Owens Valley Groundwater Sustainability Plan:
Monitoring Plan and Data Gaps Analysis

Prepared For

Owens Valley Groundwater Authority
Owens Valley, CA

OWENS VALLEY GROUNDWATER AUTHORITY

Prepared by

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November 30, 2021

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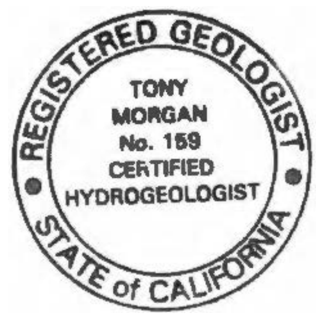

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Date signed: December 1, 2021

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Acronyms and Abbreviations

Acronym	Acronym definition
AB	assembly bill
ADCP	acoustic doppler current profiler
AF	acre-feet
AFY	acre-feet per year
Ag	agriculture
AMI	automated (or advanced) metering infrastructure
amsl	above mean sea level

APN	assessor parcel number
B	boron
BCM	Basin Conceptual Model (USGS)
bgs	below ground surface
BMP	best management practices
BOS	bottom of screen
CA	California
CalGEM	Geologic Energy Management Division (formerly DOGGR)
CASGEM	California statewide groundwater elevation monitoring
CCR	California Code of Regulations
CDPH	California Department of Public Health
CFS	cubic feet per second
CIMIS	California irrigation management information system
Cl	chloride
COC	chemical of concern
CWC	California Water Code
DBS&A	Daniel B. Stephens & Associates, Inc.
DDW	[SWRCB] Division of Drinking Water
DEM	digital elevation model
DOGGR	Division of Oil, Gas, and Geothermal Resources (reorganized as CalGEM)
DPWM	Distributed Parameter Watershed Model
DQO	data quality objective
DTW	depth to water
DWR	[CA] Department of Water Resources
DWUs	downstream water users
EGM96	Earth Gravitational Model of 1996
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration

ET_0	reference evapotranspiration
FT or ft	feet
GAMA	[USGS] groundwater ambient monitoring & assessment
GIS	geographic information system
GPS	global positioning system
GBUAPCD	Great Basin Unified Air Pollution Control District
GSA	groundwater sustainability agency
GSP	groundwater sustainability plan
HASP	health and safety plan
HCM	hydrogeologic conceptual model
Hydrodata	hydrologic data server
ID	identification
IWVWA	Indian Wells Valley Groundwater Authority
JPA	Joint Exercise of Powers Authority
LADWP	Los Angeles Department of Water and Power
LAUWMP	Los Angeles Urban Water Management Plan
LiDAR	light detection and ranging
NCCAG	natural communities commonly associated with groundwater
M&I	municipal and industrial
MCL	maximum contaminant level
MOU	memorandum of understanding
MS4	municipal separate storm sewer system
NAD	North American datum
NAVD88	North American vertical datum of 1988
ND	not detected
NGVD29	national geodetic vertical datum of 1929
NO3	nitrate
NWIS	national water information system

OFR	open file report
OLGDP	Owens Lake Groundwater Development Program
OVGA	Owens Valley Groundwater Authority
PBP	priority basin project
PSI	pounds per square inch
PSW	public-supply well
PVC	polymerizing vinyl chloride
QA	quality assurance
QC	quality control
RASA	regional aquifer-system analysis
RP	reference point (elevation)
RWQCB	[CA] Regional Water Quality Control Board
SAP	sampling and analysis plan
SO4	sulfate
SUM	summation
SWL	static water level
SWN	[CA DWR] state well number
SWRCB	[CA] State Water Resource Control Board
TD	total depth
TDS	total dissolved solids
TFR	total filterable residue
TMDL	total maximum daily load
TNC	The Nature Conservancy
TOS	top of screen
URL	uniform resource locator (web address)
USEPA	United States Environmental Protection Agency
USGS	U.S. Geological Survey
WGS84	world geodetic system 1984

WL	water level
WLE	water level elevation
WQ	water quality
WY	water year

Executive Summary

Development of an acceptable groundwater sustainability plan (GSP) requires information provided by a number of datasets to inform past, present, and future conditions in the context of the six undesirable results that can occur when a groundwater basin is managed unsustainably. These datasets (excluding those related to subsidence and interconnected groundwater and surface water) were reviewed on a management area basis for this document. Summaries of available data, including spatial maps and time series of representative monitoring points, are presented for each management area. Data gaps were assessed by evaluating the spatial coverage of data relative to the aquifer and management area boundaries, the time period for which data are available, and hydrogeologic context. Identified data gaps were then given priority ranking with recommendations on how to address them.

The highest priority data gaps occur within the Fish Slough and Tri-Valley management area, where limited groundwater elevation, well location, groundwater extraction, and subsurface flow data have been collected. The few data points available show steady, long-term groundwater level declines in the Tri-Valley area on the order of one to two feet per year. A connection between the Owens Valley subbasin and the Fish Slough subbasin is observed in correlated water level and spring flow declines, but no groundwater flow model has been developed to quantify fluxes between the two subbasins. Lower priority data gaps include obtaining data that were not assimilated into the Owens Valley Groundwater Authority (OVGA) database as they were discovered after that phase of initial GSP development had been completed, and further refining water budget components.

Introduction

Daniel B. Stephens & Associates, Inc. (DBS&A) has prepared this Owens Valley Monitoring Program and Data Gap Analysis Technical Memorandum (Tech Memo) for the Owens Valley Groundwater Authority (OVGA) and is under contract to prepare their Groundwater Sustainability Plan (GSP or Plan) as required by the 2014 Sustainable Groundwater Management Act (SGMA). This Tech Memo is intended to be included as an Appendix in the final GSP.

SGMA requires that all groundwater basins designated by the California Department of Water Resources (DWR) as “medium” and “high” priority basins be managed sustainably, defined as the absence of "significant and unreasonable" undesirable results that occur when the basin is not in a long-term dynamic steady-state condition. Basins identified as “Critically Overdrafted” are required to submit their Plans to the DWR by January 31, 2020. Although Owens Valley is currently listed as "low" priority and therefore not required to submit a GSP, the OVGA is voluntarily submitting one by the January 31, 2022 deadline for "medium and "high" priority basins. For the purposes of this Tech Memo, Owens Valley refers to the DWR subbasins 6-012.02 (Owens Valley) and 6-012.02 (Fish Slough) unless stated otherwise.

1.1 Purpose and Background

This section describes the purpose of the Tech Memo and provides technical background information for Owens Valley.

1.1.1 Purpose

The purpose of this Monitoring Program and Data Gap Analysis Tech Memo is to aid in the development of a monitoring network that is capable of providing sustainability indicator data of sufficient accuracy and quantity to demonstrate sustainable management of Owens Valley groundwater basin. The Tech Memo describes the datasets available for GSP preparation, established monitoring networks and how data (knowledge) gaps could be filled in the future. Tech Memo components detail:

- Historical datasets
- Existing monitoring networks
- Groundwater data trend analysis
- Data gap analysis
- Recommendations

This Tech Memo is not intended to impose specific monitoring wells and/or sampling locations on OVGA with respect to their existing long-standing monitoring programs. However, SGMA requires principal aquifer-specific evaluation (DWR, 2016b), which from a review of the existing monitoring networks, may be a challenge in Owens Valley (see Section 1.2.6). Aquifers outside of the adjudicated area (see Section 1.1.2) in the Owens Valley are relatively lightly pumped, or not pumped at all, which minimizes drawbacks of the lack of an aquifer specific analysis. Optimization and/or expansion of current monitoring programs may be necessary as many existing groundwater monitoring points in the basin utilize agricultural wells or municipal wells potentially screened across multiple water-bearing units, or are located on LADWP lands that are exempt from SGMA (see Section 1.1.2).

Where appropriate, hydrologic data are displayed graphically on maps and charts in this Tech Memo and can also be viewed on the Owens Valley GSP data portal (https://owens.gladata.com). This Tech Memo serves as a starting point for GSP preparation and provides a general data summary and overview of historical and current groundwater conditions in the basin.

