OWENS LAKE GROUNDWATER DEVELOPMENT PROGRAM

PROGRAM SUMMARY

PREPARED FOR: Owens Lake Science Advisory Panel (OLSAP) of the National Academy of Sciences

PREPARED BY: Los Angeles Department of Water and Power (LADWP)

DATE: July 2024

1 INTRODUCTION

The Los Angeles Department of Water and Power (Department) has been investigating the potential use of groundwater as a supplemental water supply for the Owens Lake Dust Mitigation Program (OLDMP) since the late 1990s, and more recently since 2009. The objective of the Owens Lake Groundwater Development Program (OLGDP) is to optimize groundwater management at Owens Lake by utilizing water beneath Owens Lake to provide water supply redundancy and resiliency to the OLDMP. Supply redundancy is an important aspect for meeting dust mitigation requirements in an environmentally sustainable manner. To-date, the OLGDP has consisted of extensive data collection, field work, updating of the conceptual hydrogeologic model, development of a numerical groundwater model for Owens Lake and surrounding area (Owens Lake Groundwater Model, or OLGM), and extensive data collection to understand important resources around Owens Lake, including seeps and springs and vegetated dune areas. This work has significantly advanced our understanding of Owens Lake hydrogeology and surrounding ecosystems, and informed the development of robust resource protection plans for sensitive resources.

This document is intended to provide a summary of the OLGDP, including descriptions of major studies and monitoring efforts, the test plan for Test Well East (TW-E), and resource protection plans (RPP) for sensitive resources. Numerous related documents and reports describing well installation, monitoring efforts, and modeling work on the OLGDP are available on the LADWP website: www.ladwp.com/olg

2 MAJOR EFFORTS AND MONITORING COMPLETED TO DATE

There are several key reports and documents that summarize major efforts and monitoring in support of the OLGPD. These documents are summarized in Table 1 below and described in more detail in the subsequent sections. Numerous other documents (well installation reports, preliminary monitoring reports, meeting presentations, etc.) are available on the LADWP OLGDP website.

TABLE 1. LIST OF KEY REPORTS AND DOCUMENTS SUMMARIZING MAJOR EFFORTS IN SUPPORT OF THE OLGDP.

No.	Document Title	Summary	Document Link
1	Final Report on the Owens Lake Groundwater Evaluation Project (MWH 2012)	Describes work completed between 2009 to 2012, including evaluations of existing data, collection of additional data, development of a hydrogeologic conceptual model for Owens Lake, development of the Owens Lake groundwater model, and other topics.	https://formationenv.sharefile.com/d-s54f54cb6f6a84e20becd8367495b569f
2	Groundwater Model Documentation (MWH 2012)	Complete documentation of the Owens Lake groundwater model; describes model attributes, steady-state calibration results, transient calibration results, modeling of dust control measures (DCMs), unique characteristics of the OLGEP model, and conclusions and recommendations.	https://formationenv.sharefile.com/d-s159f17522a864d44b501d6e0126ed925
3	Model Documentation Report for the Owens Lake Groundwater Model Update (Stantec 2020)	Describes updates updates to the conceptual and numerical model, utilization of new tools, simulation of head or groundwater level changes, and evaluation of fault and fault zone effects on groundwater flow and model assumptions.	https://formationenv.sharefile.com/d-sd70097449bb348a3ad2d60c610a4cde0
4	Isotope Analysis and Hydrogeologic Review (Stantec 2023)	Summarizes an updated analysis of historical and recent isotope data from a variety of locations, including wells on Owens Lake lakebed and shallow wells in the Owens Lake Vegetated Dune Areas (VDAs). Isotopic analysis is evaluated alongside updated geologic cross-sections. Results suggest that the shallow surficial aquifer under the VDAs is separated from the deeper aquifers.	https://formationenv.sharefile.com/d-scacedb6601994a3cb0d7cf81fcb3f6c9
5	Six-Month Operational Test of Testing Well TW-E at Owens Lake (LADWP 2021)	Describes the proposed operational testing plan for Testing Well East (TW-E), including the purpose of the test (resolve data gaps, understand aquifer connections, improve numerical model), pumping parameters (e.g., rate, length etc.), and monitoring data collection and reporting.	https://formationenv.sharefile.com/d-s3cef7ae0b810487e96e30c4c248eabfd
6	Resource Protection Protocol for Springs and Associated Alkali Meadows at and around Owens Lake (Owens Lake Habitat Work Group 2018)	Describes the resources to be protected (seeps and spring habitat), resource protection criteria (seasonal leaf area index and acreage of transmontane alkali meadow), monitoring data collection and reporting, early warning indicators, and management tier thresholds.	https://formationenv.sharefile.com/d-s9867186f1fdb40d294c1bb63b427dfdc

No.	Document Title	Summary	Document Link
7	Owens Dunes Field Vegetation Transects: Results and Interpretation (Richards 2019)	Describes a field study documenting vegetation cover and composition in fifteen (15) VDAs around Owens Lake. Vegetation data were evaluated and described in the context of elevation/topography, historic shoreline features, flood flows, and 'apparent' groundwater depth.	https://formationenv.sharefile.com/d-sf6290839e6e6456f9fdce7fea7c2e62a
8	Vegetated Dune Area (VDA) Data Collection and Technical Approach Documentation (Formation/LADWP 2021)	Describes baseline study to understand current and historical variability in sand dune volume and height, vegetation height, vegetative cover, leaf area index (LAI), and actual evapotranspiration (ETa) in 15 VDAs. Document also describes a detailed characterization of soil and rootzone characteristics (lithology, salinity, nutrient and moisture content, plant available water, and root density distribution), groundwater depth and quality, vegetation elemental concentrations, and soil geophysics.	https://formationenv.sharefile.com/d-s2b0f2887f63043b387fa84768b181af6
9	Groundwater and Plant Available Water Monitoring for the Owens Lake Vegetated Dune Areas (Formation/LADWP, 2023)	Describes the approach to monitoring groundwater depth / elevation and soil moisture (as plant available water) in the VDAs as part of the resource protection plan for the VDAs during the operational test of TW-E. The document provides extensive detail on piezometer installation, instrumentation, and data analysis, as well as neutron probe access tube installation, calibration, and calculations of plant available water.	https://formationenv.sharefile.com/d-sf94dea77aac14d879331c087c86d6831
10	Plant Growth, Function, and Water Sources in the Owens Lake Vegetated Dune Areas (Formation/LADWP, 2023)	Technical document describing the detailed field studies (data) that have informed a conceptual model of vegetation growth, physiology, and water sources in the VDAs around Owens Lake. Data presented include plant water potentials, leaf gas-exchange and chlorophyll fluorescence, leaf chemistry, shoot growth and leaf drop, plant, soil, and groundwater isotopes, and eddy covariance data.	https://formationenv.sharefile.com/d-sd6770f949bb840a4bf111f96e0e27ee0

2.1 Owens Lake Groundwater Evaluation Project

The report on the Owens Lake Groundwater Evaluation Project (**Document 1, Table 1**) summarizes work completed between 2009 to 2012. This extensive report summarizes compilations and evaluations of existing data, identification of data gaps, collection of additional field data, development of a hydrogeologic conceptual model for Owens Lake, development of the Owens Lake groundwater model and model simulations, development and implementation of a public outreach plan, participation of a Blue-Ribbon Panel, evaluation of geophysical data and isotope data from groundwater and surface discharge areas.

