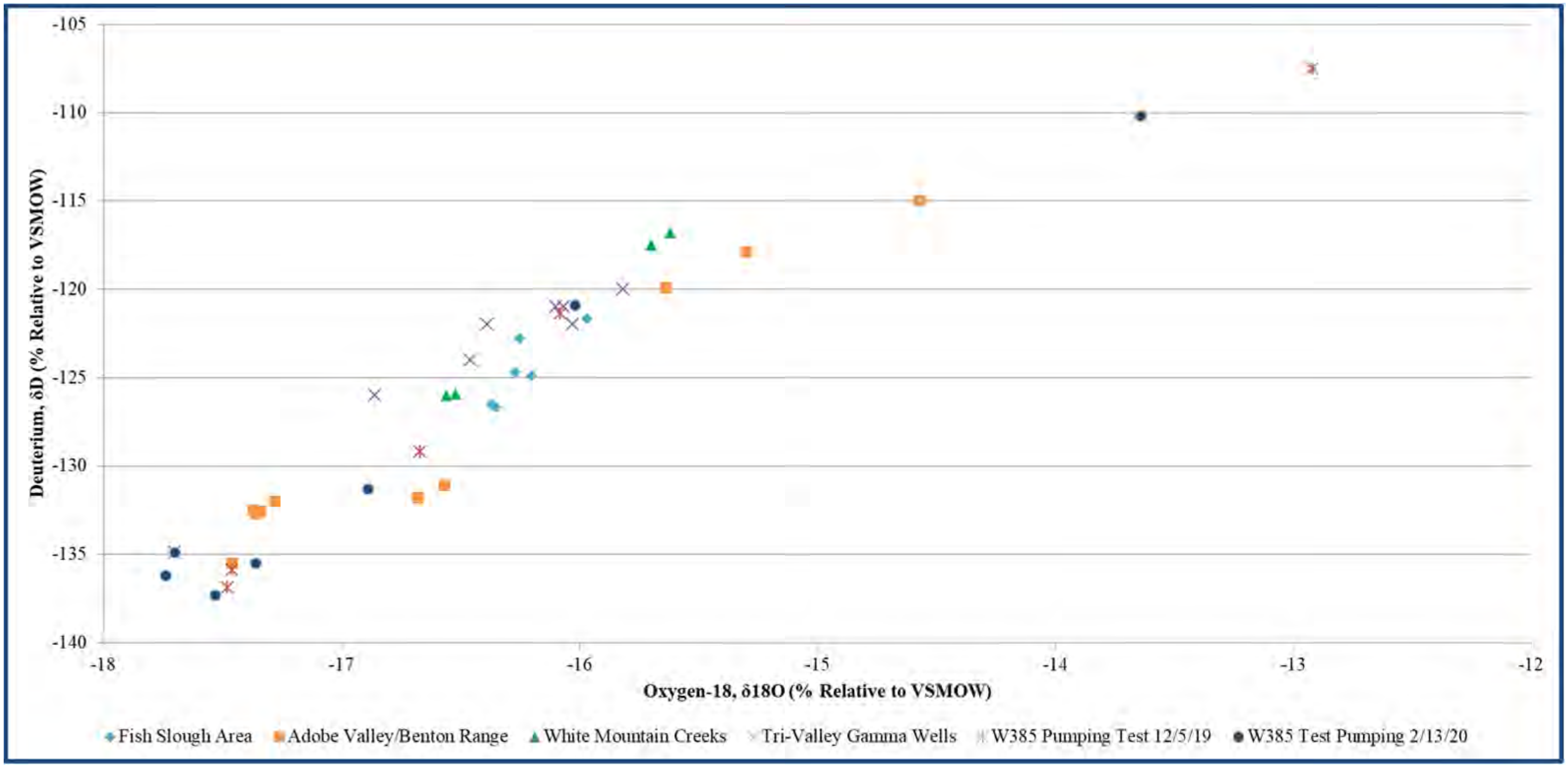



**Figure 18– Isotope Chemistry Parameter Results**

# Appendices

## A – Pumping Test Daily Measurements

## B – Hydrographs of Non-Trigger Wells

## C – Historical Isotope Measurements of Nearby Regions

# References


1. ICWD. *Draft Report 94-1* (1994).
2. LADWP. *Owens Valley Well Modification Project* (2015).
3. LADWP. Pumping Test of W385R in the Laws Wellfield Monitoring Plan (2016).
4. Zdon et. al. Identification of Source Water Mixing in the Fish Slough Spring Complex, Mono County, California, USA (2019).