1.1.2 Background

Much of the land and the majority of water rights in Owens Valley are owned by the City of Los Angeles Department of Water and Power (LADWP) for the purpose of exporting water from the eastern Sierra to Los Angeles. Los Angeles has developed extensive facilities for water storage and export, land and water management, groundwater production, groundwater recharge, surface water and groundwater monitoring, and dust control. Because of the importance of water supplied from Owens Valley to Los Angeles, LADWP water monitoring is extensive and considerable study has been devoted to Owens Valley hydrology. Because Los Angeles owns relatively little land in Chalfant, Hammil, and Benton valleys, they are less studied and monitoring is sparse compared to the rest of the Owens Valley.

For the purposes of SGMA, lands owned by LADWP are considered adjudicated under the Inyo-Los Angeles Long Term Water Agreement (LTWA). Therefore, LADWP land is exempt from SGMA regulations. Other SGMA exemptions in Owens Valley include tribal lands owned by the Bishop Paiute Tribe, Big Pine Paiute Tribe, Fort Independence Paiute Tribe, Lone Pine Paiute Shoshone Tribe, and lands held in trust by the US Bureau of Indian Affairs (Figure 1-1). The GSP area is defined as the area of the groundwater basin that does not coincide with the SGMA exempt lands. Spatial coverages for the groundwater basin and the SGMA-exempt lands were all obtained from the DWR SGMA Data Viewer (https://data.cnra.ca.gov/showcase/sgma-data-viewer).

DBS&A has developed this Tech Memo as a companion document to the Owens Valley Sampling and Analysis Plan (SAP) (OVGA, 2020). The SGMA focused SAP details monitoring protocols and standard methods for water quality and groundwater level data collection in the Owens Valley.

The SAP is referenced throughout this Tech Memo where applicable. SAP components include, but are not necessarily limited to, descriptions of the following:

- Water sample collection procedures
- Analytical methods to be used

- Groundwater level measurement protocol in water wells
- Data quality assurance (QA) and quality control (QC) procedures

1.1.3 Technical and Regulatory Guidance

DBS&A has developed this Tech Memo in accordance with the Best Management Practices (BMP) technical guidance series produced by the DWR. This Tech Memo has been prepared in general accordance with the DWR's BMP #2 - Monitoring Networks and Identification of Data Gaps (DWR, 2016b). Much of the content contained in the DWR's BMP #2 was directly applicable to the development of this Tech Memo and BMP content has been liberally reproduced in this Tech Memo. URL links to complete documents, available online (OVGA.us) and cited in this Tech Memo, are included in the References Section, where available.

Additional sources of technical guidance considered in preparation of this Tech Memo include, but are not limited to, the following documents:

- BMP #1 - Monitoring Protocols, Standards, and Sites (DWR, 2016a)
- Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4 (EPA, 2006)
- Title 23 of the California Code of Regulations (CCR)

This Tech Memo has been prepared to satisfy, in part, criteria contained in 23 CCR Subarticle 4 - Monitoring Networks:

- § 354.32 - Intro to Monitoring Networks
- § 354.34 - Monitoring Networks
- § 354.36 - Representative Monitoring
- § 354.38 - Assessment & Improvement of Monitoring Networks (Data Gaps)
- § 354.40 - Reporting Monitoring Data to the Department (addressed in the SAP)

Monitoring programs are to be reviewed and modified, as necessary, at least every five years as part of the periodic GSP evaluation (5 year updates).

1.1.4 SGMA Sustainability Indicators

Six sustainability indicators are defined in the SGMA legislation. These are potential effects caused by groundwater conditions occurring in a basin that, when significant and unreasonable, are considered undesirable results. The GSP will describe sustainable management criteria (SMCs) that will serve as metrics for evaluating undesirable results relative to the sustainability indicators. Data must be sufficient to limit uncertainty when used to assess the sustainability indicators (DWR, 2017). The six indicators are related to:

- Groundwater levels
- Groundwater storage
- Seawater intrusion
- Water quality
- Land subsidence
- Interconnected surface water

Land Subsidence and Ecological (i.e., interconnected surface water) monitoring networks and available data are not included in this Tech Memo, as they are discussed separately in other appendices included with the GSP. This Tech Memo addresses data collection related to water quality and groundwater levels. Seawater intrusion is not an applicable sustainability indicator of concern for the Owens Valley due to its geographic location.

1.1.5 Historical and Current Groundwater Management

Prior to SGMA, groundwater management for the Inyo County portion of Owens Valley was performed pursuant to the LTWA. The overall goal of the LTWA is "to avoid certain described decreases and changes in vegetation and to cause no significant effect on the environment which cannot be acceptably mitigated while providing a reliable supply of water for export to Los Angeles and for use in Inyo County" [City of Los Angeles v. County of Inyo, 1991]. Implementation methods for these goals are described in the "Green Book," a technical appendix to the LTWA [County of Inyo and City of Los Angeles, 1990]. All lands owned by the City of Los Angeles in Inyo County are governed by the LTWA, and these lands are considered adjudicated and exempt for the purposes of SGMA.

In general, the primary goal of LTWA groundwater management for the LA-owned portion of the Owens Valley in Inyo County is to manage groundwater pumping to protect and sustain phreatophytic vegetation that depends on shallow groundwater as a primary water source. The primary goal is accomplished by a combination of monitoring, modeling, and forecasting of vegetation and hydrologic conditions on an annual basis. If pumping reduces, or is projected to reduce, soil moisture below a threshold that would cause irreversible damage to vegetation then pumping is decreased or stopped completely until water levels and soil water recover. Annual pumping plans provided by LADWP are prepared and analyzed using recent monitoring data and modeling. Since the vast majority of groundwater is pumped by the LADWP, the LTWA applies to most groundwater extraction in the Inyo County portion of Owens Valley.

In the Mono County portion of the Owens Valley, groundwater management is the responsibility of the Tri-Valley Groundwater Management District (TVGMD). According to the most recent General Plan Update [County of Mono, 2015], the TVGMD was formed in response to concern over possible exportation of groundwater from the area and implements an area-wide well-monitoring program. However, it is not clear that a comprehensive pumping or water level monitoring program exists as no groundwater data has been provided to the OVGA by the TVGMD to date. Furthermore, the TVGMD website appears to function primarily to host public announcements of monthly meetings, and does not contain groundwater management plans, or reporting and monitoring requirements. As noted by Langridge and others [2016], the TVGMD is a functioning public agency which holds periodic public meetings, but with no permanent staff and no employees on payroll. The scope of the district's activities appear to be quite limited and primarily focused on preventing groundwater export from the area.

1.2 Hydrogeologic Conceptual Model

The varying combinations of topography, geology, and climate over the large area of the Owens Valley groundwater basin has resulted in hydrogeologic conditions varying spatially, generally from north to south. These can be broadly grouped into three categories representing the hydrogeologic conditions. The spatial distribution of these categories are used in the GSP to divide the basin into separate management areas (Figure 1-2) which allow for development of unique SMCs that take into account hydrogeologic conditions present in the area.

The following is a summary description of the Owens Valley Hydrogeologic Conceptual Model (HCM). Data used to develop the conceptual model are presented for the basin as a whole, but the hydrogeologic framework for each management area is discussed individually. For a more detailed description, please refer to Appendix 7 and Section 2.2.1 of the Owens Valley GSP.