The *Final Report on the Owens Lake Groundwater Evaluation Project* and related documents can be downloaded from the LADWP Groundwater Development Program website: www.ladwp.com/olg

The OLGDP public outreach program included mailing fact sheets, three public meetings, an educational outreach program, and meetings with targeted stakeholders. The expert Blue-Ribbon Panel was composed of experts from the U.S. Geological Survey, academia, and private industry in groundwater modeling and ecology. The panel was consulted at key points during the project.

This final report on the OLGEP provides a series of recommendations for the groundwater development program, including pumping criteria and maximum amounts, strategy for implementation of groundwater pumping, locations of new wells, well construction and design, monitoring locations and triggers, and recommended future studies.

2.2 Owens Lake Groundwater Model Development

Between 2009 and 2012 MWH (now Stantec) and LADWP conducted the Owens Lake Groundwater Evaluation Project (OLGEP). The OLGEP culminated in the construction of a numerical groundwater model for the Owens Lake area (described in **Document 2, Table 1**). This model was used to simulate potential groundwater pumping alternatives to provide groundwater for a portion of dust control measures. Since 2012, a suite of new data has been collected. Lithologic data, pumping test data and water quality sampling results have been analyzed and incorporated in the improvement of both the conceptual and numerical model.

Furthermore, since the creation of the original 2012 model, several significant new tools and modules have been developed for MODFLOW that greatly enhance the OLGEP model. In addition, the simulation of evapotranspiration (ET) has been improved in the model, using methods that have recently proved successful in the modeling of the Bishop/Laws area. Finally, the model domain has been extended to include thin alluvial deposits to the east and northwest of Owens Lake, dividing the upper layer of the 2012 model to support the integration of RPPs as part of the California Environmental Quality Act (CEQA) environmental review process.

The following is a summary of key improvements to the transient groundwater flow model:

- Expanded the model domain to the east and northwest to accommodate the evaluation of RPPs and the role of faulting on groundwater flow with planned locations for additional monitoring wells.

- Converted the model to the relatively new USG version of MODFLOW (MODFLOW-USG), thereby increasing the stability of the model and allowing the use of the connected linear network feature of the unstructured grid version.

- Subdivided the 2012 OLGEP model Layer 1 into two model layers to more precisely model shallow groundwater and its influence on vegetation.

- Modified methods to simulate ET using the EVT package of MODFLOW. Reduced stress period length from six months to two months to achieve a more precise simulation of seasonal water level fluctuation in shallow aquifers.

- Refined the model grid in areas of concern, such as pumping wells and sensitive spring locations.

Updates to the OLGEP model are fully described in **Document 3**, **Table 1**.

2.3 Isotopic Analysis and Hydrogeologic Review

In May 2023, Stantec completed a groundwater isotopic and hydrogeologic analysis to complement the Owens Lake hydrogeologic conceptual model with refined compartmentalization of the Owens Lake area aquifers and address data gaps to complement ongoing investigations at the VDAs with new isotope data (see **Document 4, Table 1**). This analysis was specifically designed to evaluate the connection between surficial groundwaters at the Vegetated Dune Areas (VDAs) and deeper groundwaters tapped by testing well TW-E.

The analysis included a review of several water quality and isotope studies that have been performed in the Owens Lake area, including previous work by others, the Owens Lake Groundwater Evaluation Project (OLGEP), and subsequent work. In addition, piezometers were installed at the VDAs, and vertical groundwater gradients interpreted. In 2022 and 2023, additional rounds of groundwater sampling for $\delta^{18}O$ and $\delta^{2}H$ were performed on the VDA piezometers and selected wells throughout the Owens Lake area. Using these previous studies, interpreted groundwater gradients, and the recently sampled isotope data, Stantec re-evaluated isotopic variation among the Owens Lake aquifers to determine likely sources and flow directions of groundwater recharge, as well as further evidence of barriers to horizontal or vertical groundwater flow, with an emphasis on the VDA areas.

Geologic cross-sections based on drilling data and seismic reflection studies demonstrate an alternating series of aquifers and aquitards that extend both the length and the width of Owens Lake. While the VDA vegetation and piezometers may draw on groundwater in the surficial aquifer, the proposed well TW-E would extract from Aquifers 2 through 5, separated by at least two aquitards of approximately 400 feet in combined thickness from the surficial aquifer and VDA resources.

Figure 1 shows locations of the geologic cross-sections shown in **Figure 2** and **Figure 3**, and the extensive network of monitoring wells around the northern part of Ownes Lake (vegetated dune area (VDA) locations are also shown). **Figure 2** (cross section B-B’) is an example east-west hydrogeologic cross section trending from the bedrock of the Inyo Mountains on the east to the bedrock of the Alabama Hills to the west. This section illustrates the continuous nature of aquitards across the valley and the approximately 500-foot separation of surficial aquifer (where the VDAs are located) and Aquifer 2 (the shallowest screened interval of TW-E) and the several hundred feet of aquitard separating the two.

Figure 3 (cross section C-C') is an example of north-south cross section illustrating the separation of the surficial and deep aquifers and the screen depth of TW-E.

The analysis specifically comparing the isotopic composition measured in the VDA piezometers with that of TW-E and another deeper screened well, DWP-9 (T896, T897, T898) (an appropriate proxy for TW-E based on location and screened interval), demonstrates two distinct groupings of groundwater types. These groups appear to indicate different sources of groundwater recharge for the surficial VDA aquifer and the aquifer where the TW-E wells will draw water (**Figure 4**). Global Meteoric Water Line (GMWL) is the linear relationship of δ^2H and $\delta^{18}O$.

The production zone at TW-E appears to be separated both vertically and horizontally from the VDAs on the east side of Owens Lake. The VDAs are separated vertically by several hundred feet of silt and clay in at least two separate aquitards. The VDAs are separated horizontally from TW-E by the Owens Valley and Owens River Fault Zones (on the west and east side of Owens Lake, respectively), both believed to be barriers to groundwater flow. An operational test of TW-E is a critical final step for determining whether the shallow groundwater under the VDAs is separated from deeper aquifers.

FIGURE 1. LOCATIONS OF GEOLOGIC CROSS-SECTIONS AT THE NORTHERN END OF OWENS LAKE SHOWN IN FIGURE 2 AND FIGURE 3.