# Appendix B

# W386 Lithologic and Electronic Borehole Log

**TRIPLICATE**
**Owner's Copy**

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES

# WATER WELL DRILLERS REPORT

*Do not fill in*

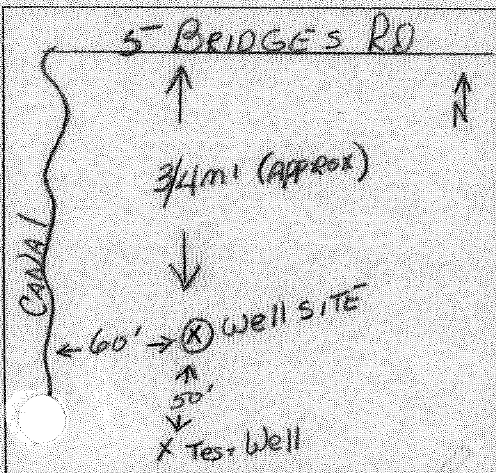
No. 160986

Notice of Intent No. 147263
Local Permit No. or Date

State Well No.
Other Well No. 386

**(1) OWNER:** Name Dept. of Water & Power, City of Los
Address Angeles, 111 N. Hope St., P.O. Box 111, Room 606
City Los Angeles, CA Zip 90051

**(2) LOCATION OF WELL** (See instructions):
County Inyo Owner's Well Number #2 (Phase II)
Well address if different from above Bishop, CA - Laws area
Township 6-S. Range 33-E Section 19
Distance from cities, roads, railroads, fences, etc.




WELL LOCATION SKETCH

**(3) TYPE OF WORK:**
New Well ☒ Deepening ☐
Reconstruction ☐
Reconditioning ☐
Horizontal Well ☐
Destruction ☐ (Describe destruction materials and procedures in Item 12)

**(4) PROPOSED USE:**
Domestic ☐
Irrigation ☒
Industrial ☐
Test Well ☐
Stock ☐
Municipal ☐
Other ☐

**(5) EQUIPMENT:**
Rotary ☒ Reverse ☐
Cable ☐ Air ☐
Other ☐ Bucket ☐

**(6) GRAVEL PACK:**
Yes ☒ No ☐ Size 1/4 x 10 Kern Rock
Diameter of bore 28 in.
Packed from 0 to 560 ft.

**(7) CASING INSTALLED:**
Steel ☒ Plastic ☐ Concrete ☐

**(8) PERFORATIONS:**
Type of perforation or size of screen

| From ft. | To ft. | Dia. in. | Gage or Wall | From ft. | To ft. | Slot size |
|---|---|---|---|---|---|---|
| 0 | 560 | 18 | 5/16 | 50 | 550 | .080 |
| 0 | 50 | 30 | 1/4 | (Roscoe Moss Full Flow) | | |

**(9) WELL SEAL:**
Was surface sanitary seal provided? Yes ☒ No ☐ If yes, to depth 50 ft.
Were strata sealed against pollution? Yes ☐ No ☒ Interval ft.
Method of sealing 9 sack cement grout/conductor pipe cemented in

**(10) WATER LEVELS:**
Depth of first water, if known 10 ft.
Standing level after well completion Flowing 3 1/2# ft.

**(11) WELL TESTS:**
Was well test made? Yes ☒ No ☐ If yes, by whom? Rottman Drlg
Type of test Pump ☐ Bailer ☐ Air lift ☒
Depth to water at start of test Flowing ft. At end of test 55 ft
Discharge 4060 gal/min after 20 hours Water temperature
Chemical analysis made? Yes ☒ No ☐ If yes, by whom? DWP
Was electric log made? Yes ☐ No ☒ If yes, attach copy to this report