1.2.1 Geography and Physiography

Owens Valley is located on the eastern side of the Sierra Nevada Mountains in California on the western edge the Basin and Range Province. The Owens River watershed is approximately 3,287 mi^2, extending from Long Valley and Benton Valley in the north to Haiwee Reservoir in the south. The watershed is comprised of two main geographic components: the mountains that surround the valley and provide most of the water in the form of snowmelt runoff, and the relatively flay lying valley floor which makes up the groundwater basin (Figure 1-3). The groundwater basin is a geographic subset of the watershed. Locally, the northern arm of the Owens Valley subbasin that contains Chalfant, Hammil, and Benton Valleys is referred to as "Tri-Valley." Fish Slough is a small subbasin to the west of Chalfant and Hammil Valleys that discharges groundwater to the Owens Valley north of the City of Bishop. Elevations in the watershed range from 14,505 ft above mean sea level (amsl) at the summit of Mt. Whitney to 3,529 ft amsl in the Owens Dry Lake portion of the watershed. The Owens Valley is a closed basin due to the Coso Range at the southern end of the watershed preventing groundwater and surface-water outflow.

Although the terms “watershed” and “groundwater basin” are commonly used interchangeably, they have very specific meanings in this document. The watershed is defined as the area that channels rainfall and snowmelt to the Owens Lake area as there is no natural outlet from the watershed. This includes the high elevation mountains that surround the Owens Valley. The groundwater basin is the portion of the watershed where alluvial and fluvial sediments have accumulated to form aquifers, typically characterized by relatively low topographic relief. The boundaries of the Owens River watershed and the Owens Valley groundwater basin are shown in Figure 1-3.

1.2.2 Climate

Climate in Owens Valley watershed is strongly correlated with elevation. The high elevation portions of the watershed are cooler and receive the greatest amount of precipitation (Figure 1-4), primarily as snow from October-March. The watershed experiences a strong precipitation gradient due to the "rain shadow effect" caused by the Sierra Nevada. Moist air masses moving westward off the Pacific Ocean rise when they encounter the Sierra Nevada, the rising air cools, and water vapor condenses and falls as rain or snow. As air masses descend the eastern slope, the descending air warms, clouds evaporate, and precipitation declines east of the Sierra Nevada. The combination of topography and the "rain shadow effect" results in highly variable precipitation in the watershed.

1.2.3 Vegetation

Native vegetation covers most the Owens Valley watershed (Figure 1-5) as the majority of land is owned by federal, state, or municipal ownership. Vegetation in the Owens Valley groundwater basin varies with elevation, floristic region, soil salinity, and water availability. Vegetation communities range from salt-tolerant shadscale scrub, alkali sink scrub, desert greasewood scrub, alkali meadow, and desert saltbush or rabbitbrush scrub on the low elevations of the valley floor, to more drought-tolerant Mojave Mixed Woody Scrub, Blackbush Scrub, and Great Basin mixed scrub on alluvial fans [USGS, 2011; Howald, 2000].

In the arid environment of the Owens Valley, vegetation communities are mediated by hydrology. On alluvial fan surfaces, where the water table is disconnected from the root zone, plants subsist on precipitation alone. Near stream channels, ditches, canals, and along the Owens River, surface-water supports riparian communities such as meadows, marshes and patches of willow and cottonwood. Areas of shallow groundwater, primarily located along the valley floor adjacent to the Owens River, support alkali meadow, alkali sink scrub, shadscale scrub, and desert saltbush and rabbitbrush scrub communities and intermediate types between these general classes. Discrete groundwater discharge zones, often related to faulting, support springs, alkali meadow, phreatophytic scrub communities, transmontane alkali marsh and aquatic habitat.

1.2.4 Soils

Surficial soil data were obtained from the Natural Resources Conservation Service (NRCS) soil survey geographic (SSURGO) database. Areas of similar soils are grouped into map units, which have similar physical, hydrologic, and chemical properties. Map unit properties are assigned a range of values based on the soils contained within them.

The large geographic extent and complex geology of Owens Valley results in a wide range of soil types. A total of 598 soil-map units were identified within the Owens Valley watershed, with 263 overlying the groundwater basin. Figure 1-6 shows a general summary of these map units classified by soil texture, which covers approximately 78% and 91% of the watershed and groundwater basin area, respectively. Areas not covered by the SSURGO data include the eastern Sierra Nevada and the southeastern portion of the watershed. Soil development is these areas is likely limited due to steep topography and/or very little precipitation.

Surface soil textures are dominated by sands and gravels, primarily silty sand which accounts for 46% of the groundwater basin area and generally results in high infiltration rates for the basin. Finer grained soil textures such as silts and clays make up approximately 25% of the area and are generally located adjacent to the Owens River. About 12% of the area is labeled "Unknown" in the SSURGO database. The majority of this category is located near Owens Lake, where soils are dominated by evaporite salt deposits [Murphy, 1997].

1.2.5 Geology

The geologic history of Owens Valley is a complex mixture of rifting, faulting, volcanism, and deposition (Figure 1-7). The basin formed as a result Basin and Range extensional tectonics that caused land surface parallel to the fault trace to subside. This subsidence created space into which valley-fill has accumulated, consisting mainly of sediment shed from the adjacent uplifted mountain blocks. Volcanic deposits associated with crustal thinning from the extensional tectonic regime are interbedded with the valley-fill in numerous locations. Sedimentary material consists of unconsolidated to moderately consolidated alluvial fan and glacial moraine deposits adjacent to the mountain range fronts, fluvial plain deposits near the axis of the valley, deltaic deposits, and lacustrine deposits. Older alluvial fan deposits tend to be elevated and at the margins of the valleys. Sediments of the central axis of the valleys are typically fluviolacustrine, playa, and dune deposits. In well logs, valley fill sediments are expressed as sands, gravels, boulders, and clay layers. Sedimentary strata are variable vertically and laterally. Depositional environments change over relatively short horizontal distances resulting in laterally discontinuous sand, gravel, and clay lenses. Tectonic activity and climate variations change sediment supply and depositional energy at any given point, resulting in lithologies changing over vertical distances of a few feet to a few dozen feet. Laterally extensive clay strata are present beneath Owens Lake and in the Big Pine area. Total thickness of the basin alluvium ranges from a few feet on the margins of the valley to more than 8,000 ft beneath Owens Lake, although most wells are only screened in the upper 700 ft [Hollett and others, 1991; Danskin, 1998].

1.2.6 Hydrogeologic Framework

The following sections describe the general hydrogeologic conditions of each management area.

1.2.6.1 Fish Slough and Tri-Valley Management Area

Fish Slough, located to the north of the City of Bishop and to the west of Hammil and Chalfant Valleys in an area known as the Volcanic Tablelands, is a federally-designated Area of Critical Environmental Concern (ACEC) due to the presence of rare plants and animals. The aquifer is unconfined and composed of recent alluvium that has filled an asymmetric half-graben [Jayko and Fatooh, 2010; Zdon and others, 2019] bounded by the relatively impermeable Bishop Tuff.

Groundwater flows generally from the north to the south. Several springs discharge water along the Fish Slough fault zone and support habitat in the area. Water discharged along faults is considered to be the primary input to Fish Slough, as little precipitation falls directly on the subbasin and there are no natural drainages terminating within it (Figure 1-8). Based on geologic, hydrologic and geochemical studies, it is hypothesized that most of the water discharging from Fish Slough is sourced from the Tri-Valley and Casa Diablo areas via fracture flow though the Volcanic Tablelands that physically separate them. Spring flow is sufficient to establish a continuous meandering stream that is managed to support ponds, marsh, and meadow habitat and which eventually flows into the Owens River about seven miles to the south. This runoff, along with ET from phreatophytic vegetation, are the primary water-balance outflows from Fish Slough.

The majority of the Tri-Valley aquifer is unconfined, bounded by the Benton Range to the north, the Volcanic Tablelands (Bishop Tuff) to the west, the White Mountains to the east. It is composed of alluvial sediments shed from the surrounding uplands. Depth of alluvium has not been determined, but appears to be at several thousand feet thick in some locations [Bateman, 1965; PWA, 1980].