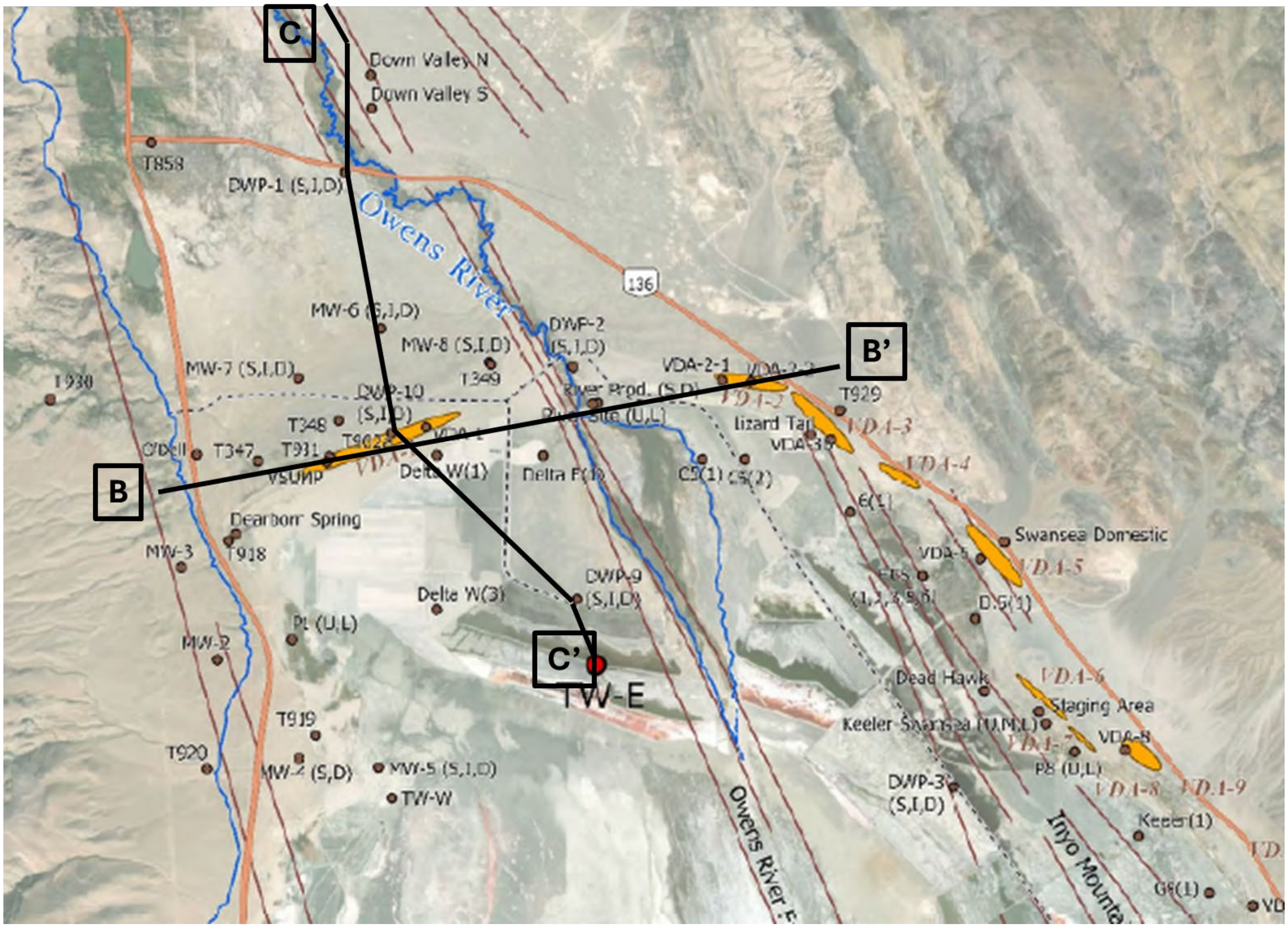


FIGURE 2. GEOLOGIC CROSS-SECTION SHOWING THE SEPARATION OF THE SURFICIAL AND DEEPER AQUIFERS AT OWENS LAKE.