**(12) WELL LOG:** Total depth 580 ft. Depth of completed well 560 ft.

| from ft. | to ft. | Formation (Describe by color, character, size or material) |
|---|---|---|
| 0 | 30 | Boulders, coarse sand & gravel |
| 30 | 50 | Med. & coarse sand & gravel w/sml boulders |
| 50 | 110 | Med. to coarse sand, sml boulders, small to large gravel |
| 110 | 140 | Sml gravel, fine to coarse sand w/silt lenses |
| 140 | 180 | Fine to coarse sand & gravel |
| 180 | 200 | Fine to coarse sand & gravel w/clay lenses |
| 200 | 320 | Fine to coarse sand, reddish pumice |
| 320 | 340 | Fine to coarse sand & reddish pumice |
| 340 | 580 | Med. to coarse sandw/gravel |

Work started March 11 1987 Completed March 20 1987

**WELL DRILLER'S STATEMENT:**
*This well was drilled under my jurisdiction and this report is true to the best of my knowledge and belief.*

SIGNED (Well Driller)
NAME Larry W. Rottman, President
Rottman Drilling Co.
(Person, firm, or corporation) (Typed or printed)
Address 46471 N. Division
City Lancaster, CA Zip 93534
License No. 316599 Date of this report May 14, 1987

DWR 188 (REV. 7-76) IF ADDITIONAL SPACE IS NEEDED, USE NEXT CONSECUTIVELY NUMBERED FORM

# BARBOUR

Well Surveying Corporation

(805) 482-4988

COMPANY L.A. DEPT OF WATER & POWER

WELL Phase II site #2 — (South) - Near Fish Springs Ditch

FIELD LAWS 386/733T

COUNTY Inyo STATE Calif

Location: Nickolas & Nickolas gravel pit.

Other Services: E-Log

Sec ______ Twp ______ Rge ______

| | | | |
|---|---|---|---|
| Permanent Datum | G.L. | Elev | Elev KB |
| Log Measured From | G.L. | Ft Above Perm Datum | DF |
| Drilling Measured From | G.L. | | GL |

| | | | | |
|---|---|---|---|---|
| Date | 2/8/87 | | | |
| Run No | one | | | |
| Depth—Driller | 720' | | | |
| Depth—Logger | 718' | | | |
| Btm Log Inter | 715' | | | |
| Top Log Inter | | | | |
| Casing—Driller | @ | @ | @ | @ |
| Casing—Logger | | | | |
| Bit Size | 8 3/4" | | | |
| Type Fluid in Hole | bentonite | | | |
| Dens I Visc | I | I | I | I |
| pH I Fluid Loss | I ml | I ml | I ml | I ml |
| Source of Sample | ditch | | | |
| $R_m$ @ Meas Temp | 9.9 @ 77 °F | @ °F | Cm 1010 | @ 77 °F |
| $R_{mf}$ @ Meas Temp | @ °F | @ °F | @ °F | @ °F |
| $R_{mc}$ @ Meas Temp | @ °F | @ °F | @ °F | @ °F |
| Source $R_{mf}$ $R_{mc}$ | I | I | I | I |
| $R_m$ @ BHT | @ °F | @ °F | @ °F | @ °F |
| Time Since Circ | 1 hr. | | | |
| Max Rec Temp | °F @ | °F @ | °F @ | °F @ |
| Equip I Location | | | | |
| Recorded By | Joel Barbour | | | |
| Witnessed By | Fred Finkbeiner | | | |