Recharge is primarily sourced from infiltration of runoff from the mostly ephemeral streams draining the White Mountains on the eastern side of the valley (Figure 1-8). Model results indicate direct precipitation on the valley floor contributes little to aquifer recharge (see Section 2.2.3 and Appendix 10 of Owens Valley GSP). Other potential inflows to the Tri-Valley aquifer are lateral groundwater flows across the California-Nevada border, recharge from runoff coming into the valley from the Volcanic Tablelands, and mountain front recharge along the margins of the valley. Lateral groundwater flows from Nevada and runoff from the Volcanic Tablelands are not anticipated to be large groundwater inflows. Contributions from mountain front recharge are poorly understood and commonly estimated during calibration of a groundwater flow model, which has not been developed for the Tri-Valley area.

Outflows from the Tri-Valley aquifer include groundwater pumping, intercepted groundwater that discharges within Fish Slough, ET from phreatophytic vegetation and irrigated lands, and lateral groundwater flow from Chalfant Valley to the Laws area of Owens Valley. Groundwater pumping for irrigated agriculture is likely the largest outflow from the Tri-Valley aquifer based on estimated pumping rates compared to observed Fish Slough discharge. Groundwater pumped for domestic use is likely a small fraction of the total volume of groundwater use given the low population density of the area.

Groundwater flow is generally north to south and toward the axis of the valley, following the topographic gradient. Gravity data indicate a bedrock high exists at the southern end of Chalfant Valley, which either limits lateral groundwater flow to the Owens Valley or deflects flow to the west under Fish Slough where the Bishop Tuff was deposited on top of the aquifer [Pakiser and others, 1964; Bateman, 1965; Hollet and others 1991]. No direct surface-water connection exists between the Tri-Valley area and the Owens River except for an ephemeral wash that occasionally flows from Chalfant into the Laws area during extreme precipitation events.

1.2.6.2 Owens Valley Management Area

The aquifer system of the Owens Valley management area is a complex, highly heterogeneous mixture of alluvial, fluvial, and lacustrine sediments interlayered with volcanic flows bounded by the Sierra Nevada to the west and the White/Inyo Mountains to the east. While no individual aquifers or extensive zones of permeability have been defined from well log data, the groundwater system is commonly described as a two aquifers separated by a confining layer (Danskin, 1988; Hollet and others 1991; Harrington, 2016). The upper unit is unconfined, while the lower unit is confined to semi-confined (Figure 1-9). Near the margins of the valley the confining unit generally thins out and the upper and lower units coalesce and form a single hydrogeologic unit. Therefore, aquifer characteristics are dependent on the specific location within the basin.

Most of the valley fill is clastic material shed from the surrounding mountains, the majority of which is sand and gravel. Alluvial fan sediments are coarse, heterogeneous, and poorly sorted at the head of the fans and finest at the toes, beyond which fans transition to lake, delta, or fluvial plain sediments [Hollett and others, 1991]. The transition zone from fan to valley floor is characterized by relatively clean, well-sorted sands and gravels that likely originated as beach, bar, or river channel deposits. This zone is a favored location for LADWP groundwater wells because the well-sorted sandy aquifers provide high well yields. This transition zone between the alluvial fans and valley floor roughly corresponds to the alignment wellfields that supply the Los Angeles-owend lands and the aqueduct. Extraction of groundwater from the transition zone has impacted groundwater dependent vegetation such that LADWP has implemented or plans to implement a number of revegetation, irrigation, and habitat enhancement projects to mitigate the effects of groundwater pumping [County of Inyo and City of Los Angeles, 1991].

Although volcanic flows comprise a relatively small volume of the valley fill, the most transmissive aquifers in the Owens Valley management area occur in basalt flows between Big Pine and Independence. Historically, the largest springs in the Owens Valley management area occurred where high permeability basalt flows terminate against lower permeability sediments or are in fault contact with sediments. Most of these large springs stopped flowing shortly after 1970 due to increased groundwater pumping.

The Owens Valley management area aquifer system is dominated by infiltration of water from streams draining the Sierra Nevada as they flow over alluvial fans on the west side of the basin. Recharge from streams draining the Inyo Mountains on the east side of the basin also occurs, but the magnitude is much less due to the rain-shadow effect. A minor amount of recharge from direct precipitation on the valley floor also occurs, estimated to be less than 10 percent of the average annual precipitation rate [Danskin, 1998]. Deep percolation of water applied to irrigated agricultural fields is also an inflow but is partly comprised of pumped groundwater and is considered to be a small fraction of the overall water budget. Mountain front recharge may also contribute water to the aquifer system, but this process is poorly understood and therefore estimated values are highly uncertain.

Outflow from the Owens Valley management area aquifer system is primarily groundwater extracted from flowing artesian and pumped wells. Some of this water is used for irrigation, municipal, and domestic purposes within the valley, but the majority is exported out of the basin via the Los Angeles Aqueduct. Natural groundwater discharge includes evapotranspiration (ET) by phreatophytic vegetation that extract water from the shallow aquifer, discharge of water by springs and seeps, discharge of groundwater along gaining sections of the Owens River, and lateral groundwater flow to the south into the Owens Lake management area aquifer system.

1.2.6.3 Owens Lake Management Area

The Owens Lake management area is the most southern portion of the Owens Valley and the natural terminus of the basin. Prior to construction of the Los Angeles Aqueduct in the early 20th century inflows to the valley generally exceeded ET rates and formed Owens Lake, which covered more than 100 mi^2 and had depths greater than 20 ft [Danskin, 1998]. Climatic variations throughout recent geologic history created transgressive/regressive sedimentation at the lake and this depositional environment has resulted in the most stratified aquifer system in the groundwater basin, with at least five aquifers identified (Figures 3-3 through 3-8 in MWH, 2013b). All of these aquifers are confined due to the presence of a thick clay layer at the surface, with groundwater movement primarily directed upwards and towards the southern end of the brine pool (the lowest elevation of the dry lake) [MWH, 2013b].

Inflows to the Owens Lake management area aquifer system include recharge from streams draining the Sierra Nevada and Inyo/Cosos mountains as they cross over alluvial fans, down-valley groundwater flow from the Owens Valley management area, and northward seepage from

Haiwee Reservoir. Recharge enters along the margins of the Owens Lake management area, as the thick clay units that make up the playa bed combined with high ET rates and upward hydraulic gradients in the area prevent any direct recharge from precipitation.

Outflow from the Owens Lake management area aquifer system is primarily evaporation of water from the saturated clay layers that make up the playa surface and from discharge of water via springs, seeps, and flowing artesian wells. Evaporative concentration of solutes (primarily salts) in the aquifer due to the lack of a physical outlet has resulted in generally poor groundwater quality, and therefore limited pumping demand. The largest groundwater pumper in the area is the LADWP, which extracts approximately 1,500-2,000 acre-ft/yr near Olancha for agricultural irrigation when surface-water is not available. Crystal Geyser Roxane operates a bottling facility near Olancha and exports approximately 300 acre-ft/yr. The volume of groundwater pumped for municipal or domestic use is likely small due to the very low population density of the area. Groundwater extractions in the Owens Valley management area may increase in the future as LADWP is evaluating replacing some of the high-quality aqueduct water it currently uses for dust suppression activities on the playa with low-quality groundwater from the Owens Lake aquifer system [MWH, 2013a]. Owens Lake is owned and managed by the State of California; LADWP (or OVGA) activities on the lakebed must be permitted and conducted in cooperation with the California State Lands Commission.

1.3 Groundwater Flow Models

No groundwater flow model has been developed for the entirety of the Owens Valley groundwater basin. The model with the largest extent in the valley was developed by the U.S. Geological Survey (USGS) and simulates groundwater flow from the southern portion of Chalfant Valley to the southern tip of the Alabama Hills (see Figure 2 in Danskin, 1998) from October 1, 1962 to September 30th, 1988 (water years 1963-1988). This model is publically available, but of limited use as it has not been updated in over 30 years and has relatively coarse spatial (2,000 ft grid cells) and temporal (annual time steps) discretization reflective of the computational limitations at the time.

The LADWP has developed several groundwater flow models that cover the majority of the Owens Valley groundwater basin for the Owens Valley and Owens Lake management areas (Figure 1-10). Reports discussing model development have been provided by the LADWP, but repeated requests for model input files or detailed results from the LADWP models have not been fulfilled as of the date of this Tech Memo.