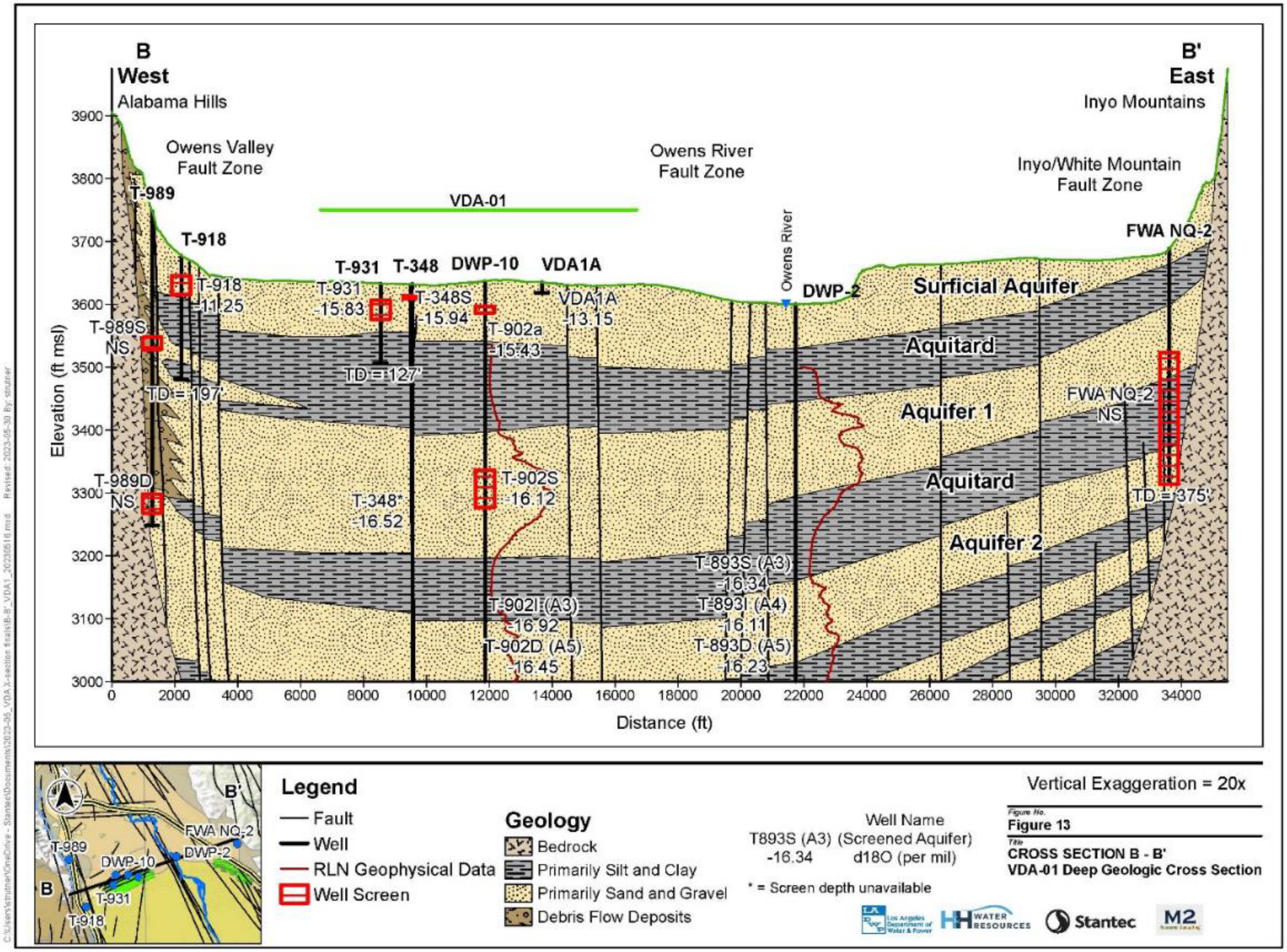


FIGURE 3. GEOLOGIC CROSS-SECTION SHOWING THE SEPARATION OF THE SURFICIAL AND DEEPER AQUIFERS AT OWENS LAKE AND THE LOCATION (AND SCREEN DEPTH) OF TEST WELL EAST (TW-E) IN RELATION TO OTHER WELLS AND LANDSCAPE FEATURES.

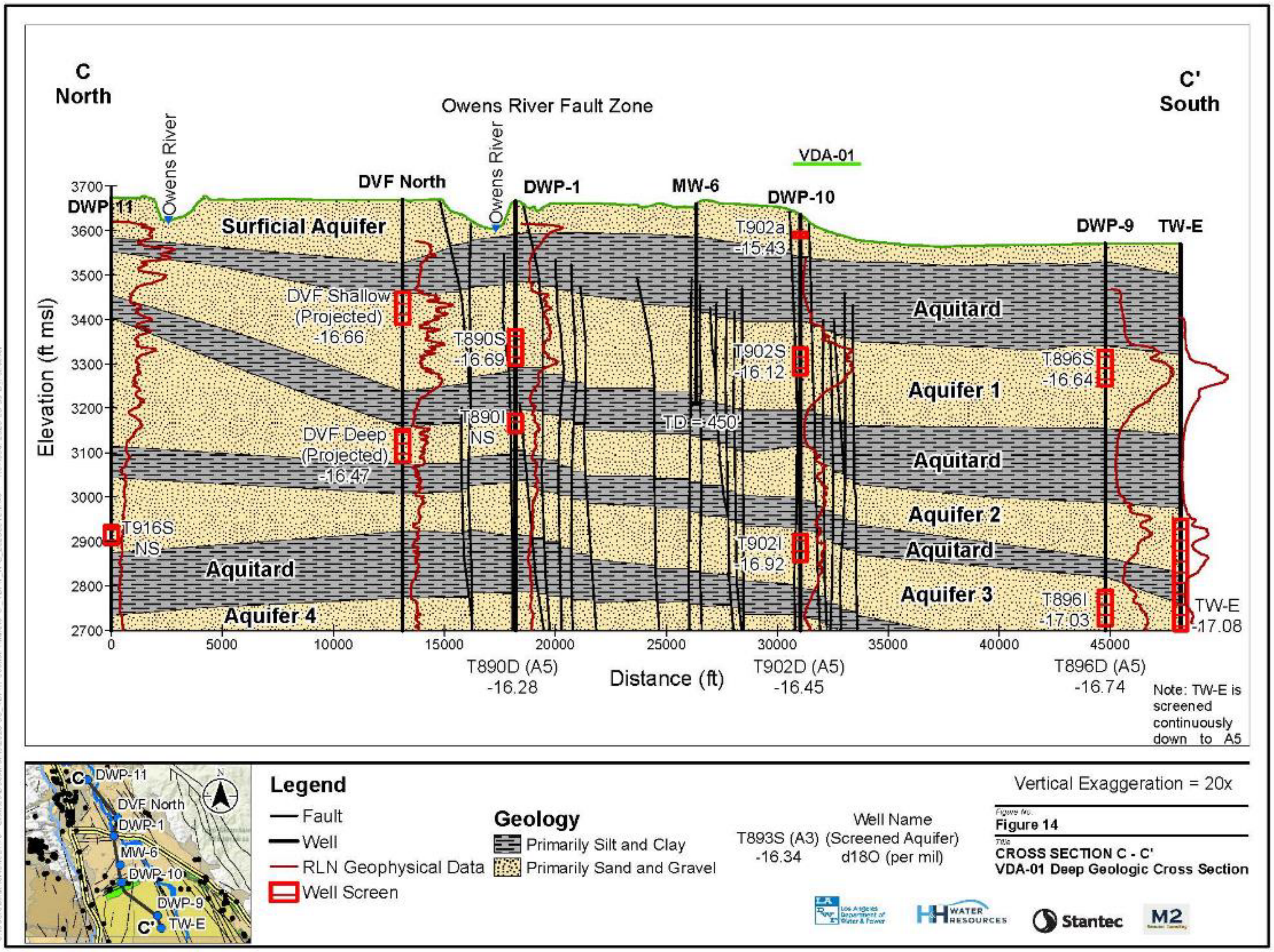
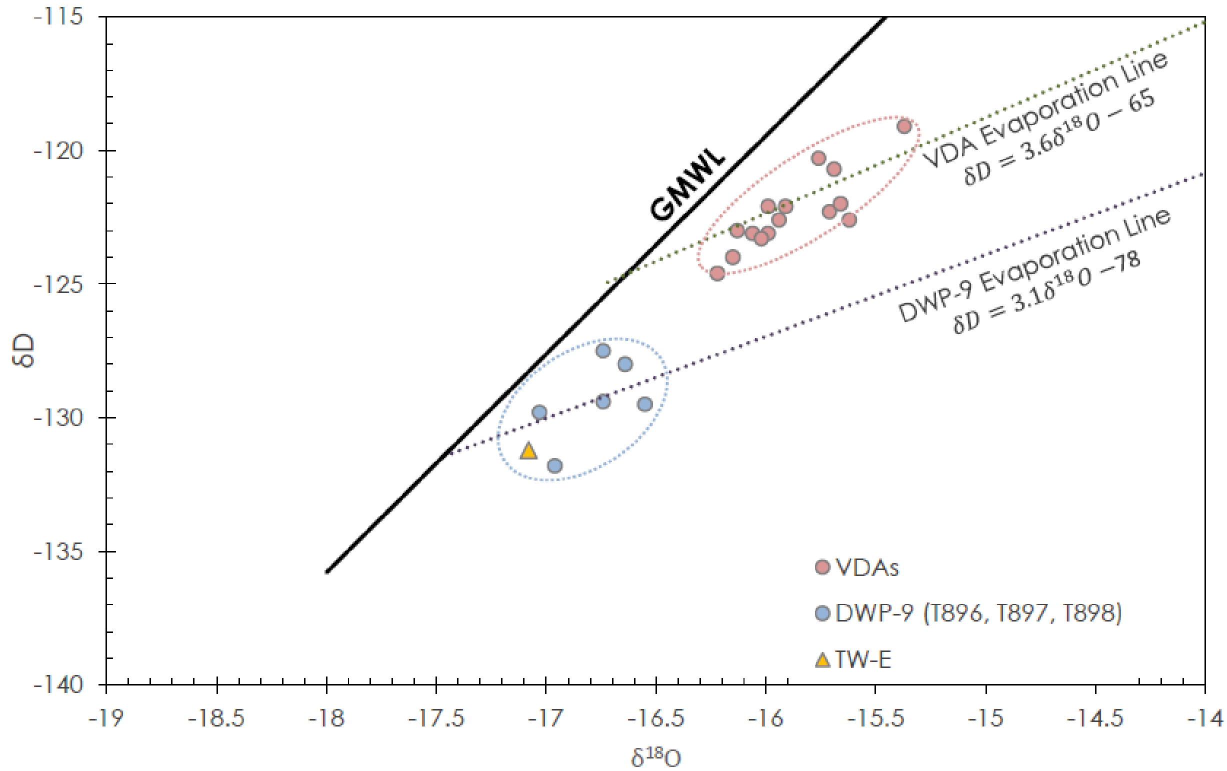