Service Ticket No. Remarks:

| Change in Mud Type or Additional Samples | none | |
|---|---|---|
| Date \| Sample No | I | I |
| Depth—Driller | 720' | |
| Type Fluid in Hole | bentonite | |
| | | |
| Dens \| Visc | I | I |
| ph \| Fluid Loss | I ml | I |
| Source of Sample | ditch | |
| $R_m$ @ Meas. Temp | 9.9 @ 77 °F | @ °F |
| $R_{mf}$ @ Meas. Temp | @ °F | @ °F |
| $R_{mc}$ @ Meas. Temp | @ °F | @ °F |
| Source $R_{mf}$ \| $R_{mc}$ | I | I |
| $R_m$ @ BHT | @ °F | @ °F |
| $R_{mf}$ BHT | @ °F | @ °F |
| $R_{mc}$ BHT | @ °F | @ °F |
| $C_m$ @ Meas. Temp. | 1010 @ 77 °F | @ °F |

| Type Log | Depth | Horizontal Scale |
|---|---|---|
| S.P. | 715' | 10 MV/div |
| 16" normal | 715' | 10 ohm/m per div |
| 64" normal | 715' | 10 ohm/m per div |
| 6' lateral | 715' | 20 ohm/m per div |

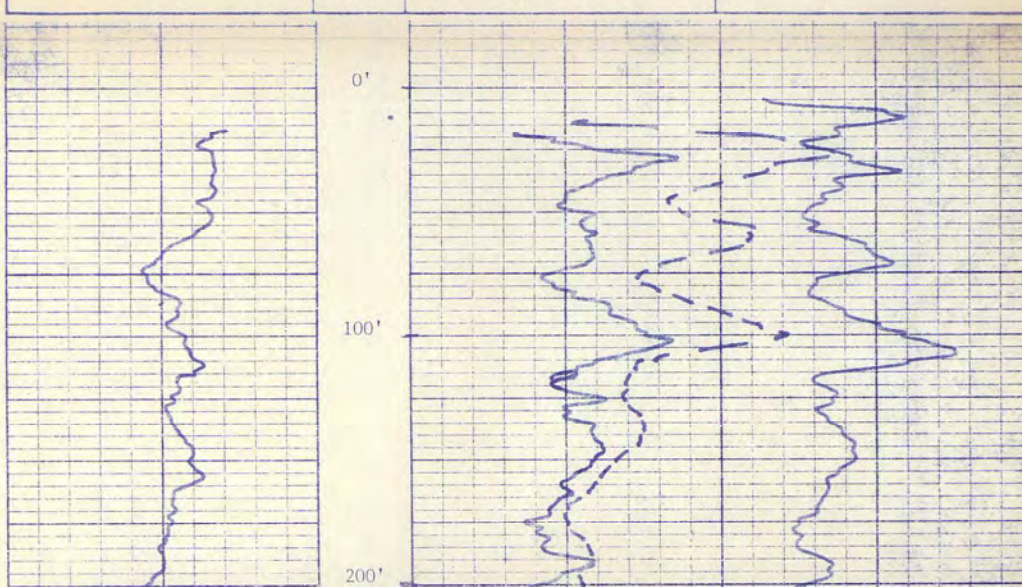
EQUIPMENT DATA

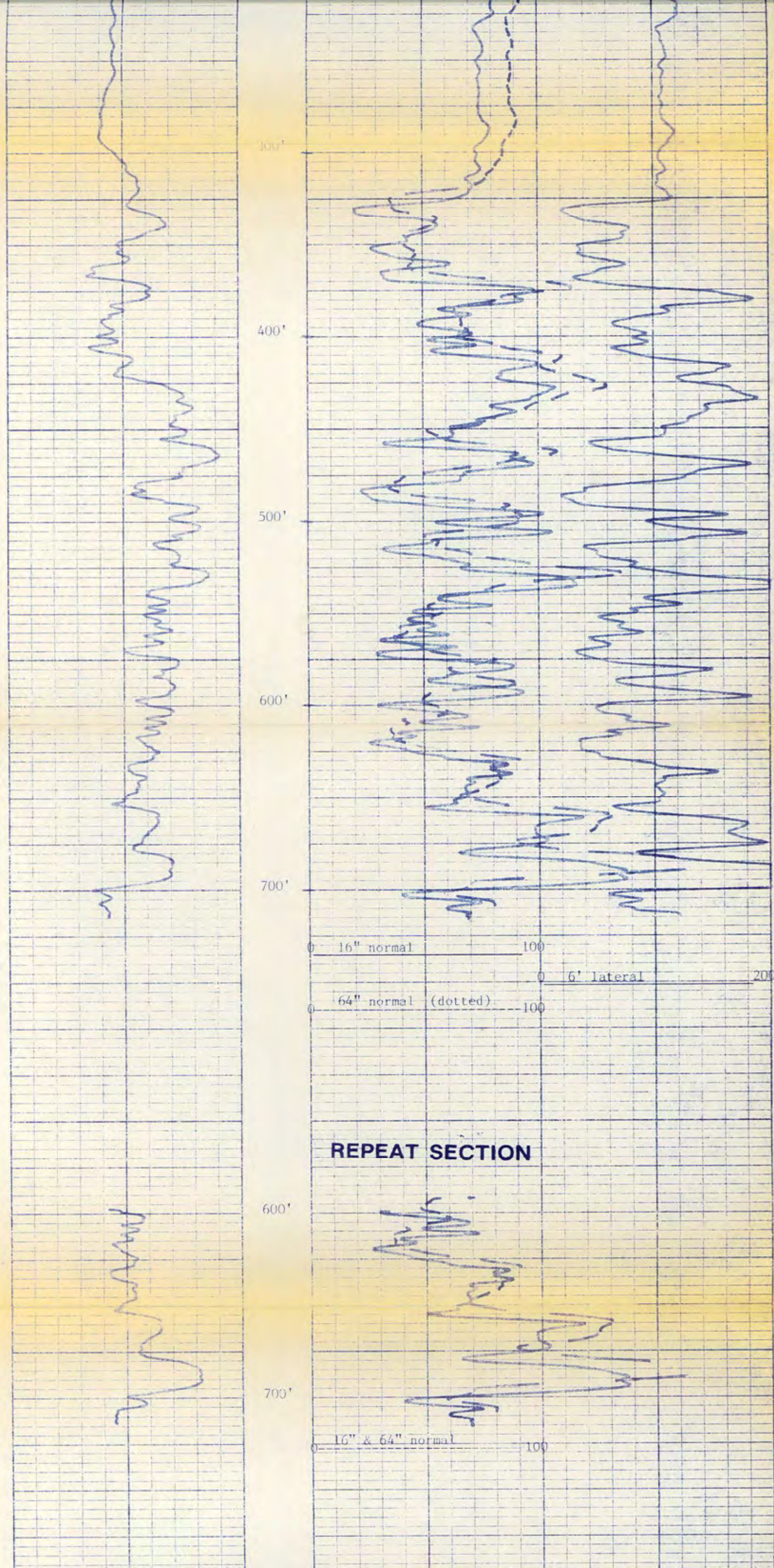
| Run No | Tool Type and No | Pad Type | Tool Position | Other |
|---|---|---|---|---|
| one | ELP-41277 | | free | |

All interpretations are opinions based on inferences from electrical or other measurements and we cannot, and do not guarantee the accuracy or correctness of any interpretations, and we shall not, except in the case of gross or willful negligence on our part, be liable or responsible for any loss, costs, damages or expenses incurred or sustained by anyone resulting from any interpretation made by any of our officers, agents or employees.

VERTICAL SCALE ☒ 2" = 100' ☐ 5" = 100' ☐ 10" = 100'

| S.P. MV | DEPTH (FT.) | LOG/SCALE | LOG/SCALE |
|---|---|---|---|
| − ⟶ 10 ⟵ + | | 0 16" normal 100 | 0 6' lateral 200 |
| | | 0 64" normal (dotted) 100 | |




300'
400'
500'
600'
700'
0 16" normal 100
0 6' lateral 200
0 64" normal (dotted) 100
REPEAT SECTION
600'
700'
0 16" & 64" normal 100