1.4 Data Quality Objectives

The quality of the available data evaluated in this Tech Memo were assessed with respect to sufficiency for use in GSP preparation. Members of the OVGA board, technical staff, and stakeholders must have a satisfactory level of confidence in the quality of the data which inform their decisions. Two primary data quality attributes are quantity (e.g., spatial and temporal coverage) and accuracy (see Appendix 4 of the OVGSP). Tech Memo evaluations are performed to assure that Data Quality Objectives (DQOs) are met, and that the analysis level of confidence is known and documented.

1.4.1 U.S. EPA Data Quality Objective Process

The following excerpt is from DWR's BMP #2:

> *"The GSP Regulations require GSAs to develop a monitoring network. The monitoring network must be capable of capturing data on a sufficient temporal frequency and spatial distribution to demonstrate short-term, seasonal, and long-term trends in basin conditions for each of the sustainability indicators, and provide enough information to evaluate GSP implementation. A monitoring network should be developed in such a way that it demonstrates progress toward achieving measurable objectives.*
>
> *As described in the Monitoring Protocols, Standards, and Sites BMP, it is suggested that each GSP incorporate the Data Quality Objective (DQO) process following the U.S. EPA Guidance on Systematic Planning Using the Data Quality Objectives Process (EPA, 2006). Although strict adherence to this method is not required, it does provide a robust approach to consider and assures that data is collected with a specific purpose in mind, and efforts for monitoring are as efficient as possible to achieve the objectives of the GSP and compliance with the GSP Regulations"* (DWR, 2016b).

DQOs are qualitative and quantitative statements developed through the seven-step DQO process (EPA, 2006). The DQOs clarify the monitoring program objectives, define the most appropriate types of data and conditions under which to collect the data, and specify acceptance criteria that will be used to evaluate whether the quantity and quality of data collected are sufficient to support decision making. The DQOs are used to develop a scientific and resource-effective design for data collection.

1.4.2 Basin-Specific Data Quality Objectives

The seven steps of the DQO process for this Tech Memo are presented in Table 1-1.

Table 1-1. Data Quality Objective Process

Step 1: State the Problem - define sustainability indicators and planning considerations of the GSP and sustainability goal
Historical datasets and existing monitor sites included in active monitoring networks (e.g., water quality and groundwater level data collection) are administered by independent entities that are not necessarily directly regulated by the OVGA and were designed and developed prior to SGMA with their entity specific purposes and goals. Data originally collected for other purposes must be sufficient to limit uncertainty when used to assess the sustainability indicators.
Step 2: Identify the Goal(s) - describe the quantitative measurable objectives (MOs) and minimum thresholds (MTs) for each of the sustainability indicators
Develop an OVGA monitoring program, relying on existing monitoring networks to the extent practicable, that is capable of providing sustainability indicator data of sufficient accuracy and quantity to demonstrate that the basins are being sustainably managed. MOs and MTs will be developed by the OVGA board of directors as part of the basin GSP's sustainable management criteria.
Step 3: Identify Required Information - describe the data necessary to evaluate the sustainability indicators and other GSP requirements (i.e., water budget)
Water budget components that are described in this Tech Memo include, but are not necessarily limited to, the following: • Land surface water budgets • Groundwater extraction (production) • Streamflow Additional data necessary to evaluate the sustainability indicators described in this Tech Memo include, but are not necessarily limited to, the following: • Water level data • Water quality data • Remotely sensed (satellite) data
Step 4: Define the Boundaries of the Study - This is commonly the extent of the Bulletin 118 groundwater basin or subbasin, unless multiple GSPs are prepared for a given basin. In that case, evaluation of the coordination plan and specifically how the monitoring will be comparable and meet the sustainability goals for the entire basin should be described
• Horizontal study boundaries are defined as the Owens Valley (6-012) Bulletin 118 groundwater basin. • Vertical boundaries are defined as the base of groundwater below ground surface that is of a sufficient quality and quantity that it can be beneficially used.

• There is no foreseeable temporal boundary as up-to-date water quality and water level data will continue to be necessary through GSP implementation and into the future to ensure sustainability in the basins is maintained once achieved.
Step 5: Develop an Analytical Approach - Determine how the quantitative sustainability indicators will be evaluated (i.e., are special analytical methods required that have specific data needs)
• Groundwater levels will be compared to the OVGA approved sustainable management criteria for which water level is established as a viable proxy in the basin's GSP. • Groundwater quality sample analytical results will be compared to the OVGA approved sustainable management criteria protective of water quality in the basins.
Step 6: Specify Performance or Acceptance Criteria - Determine what quality the data must have to achieve the objective and provide some assurance that the analysis is accurate and reliable
Analytical and Methodological Data Quality Objectives are described in the OVGA SAP (OVGA, 2020). The Data Gap Analysis component (Section 5) in this Tech Memo evaluates historical datasets and active monitoring sites included in current monitoring networks active in the basins. Spatial and temporal data gaps are considered in this evaluation and recommendations are presented on how refinement and expansion of the existing monitoring programs might minimize or eliminate data gaps, especially in critical areas.
Step 7: Develop a Plan for Obtaining Data - Once the objectives are known, determine how these data should be collected. Existing data sources should be used to the greatest extent possible
It is not the purpose of this Tech Memo to establish specific monitoring points but it is recognized that optimization and/or expansion of current monitoring programs may be necessary as many existing groundwater monitoring points are located outside of or adjacent to the GSP area.

1.5 Representative Monitoring Points

Representative Monitoring Points (RMPs) are a subset of the complete monitoring network within a basin [DWR, 2016b], which can be used to consolidate reporting of quantitative observations when multiple monitoring points exhibit similar behavior and trends. It is at the discretion of the GSA to adopt a single network of RMPs or identify RMPs for each sustainability indicator.

The following excerpt is from DWR's BMP #2:

> *"If RMPs are used to represent groundwater elevations from a number of surrounding monitoring wells, the GSP should demonstrate that each RMP's historical measured groundwater elevations, groundwater elevation trends, and seasonal fluctuations are similar to the historical measurements in the surrounding monitoring wells. If RMPs are used to represent groundwater quality from a number of surrounding monitoring wells, the GSP should demonstrate that each*

RMP's historical measured groundwater quality and groundwater quality trends are similar to historical measurements in the surrounding monitoring wells.

The use of groundwater levels as a proxy may be utilized where clear correlation can be made for each sustainability indicator. The use of the proxy can facilitate the illustration of where minimum thresholds and measureable objectives occur. A series of RMPs or a single RMP may be adequate to characterize a management area or basin. Use of the RMP should include identification and description of possible interference with the monitoring objective" (DWR, 2016b).

Numerous monitoring points have been established in the Owens Valley by multiple entities for various purposes (See Section 2.1.1). The majority of water levels in the basin are measured on a monthly or semi-annual basis by the LADWP or Inyo County Water Department (ICWD) as part of the LTWA. Other water level measurements in the basin include quarterly observations at solid waste (landfill) facilities, biannual observations collected as part of the California Statewide Groundwater Elevation Monitoring (CASGEM) program, observations collected monthly to biennially from public water providers, and observations collected by private well owners. From late 1997 through early 2010 hourly data is available for some shallow piezometers in the Owens Lake management area. These wells represent a viable starting point for identifying RMPs for the basin and were included in the database management system supporting the GSP development and used for trend analysis in Section 4 of this Tech Memo.

Historical Datasets

This Section describes historical datasets and Section 3 discusses existing monitoring networks in the basins that will serve as ongoing sources of data collection in the basin that will add to the historical datasets and provide additional data for analysis that will inform GSP annual reporting and 5-year updates.