FIGURE 4. PLOT OF GROUNDWATER ISOTOPE SIGNATURES (δ^2H AND $\delta^{18}O$) FROM SHALLOW VDA PIEZOMETERS AND DEEPER GROUNDWATER WELLS SCREENED IN DEEPER AQUIFERS.

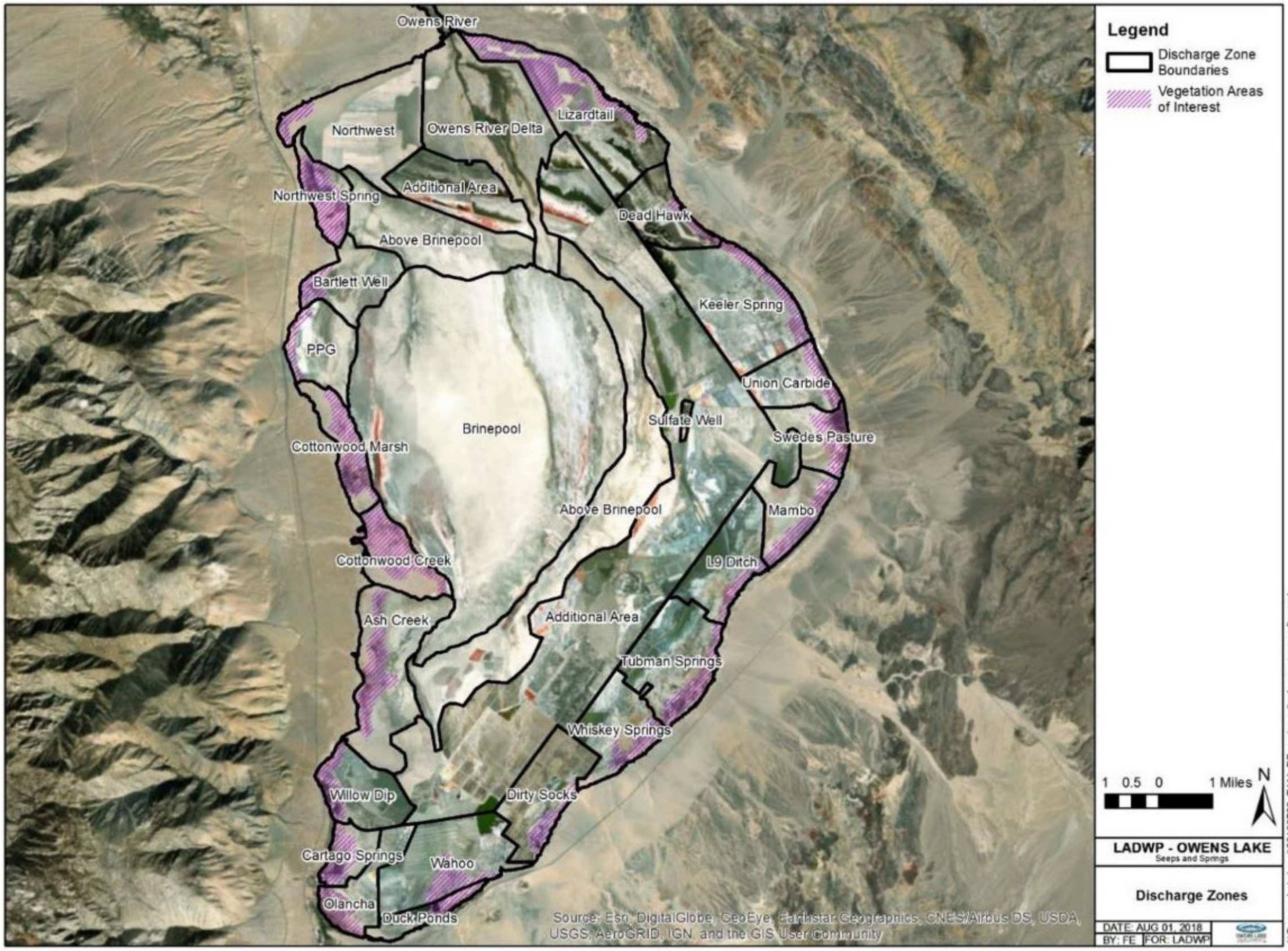


2.4 ALKALI MEADOWS

The highest groundwater levels and lowest salinities are generally found near the historic shoreline at approximately 3,600 ft amsl. Transmontane alkali meadows (TAM) and associated springs (including areas commonly referred to as seeps) generally occur in these areas and may be impacted by groundwater pumping. Since the majority of groundwater flow to the surface is not from a discrete point source that is easily measured, but instead occurs across wide areas with shallow water seepage, seasonal leaf area index (LAI) and acreage of TAM vegetation were selected as parameters for assessing the historical range of variation (HRV) in meadow and spring vegetation. The parameters also became the focal resource protection criteria (RPC) in the resource protection plan (RPP) for protecting meadows, seeps, and springs.

In 2012, LADWP initiated work to map and characterize the transmontane alkali meadow vegetation and determine HRV in seasonal LAI and TAM acreage. To accomplish this, a 33-year record (1985-2017) of Landsat imagery was developed and analyzed for meadows, seeps, and springs located in numerous discharge zones around Owens Lake (**Figure 5**). For each year in the historical record, LAI was plotted over time at the pixel scale (30m x 30m) to derive an estimate of biomass productivity of that pixel over the course of the growing season. LAI was plotted on an individual pixel basis to produce a temporal curve that summarized the various stages of vegetation phenology (related to greenness or photosynthetic activity) that occur during a growing season. Curves at the pixel level were statistically analyzed using a modified Timesat approach to extract and quantify growing season leaf area dynamics. This approach has been used in numerous studies and is being used by the United States Geological Survey (USGS) at the national scale to provide trends in intra- and inter-annual vegetation change. The integral of LAI on the seasonal level (referred to as seasonal LAI) was then further analyzed using a probability-based approach to provide a reliable metric for determining if current vegetation conditions are similar to past conditions. The resulting probability was used to create quantile scores on a yearly basis per pixel (iteratively removing the specific year of interest in the probability calculation). The quantile scores are a measure of how unusual or normal a given pixel's seasonal LAI value is compared to its historical observations in the Landsat record. The quantile scores and the metrics of intensity, duration, and spatial scale were used to provide the basis for the management tier thresholds in the Seeps and Spring Resource Protection Plan. More details on this approach are provided in **Document 6, Table 1**.

FIGURE 5. MAP SHOWING 22 SEEPS AND SPRINGS DISCHARGE ZONES AROUND OWENS LAKE AND VEGETATION AREAS OF INTEREST.



2.5 Vegetated Dune Areas

Studies to better understand the VDAs around Owens Lake began with a transect study, as described in **Document 7, Table 1**. The results of the transect study indicated that *Sarcobatus vermiculatus*, *Suaeda nigra*, and *Atriplex parryi* are the most common shrub species across the VDAs. The first two species occur in all VDAs, with *S. vermiculatus* being especially abundant on shoreline berms, ridges, and coppice dunes. Importantly, *S. vermiculatus* establishment and persistence is not solely related to proximity to groundwater, since the largest and most dense *S. vermiculatus* dunes often occur at higher elevations, which generally have greater depths to groundwater. These large, healthy dunes seem associated with overland flood flows / run-on and sediment (silt) deposition, which increase water-holding capacity and nutrient availability.

Beginning in September 2019, LADWP initiated an extensive baseline study to understand current and historical variability in sand dune volume and height, vegetation height, vegetative cover, LAI, and actual evapotranspiration (ETa) in all 15 VDAs. The results of this work and all associated data are presented in **Document 8, Table 1**. Across VDAs, areas where *S. vermiculatus* shrubs are largest and most extensive, have the highest dune volume (roughly 33,800 m^3 to 569,000 m^3), highest vegetation cover (12.6% to 42.6%), and in general, the highest seasonally integrated LAI (5.1 to 17.8). The average annual ETa in these areas varies from 3.6 to 5.3 in. Long-term drivers of LAI and ETa variation for each VDA were also evaluated. This analysis indicated that when Owens Valley runoff increases, VDA LAI and ETa generally increase. The interpretation is that high runoff years increase flow and run-on into the VDAs, thereby increasing both vadose zone moisture and groundwater recharge.

Following the transect study and extensive baseline study, LADWP completed a detailed Phase 1 Workplan study (August 2020 – October 2020) that characterized the soil profile, lithology, salinity, nutrient and moisture content, groundwater depth and quality, vegetation nutrition and elemental concentrations, and root density distribution across 14 VDA locations. The results of this work and all associated data are presented in **Document 8, Table 1**. Some particularly notable results include the following:

- Total plant available water in the vadose zone at the time of soil sampling was several multiples of annual precipitation and historic maximum monthly ET.
- Roots are present throughout the entire soil profile, although most roots are in the top 1 – 6 ft of the soil profile. There is evidence of slightly greater root density close to groundwater.
- VDA soils are mostly sand, but some VDAs contain layers of fine silt from alluvial deposits that increase water holding capacity and nutrient availability.
- VDA03 is the only known location where an impeding (cemented) layer is present. The layer occurs within a few feet of the ground surface. Soil salinity is generally low relative to shrub salt tolerance.

Following the completion of Phase 1, GBUAPCD recommended more focused studies on temporal and spatial variability in groundwater depth / elevation, vadose zone water availability, shrub growth and physiology, and shrub water sources in a smaller number of VDAs. LADWP began these focused studies in May 2022. **Documents 9 and 10, Table 1** summarize Phase 2 work completed to date:

- More than 40 months of groundwater depth and elevation data (manual and pressure transducer readings) have been collected from each piezometer (58 months from VDA03A). In general, these data indicate that groundwater elevations naturally decline in each VDA between late April and September 30th of each year. Groundwater elevations tend to increase (recharge) in each VDA between October 1 and late April. Across VDAs, average groundwater depth varies from approximately 4.5 to 22.0 ft.

- At most VDAs, total water available in the vadose zone during the October – March timeframe is greater than or equal to mean annual precipitation and / or mean annual ETa. This indicates that a large reservoir of stored soil water (separate from groundwater) is available to plants. Rain events, such as Tropical Storms Kay and Hillary, have substantially increased this reservoir.

- Shrubs grow and thrive across VDAs despite large spatial and temporal variability in groundwater elevation. Across VDAs, average annual groundwater depth is not related to shrub cover.

- Preliminary isotope data and mixing model results indicate that the proportion of groundwater usage by *S. vermiculatus* changes temporally and spatially. When soil surface and vadose zone (0-10 ft depth) water storage is high (fall, spring, following rain), shrubs primarily use vadose zone moisture to support both growth and function. During dry spring and summer conditions when shrubs are not growing and minimally active, shallow groundwater (i.e., the capillary fringe) is the primary water source.

- Shrub growth and function (i.e., water potential, photosynthesis) is lowest when conditions are hot and dry and highest when conditions are cooler and wetter. When vadose zone water increases following rain events, shrub function increases.

Figure 6 provides a timeline of major events in the OLGDP since 2009, and a detailed timeline of work completed in the VDAs through 2023. **Figure 7** shows the locations of major studies and monitoring activities in the VDAs.

FIGURE 6. TIMELINE OF THE OWENS LAKE GROUNDWATER DEVELOPMENT PROGRAM (SINCE 2009) AND A DETAILED TIMELINE OF WORK COMPLETED IN THE VEGETATED DUNE AREAS (VDAS).