An initial data transfer was received from the ICWD for use in preparation of the GSP in mid-February 2019. This dataset included available groundwater level, production, and stream gaging data collected by the LADWP and ICWD. Requests for data were made at OVGA board meetings and resulted in water levels and/or production data being provided by the City of Bishop, Eastern Sierra Community Service District, Indian Creek-Westridge Community Service District, and Wheeler Crest Community Service District. The Great Basin Unified Air Pollution Control District (GBUAPCD) provided water levels for shallow (<30 ft) piezometers and spring flow rates in the Owens Lake area. Additional well location, water level and water quality data were obtained from publically available sources.

Nearly all available groundwater level and water quality records contained in the available datasets are associated with a water well included in the OVGA well inventory (see Section 2.1.1). Spatial coordinates for six wells where water levels have been measured have not been identified. All data associated with these wells has been added to the database, but until locations are determined they are excluded from analysis. Additional information on how the OVGA intends to QA/QC data collected in the future for use in assessing sustainability in the context of the six Sustainability Indicators is available in the Sampling and Analysis Plan (Appendix 4 OVGA GSP).

The OVGA has developed an online, interactive, map-based data portal to provide the public access to data used in preparation of the Owens Valley GSP (https://Owens.GLAdata.com). This publicly accessible database includes basic querying and graphing (i.e., water level hydrographs and water quality time-series data charting) tools for public use. The ICWD plans to use this database as a repository for LADWP data for their daily operations in the future, and therefore it is anticipated to be updated regularly as additional data are collected and become available for import. The OVGA will determine the timing of acquisition and updating of other data contained in the database as funding and need requires.

2.1 Groundwater Data

Available subsurface data (e.g., well logs, groundwater levels, groundwater quality, etc.) for GSP preparation in the Owens Valley has historically been collected by several organizations. Current sources (monitoring entities) of these data are described in Section 3 of this Tech Memo. Most data are available through the Owens Valley GSP data portal.

2.1.1 Well Inventory

Well locations and construction information were primarily obtained from the ICWD and the DWR Well Completion Report database. Piezometer location and construction data was obtained from the GBUAPCD. Until development of the Owens Valley GSP, no single database contained all wells within the groundwater basin. Generally, coordinates provided by the ICWD and the GBUAPCD were for the actual well location and accurate to within a couple hundred feet or less. Coordinates obtained from the DWR are typically for the centroid of the section the well is located within, and therefore only accurate to approximately one half mile (about 2,700 ft). Locations of all identified wells in the OVGA database and subsets of wells with water level and

Table 2-1. Well Information Summary

	Groundwater Basin	GSP Area	Fish Slough and Tri-Valley Management Area	Owens Valley Management Area	Owens Lake Management Area[a]
Wells	4929	-	-	-	-
Wells with coordinates	4481	1903	287	935	681
Wells with accurate coordiantes [1]	2422	936	72	465	399
Wells with screen depth information [1,2]	1095	522	18	206	298
Wells with recent water level data [1,3]	874	123	20	62	41
Wells with recent pumping data [1,3]	179	15	0	15	0
Wells with recent water qualiy data [1,3,4]	117	83	12	62	9

1. Coordiantes do not correspond with centriod of section
2. Top of screen depth reported
3. Measurement collected since January 1, 2010
4. Limited to wells sampled for arsenic, chloride, sodium, nitrate, or total dissolved solids (TDS)
a. Includes piezometers

water quality data are shown in Figures 2-1a through 2-1c. Summary statistics for each management area are presented in Table 2-1.

A total of 4,929 wells have been identified as being located within the Owens Valley groundwater basin. Of these wells, 4,481 (91%) have reported coordinates and 2,422 (49%) have coordinates that are expected to be within 200 feet of the actual well location. The majority of wells (58%) identified in the Owens Valley are located on lands owned by the LADWP or tribal lands and therefore not subject to SGMA regulations.

It should be noted that the number of wells within the GSP area reported in Table 2-1 is overestimated. This due to the fact that the polygons shapefile of adjudicated lands obtained from the DWR omitted easements adjacent to roads and highways. Wells are commonly installed near roadways as they provide easy access for drilling equipment. This results in wells technically being located within the GSP area (as defined in Section 1.1.2) despite more accurately being associated with adjudicated lands within the groundwater basin (Figure 2-2).

Table 2-2. Well Use Summary

Well Use	Groundwater Basin	GSP Area	Fish Slough and Tri-Valley Management Area	Owens Valley Management Area	Owens Lake Management Area[a]
Agricultural	113	57	36	5	16
Domestic	1412	686	185	347	154
Flowing Artesian	77	8	0	0	8
Groundwater Monitoring	1627	577	24	234	319
Municipal and Industrial	516	208	22	140	46
Other[1]	280	63	4	44	15
Unknown	904	305	17	165	123

1. Exploratory borings, contaminant extraction wells, heat exchange wells, toes drains, vapor extraction wells, and toe drains
a. Includes piezometers.

Well use varies by management area (Table 2-2). The majority of wells in the Fish Slough and Tri-Valley management area are used for irrigated agriculture and domestic water supply. Most of the wells identified in the Owens Valley and Owens Lake management areas are used for groundwater monitoring, domestic water supply, and municipal and industrial water supply. It is assumed that most of the "Unknown" wells are used for domestic water supply and therefore considered *de minimus* users defined by SGMA.

2.1.2 Groundwater Levels

More than 535,000 water level measurements have been recorded in the Owens Valley at 1,314 wells between July 1924 and May 2020. Measurements are collected as a depth to water from a reference point, typically the top of the well casing. This value is then converted into a groundwater elevation using the elevation of the reference point. If the ground surface elevation is also known, a depth to water below ground surface (bgs) can be also be calculated. Groundwater level data assembled in the Owens Valley database were collected by multiple entities, and as such have varying degrees of data quality. Due to the sheer number of water level observations a complete review of data quality prior to development of the GSP was not possible. Priority was given to checking data quality for representative monitoring points for which sustainable management criteria are based. It is anticipated that data quality issues will be addressed as they are discovered in the future.

Depth to water in the database is reported with the z axis increasing downwards, with deeper water levels having greater absolute values. Negative values of depth to water indicate confined conditions where the water level elevation is greater than the reference point elevation for the well (flowing artesian conditions). Reported depths are primarily for static water level measurements. Pumping-depressed water levels, while useful for some purposes, are generally not included in the database. Questionable measurement qualifiers are used to flag records in the database that may not represent static groundwater level conditions. Additional information on qualifying groundwater level data is presented in the Owens Valley Sampling and Analysis Plan (Appendix 4, OVGA GSP).

2.1.3 Spring Flow

Springs and seeps occur in the valley when groundwater discharges to the land surface and provide important habitat for flora and fauna. Springs are most commonly located at the toe of alluvial fans due to a combination of geologic properties, recharge from tributary streams, and the decreased surface slope at the boundary of the fan and the valley floor. They are also found in Fish Slough where groundwater discharges along faults, and in the Owens Lake area (although some of the springs are likely not naturally occurring but abandoned flowing artesian wells).

A total of 138 springs have been identified in the Owens Valley groundwater basin, with the majority of the gaged springs flows located on LADWP adjudicated lands. The only spring flow data identified in the groundwater basin is located within Fish Slough. Monthly flow volumes for a single spring (SW3208) are measured by the LADWP.

2.1.4 Groundwater Quality

The Owens Valley database contains nearly 88,000 observations of water quality at 676 wells in the groundwater basin from September 1934 to December 2019. Data are compiled from multiple sources, including the Groundwater Ambient Monitoring and Assessment Program (GAMA), GeoTracker, GBUAPCD, and municipal water providers.

With the exception of the Owens Lake area, where evaporative concentration has resulted in naturally elevated solute concentrations, water quality on the Owens Valley groundwater basin is generally good. This explains the general lack of water quality data in the basin, and why most water quality data has been collected from wells and piezometers in the Owens Lake Area. Leaking underground storage tanks and landfills appear to be the primary source of anthropogenic groundwater contamination in the basin, and therefore are highly localized and already regulated by other agencies. No Superfund sites have been established within the groundwater basin.