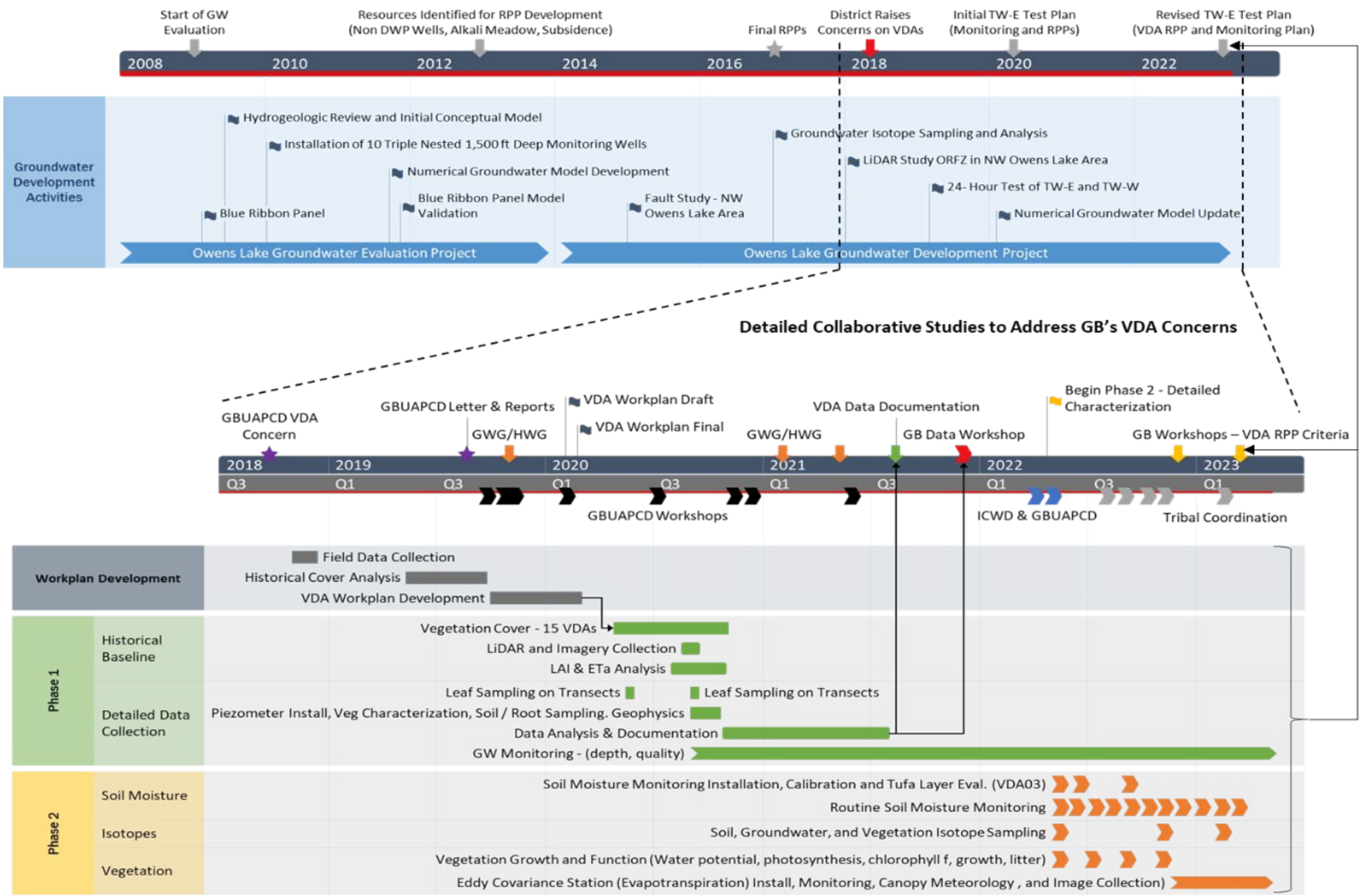
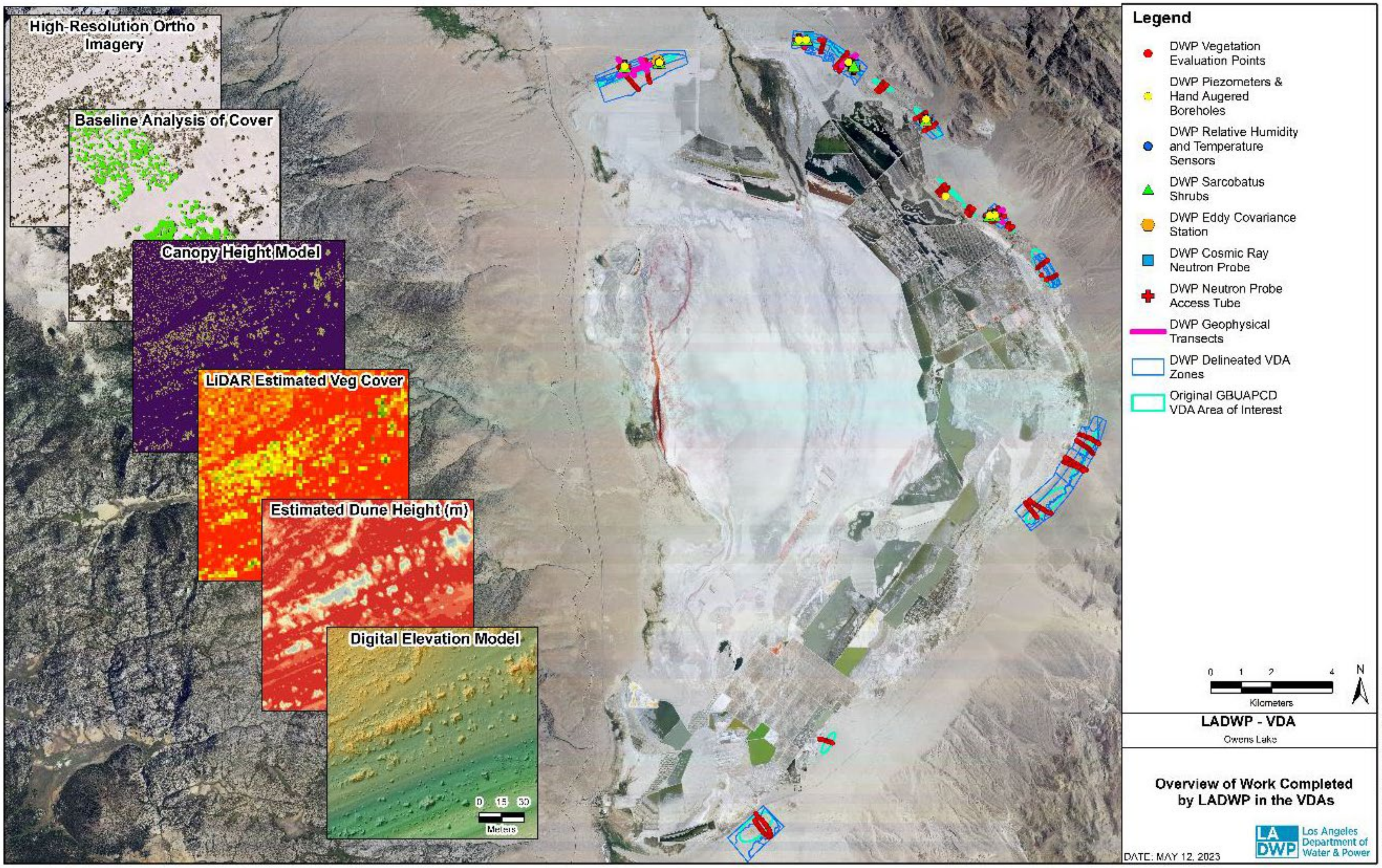


FIGURE 7. MAP SHOWING THE LOCATIONS OF VDA INVESTIGATIONS SINCE 2012.



3 DESCRIPTION OF THE TESTING PLAN FOR TW-E

The current testing plan for TW-E is **Document 5** in **Table 1**. The test plan is also available for review on the LADWP website: www.ladwp.com/olg

This document was last updated in 2021. It is currently being updated to include the VDA resource protection plan (RPP) that was jointly developed by LADWP and GBUAPCD. The test plan includes a description of previous short-term tests at Owens Lake, a description of TW-E, the proposed operational test of TW-E, the comprehensive monitoring and reporting that will take place, and protection criteria for groundwater-dependent resources. Some key aspects of the operational test are:

- **Test length:** 6 months.
- **Timing:** between October and April (the normal dust season when water for dust control is in demand).
- **Pumping rate:** 3 cubic feet per second, a constant to simulate potential future operation.
- **Monitoring:** 142 Monitoring Wells (93 primary), 26 Flumes, 7 Meteorological Sites, 5 Land Surface Elevation Sites, 15 Groundwater Quality Sites, 22 Groundwater Quality Constituents, Area-wide Remote Sensing Before and After Testing, including monitoring of horizontal and vertical groundwater gradients.
- **Resources with protections in place:** Habitat and Springs Around Owens Lake, VDAs, Non-LADWP Wells, Production Capability, Groundwater Quality, and Land Subsidence.

Criteria and Monitoring for protection of other (non-LADWP) wells and against land subsidence are described in the test plan (linked above and available on the LADWP website). The sections below focus on resource protection plans for alkali meadows (seeps and springs), and the VDAs.

4 RESOURCE PROTECTION PLANS

4.1 ALKALI MEADOWS RESOURCE PROTECTION PLAN

The main components of the Alkali Meadows / Seeps and Springs RPP (**Document 6, Table 1)** include the following:

1. Resource protection criteria to protect groundwater-dependent vegetation in springs and associated alkali meadows.
2. Monitoring the parameters identified in the RPC to ensure protection of the resources and to inform development of annual groundwater management plans.
3. A three-tiered management approach, including an early warning management indicator and two management triggers. The Tier 1 early warning management indicator is a trigger to investigate potential resource decline. The Tier 2 management trigger is to alter the amount,

location, and/or depth of groundwater pumping to reverse resource decline. The Tier 3 management trigger is to stop groundwater pumping.

4. A recovery threshold that defines when groundwater pumping can resume after the Tier 3 management trigger requires it to stop.

5. A significant impact threshold to define when management actions alone cannot reverse resource decline.

6. Mitigation to compensate for resource decline by establishing in-kind, on-site habitat or in-kind, off-site habitat if significant impacts occur.

Importantly, the seeps and spring RPP includes two resource protection criteria.

- **Resource Protection Criteria 1:** Avoid significant impacts to springs and associated alkali meadow vegetation by maintaining seasonal LAI, based on the HRV, within a minimum contiguous acreage. The purpose of this criterion is to provide an early indicator of reduced productivity, which would likely occur before an observed decline in TAM acreage. Maintenance is defined by the quantile values identified for Tier 1 and Tier 2. Contiguous areas are areas of Landsat pixels with shared boundaries, including the four sides and the four corners of the pixel (eight neighbors). Contiguous criteria were chosen to identify areas that are connected and responding in a similar way (e.g., decline) as their neighbors; not random pixels that equal a specific area requirement across the lakebed. The HRV is based on an approximately 33-year record of Landsat data between 1985 and 2017. The HRV represents a baseline in seasonal LAI. The HRV may be updated to include additional years (e.g., 2018, 2019, 2020) prior to the commencement of production pumping.

- **Resource Protection Criteria 2:** Avoid significant impacts to springs and associated alkali meadow vegetation by maintaining TAM acreage, based on the HRV, within each discharge zone. The purpose of this criterion is to assess TAM acreage to determine whether observed changes are within the HRV. This criterion will also provide the basis for the significant impact threshold and mitigation. Maintain is defined by the quantile values developed for Tier 2b and Tier 3. The HRV is based on an approximately 33-year record of Landsat data. The HRV represents a baseline in TAM acreage. The HRV may be updated to include additional years (e.g., 2018, 2019, 2020) prior to the commencement of production pumping.

4.2 Vegetated Dune Areas Resource Protection Plan

The VDA RPP remains in draft form, although the general resource protection criteria (RPC) framework has been agreed upon by LADWP and GBUAPCD. The draft VDA RPP includes Resource Protection Criteria (RPC), Rationale for Selection of RPC, Monitoring Parameters for each RPC, Management Triggers or Thresholds, and Management Actions.

Each VDA is different in terms of soil conditions, landscape position, topography, groundwater depth and seasonality, and occurrence of runon. The tentatively agreed upon VDA RPP and the selected RPC and triggers are designed to account for unique conditions in each VDA. The goal of the RPP is to avoid impacts to VDAs by ensuring that seasonal groundwater elevations change within the normal range of historic variation for each VDA. Groundwater depth or elevation are the primary monitoring parameters, although vadose zone PAW will also be monitored since it is an important water source for dune vegetation, separate from groundwater. Data collected during the test of TW-E will be evaluated to determine whether different or revised RPC are needed for the development of a new RPP for long-term pumping of TW-E.

Groundwater elevation will be continually monitored with pressure transducers installed inside piezometers at each VDA. Total vadose zone PAW will also be monitored on a monthly basis using manual neutron probe measurements, although triggers for the operational test do not include PAW. PAW (in inches) in each soil layer is calculated as the difference between current VWC and VWC at the permanent wilting point. The total PAW (inches) for each soil profile is estimated by summing the product of PAW and the thickness (inches) of the soil layer it represents. PAW estimates can be compared to the historic actual evapotranspiration (ETa) for the location to assess the amount of water stored in the vadose zone relative to ecosystem water demand.

5 CONCLUSION

It is challenging to describe in full detail the amount of field work, instrumentation, data analysis, and outreach / collaboration (with GBUACPD, Inyo County, Tribal liaisons, etc.) that has occurred to inform the OLGDP. This document only provides a brief summary of the work completed to date (emphasizing some key components), including the operational test plan for Well TW-E and development of rigorous resource protection plans, which have been developed and agreed upon with GBUAPCD through numerous workshops. It is emphasized that the resource protection plans are highly conservative and aim to maintain the Owens Lake system within the normal historical range of variation. Again, the purpose of the OLGDP is to provide water supply redundancy and resiliency to the OLDMP, while protecting groundwater-dependent resources in and around Owens Lake.