Time series graphs for wells that contain at least three analytical results for arsenic (As), chloride (Cl), sodium (Na), nitrate (NO_3), or total dissolved solids (TDS) are included in Appendix D of the GSP. A trend analysis of these chemicals (analytes) is included in Section 4.1 of this Tech Memo for wells in the groundwater basin that contain sufficient data (i.e., at least six data points) to perform the analysis.

2.1.5 Groundwater Extractions

Groundwater in the Owens Valley is extracted via pumping wells or flowing artesian wells. Data requests for groundwater pumping data were made to Inyo County, Mono County, Tri-Valley Groundwater Management District (TVGMD), municipalities, community service districts, and Crystal Geyser Roxane. Responses were received by the City of Bishop, Indian Creek-Westridge community service district (ICWCSD), Eastern Sierra community service district (ESCSD), and Wheeler Crest community service district (WCCSD), with only the City of Bishop and ICWCSD having records of pumping data. Pumping for Big Pine, Independence, and Lone Pine is from LADWP-owned wells and available through the ICWD.

2.1.5.1 Fish Slough and Tri-Valley Management Area

There are no groundwater extractions within Fish Slough due to its status as an ACEC. Groundwater pumping in the Tri-Valley area is primarily used for agricultural irrigation and domestic purposes, with agriculture being the dominant use. No pumping data have been provided by Mono County or the Tri-Valley Groundwater Management District, if any exist.

Harrington [2016] estimated agricultural groundwater pumping in 2014 was approximately 21,000 acre-ft/yr, based on irrigated acreage and an assumed application rate of 5 ft/yr. This likely represents an upper limit of groundwater pumping in Tri-Valley due to irrigation efficiency improvements in the area. Taking this and the fact that some fields have access to surface water into account, agricultural groundwater pumping in the Tri-Valley area is estimated to be 13,000 to 19,000 ac-ft/yr, using an average irrigated area of 3,800 acres [DWR, 2020] and a range of 3.5 to 5 ft/yr of applied groundwater. Pumping for domestic use is expected to be about 500 acre-ft/yr as fewer than 1,000 people live in the Tri-Valley area [Mono County, 2008].

2.1.5.2 Owens Valley Management Area

Groundwater in the Owens Valley management area is extracted via pumping wells or flowing artesian wells. Monthly volumes of water extracted are recorded by the LADWP for all of their wells and these data are provided to the ICWD as part of the LTWA. This extraction data is requested and received by the ICWD annually (most recent though 2020). While these data are helpful in creating a basin-wide groundwater budget, nearly all of the wells are located on lands owned by the LADWP and therefore exempt from SGMA regulations.

There are approximately 11,000 irrigated acres in the Owens Valley management area between the Inyo-Mono county line and the northern tip of the Alabama Hills where the transition to the Owens Lake portion of the basin begins [DWR, 2020]. It is difficult to calculate the irrigated acreage within the GSP area, as the clipping artifact from omitting road easements discussed in Section 2.2.1 results in edges of fields that clearly overly lands owned by the LADWP appearing within the GSP area (Figure 2-3). Although this area is relatively small for an individual field, it becomes significant when aggregated over the basin. Less than 900 (<8%) irrigated acres overlie the GSP area and are primarily located in Round Valley west of the City of Bishop. The DWR shapefiles do not indicate the water source for each field, but aerial imagery and local knowledge of irrigation practices suggest surface-water is used for almost all of the fields. Assuming that 20% of the agricultural area within the GSP is irrigated with groundwater at a rate of 5 ft/yr, an upper limit estimate of groundwater pumping for agricultural use in the Owens Valley management area is about 900 acre-ft/yr. As more detailed identification of agricultural lands within the GSP area would most likely result in a smaller irrigated acreage within the Owens Valley management area due to the removal of the clipping artifact present in the DWR data, actual groundwater pumping for irrigation within the GSP area is expected to be lower.

Recent extraction volumes provided by the City of Bishop and the ICWCSD show the combined pumping of the two averages about 1,600 acre-ft/yr. The City of Bishop has the greatest population in the Owens Valley, and therefore represents a significant fraction of domestic water use. Other population centers in the Owens Valley management area include Laws, Big Pine, and Independence, which are provided water from LADWP wells as part of the LTWA. Although monthly pumping volumes for these wells are known, they are significantly greater than anticipated usage based on population and indicate the wells are used for purposes in addition to local municipal supply. Assuming a conservative per capita water use of 450-500 gallons per day and a population of about 14,000 people [Alpert and others, 2019], estimated groundwater pumping for domestic use in the Owens Valley management area totals about 7,000 -8,000 acre-ft/yr.

2.1.5.3 Owens Lake Management Area

Similar to the Owens Valley management area, groundwater in the Owens Lake management area is extracted via pumping wells or flowing artesian wells. The dominant groundwater use is for irrigated agriculture to the south of the brine pool. Groundwater is also used for export in the form of bottled water from Crystal Geyser Roxane, and domestic purposes. Abandoned flowing artesian wells have also become artificial springs that support wildlife habitat. Groundwater extraction in the Owens Lake management area is relatively low due to the low population density, little LADWP extraction, and generally poor water quality in the vicinity of the lake itself. Most extraction wells are located along the margin of the playa where water quality is better, because relatively low TDS concentration recharge water occurs before mixing with the high TDS concentration aquifer water under the lakebed.

There are approximately 950 irrigated acres within the Owens Lake management area, with about 500 acres (53%) located within the GSP area. Estimated groundwater pumping for fields located within the GSP area ranges from about 5,000 - 6,000 acre-ft/yr assuming application rates of 10-12 ft/yr. The high application rates in this portion of the groundwater basin are due to the high solar intensity, aridity, and wind speeds (Aaron Steinwand, personal communication).

Pumping records were requested from Crystal Geyser Roxane but no response was received. Harrington [2016] estimated the pumping volume from the bottling plant to be 300 acre-ft/yr. Population in the Owens Lake management area is approximately 1,000 people so domestic groundwater use is expected to be less than 500 acre-ft/yr. This population includes the town of Lone Pine which has a community services district serviced by two wells (W344 and W346) located outside of the GSP area on lands owned by the LADWP. Since the year 2000, extractions from these wells have averaged about 680 acre-ft/yr.

2.2 Surface-water Data

Streamflow and water quality datasets for the Owens River and its tributaries are described below.

2.2.1 Streamflow Gaging

A total of 627 stream gaging locations operated by the LADWP and the USGS have been identified in the Owens Valley watershed (Figure 2-4), with 470 having at least one flow observation collected since January 1, 2010. The majority of the stream gages in the basin are operated by the LADWP. The only active USGS gages in the basin are located within the Bishop Creek sub-watershed.

Data collected by the LADWP are typically reported as monthly volumetric flow for the gage, whereas data from the USGS are commonly reported as average daily flow rates. Excluding the Tri-Valley area, most tributaries that contribute a significant amount of runoff into the basin are gaged, and these data provide a good estimate of the runoff entering the Owens Valley. With the exception of Coldwater and Piute creeks, streams entering the Tri-Valley area are not currently nor have been historically gaged.

2.2.2 Surface-water Quality

Surface-water runoff entering the Owens Valley is primarily sourced from Sierra Nevada snowmelt and is generally considered to be excellent in quality. As a result, limited surface-water quality data has been collected in the basin, typically consisting of a single sample for a given location. As it is impossible to determine water quality trends from a single data point, and the OVGA does not have any legal jurisdiction over surface-water, these data were not assimilated into the Owens Valley database. This may change if more surface-water quality data become available in the future.

2.3 Meteorological Data

2.3.1 Precipitation

Measured precipitation data are available at several monitoring sites within the Owens Valley watershed (Figure 2-5). The majority of stations report rain or snow accumulation on a monthly basis. Hourly data is available at the Benton (BTN) and Bishop CIMIS stations.

2.3.2 Evapotranspiration

Daily reference ET (ET_0) are available at the California Irrigation Management Information System (CIMIS) station located in the City of Bishop (Figure 2-5) from February 4th, 1983 to the present. These daily values are multiplied by a crop coefficient (K_c) factor to obtain an estimate of plant water demands [Allen and others, 1998].

Estimates of ET for the Tri-Valley area are typically based on irrigated acreage, as depth to groundwater is generally deeper than what is accessible by phreatophytic vegetation except for small acreages of GDE’s outside of Fish Slough (Appendix 9 OVGA GSP). Duell [1990] estimated annual ET rates for Alkaline scrub and meadow communities between Laws and Independence from 1984-1985 in areas with relatively shallow groundwater levels (<5 ft below ground surface). Values ranged from about 11.6 in/yr at a low-density scrub site to 44.8 in/yr at a high-density meadow site. Steinwand and others [2006] estimated annual ET for similar vegetation types and shallow groundwater conditions to range from about 7.1 in/yr to 27.0 in/yr. The authors note that the growing season ET rates are similar between the two studies; Duell [1990] estimated winter ET rates that were 1.5 to 4 times greater and assumed no interannual changes in vegetation cover, an assumption that drew skepticism. Estimates of ET rates from the Owens Lake portion of the basin range from 3.4 in/yr for evaporation from bare, sandy soils to 45.0 in/yr for free-surface evaporation from the brine pool (see Table 14 in MWH 2013b).

Recently, the LADWP has contracted with Formation Environmental, LLC to develop basin-wide estimates of actual ET from the mid-1980s to the present on a monthly time step using a combination of remote sensing and monitoring stations. These data were requested from the LADWP, but has not been released as the analysis has not been completed. It is expected this data may be included in the GSP five year update.

Existing Monitoring Networks

Multiple entities have established monitoring networks in the Owens Valley groundwater basin. The largest and most frequently measured monitoring well network is maintained by the LADWP and Inyo County Water Department. The U. S. Geological Survey (USGS) has historically conducted studies in the basin, but does not routinely monitor groundwater levels or water quality. Several studies have included targeted data collection programs and have contributed to the available datasets in the basins.

Adequacy of the existing monitoring well network for evaluating groundwater level and quality spatially is discussed in Sections 5.3 and 5.4, respectively. This includes consideration of the number and distribution of wells screened discretely within in a single aquifer zone in the groundwater basin.

3.1 Groundwater Levels

Existing monitoring networks in the Owens Valley groundwater basin form the basis for the Development of the OVGA water level monitoring program that is intended to demonstrate sustainable groundwater management. Entities that collect groundwater data in the Owens Valley include, but are not limited to:

- LADWP
- Inyo County Water Department
- USGS special studies

- Municipalities (e.g., City of Bishop, community water districts, etc.)
- Landfill operators (e.g., Benton, Chalfant, etc.)
- Consultant reports and technical studies
- Private well owners and purveyors of pumped groundwater

There are 890 wells identified with recent (January 1st, 2010 and later) water level observations, most of which are operated by the LADWP (Figure 3-1a). The vast majority of these wells are located on adjudicated lands, with only 128 wells with recent water level data identified within the GSP area (Figure 3-1b). As mentioned in Section 2.1.1, this number is also an overestimate due to many of these wells being located within road easements that were not included in the adjudicated lands shapefile provided by the DWR.

Monitoring frequency varies by entity. The LADWP typically collects monthly or bimonthly measurements. Water levels at landfills in the basin are collected on a quarterly basis. Municipalities appear to collect water level data on a quarterly to annual basis. Most of the data appear to be discreet observations collected manually; there is no evidence of a groundwater level telemetry system operational in the valley. Pressure transducers appear to have been deployed in the Owens Lake area from about the mid-1990s to early 2010, but their use has been discontinued since.

3.2 Groundwater Quality

Due to the generally high quality of water in the Owens Valley, no formal network has been established to measure and monitor groundwater quality in the basin. Monitoring is typically done on a well-specific basis according to the California Regulations Related to Drinking Water, or a site-specific basis according to the California State Water Resources Control Board in response to localized groundwater contamination (e.g., leaking underground storage tank). As a result, most groundwater quality observations are clustered around population centers in the basin.

A total of 115 wells that have at least three analytical results for arsenic (As), chloride (Cl), sodium (Na), nitrate (NO_3), or total dissolved solids (TDS) and have been sampled since January 1, 2010 have been identified within the groundwater basin (Figure 3-2a), with 82 of these wells located within the GSP area (Figure 3-2b). Most of these wells are located in and around the City of Bishop, and therefore groundwater quality data are limited or nonexistent for many portions of the basin.

Trend Analysis

The trend analysis included in this Section includes evaluation of groundwater level and quality observations from select wells in the Owens Valley groundwater basin that contain sufficient data for analysis. This includes some of the LADWP wells located outside of the GSP area, as they represent the most frequently monitored wells with the longest observation records, and also provide important context for groundwater conditions within the basin as a whole. Trends for each management area are presented separately and evaluated in the context of dry, average, and wet water year types (if sufficient data exist to do so). Water year types are defined using the San Joaquin Valley Water Year (WY) Index calculated by the DWR (2020). For better readability, the water year indices were condensed into the three categories shown in Table 4-1. Consideration of the aquifer zone or zones in which a well is screened (open) is taken into account when that information is available, as it can be important in appropriately interpreting observed trends.

Table 4-2. Water year type classifications

Condensed WY Index Classification	DWR Water Year Index Classification	Representation on Hydrograph
Dry	D (dry year type). C (critical year type)	Red rectangle
Average	AN (above normal year type), BN (below normal year type)	--
Wet	W (Wet year type)	Blue rectangle

4.1 Groundwater Levels

The Sections below contain the groundwater level trend analyses for the three management areas of the Owens Valley groundwater basin. The red and blue rectangles at the bottom of the plots indicate dry and wet years, respectively (see Section 4). Well locations for each management area are shown and can also be found by searching the Owens Valley online data portal (https://owens.GLAdata.com) using the well name indicated on the plot.

4.1.1 Fish Slough and Tri-Valley Management Area

Water level trends were analyzed for four representative wells in the Fish Slough and Tri-Valley management area (Figure 4-1). Figure 4-2 shows groundwater levels for four representative wells in the Fish Slough and Tri-Valley management area. The black line on the plot displays a linear regression, with the rate of decline and coefficient of determination (R^2) displayed. In general, water levels have been slowly but steadily declining since the late 1980s. Benton and Chalfant Valleys show similar rates of decline that average about -0.5 ft/yr, with total historical declines of about 9.5 ft and 15.3 ft, respectively. Hammil Valley water levels show an even faster rate of decline of approximately -1.8 ft/yr based on limited data.

Water levels in Fish Slough also show persistent groundwater declines since the late 1980s, with timing consistent with declines observed in the Chalfant Valley. Unlike water levels in the Tri-Valley, water year type appears to have a greater influence on water levels in the Fish Slough, with water levels appearing to stabilize or even increase slightly during wet years. As a result, the rate of water level decline is lower at approximately -0.15 ft/yr.

4.1.2 Owens Valley Management Area

Groundwater levels and trends in the Owens Valley management area vary depending on time and location. This is a result of both complicated geology, the high degree of groundwater and surface-water management in the area, and the LTWA. Figure 4-3 shows the locations of representative monitoring wells in the Owens Valley management area. Generally, groundwater levels appear to be in a dynamic steady state that track hydrologic conditions: water levels increase during wet years and decrease during wet years (Figures 4-4a through 4-4d). The rate at which this increase or decrease occurs during a given dry period appears to be well-specific, likely influenced by multiple local factors such as nearby pumping, managed surface water spreading (managed aquifer recharge or MAR), well screen interval, and geologic conditions.

The two major periods of groundwater decline observed in the Owens Valley management area since 1980 coincide with the two major droughts during this period (1986-1992 and 2012-2016).

Water levels for most wells reached their lowest values during the 1986-1992 drought, due to the severity of the drought and also due to pre-LTWA water management which included the highest annual pumping totals in history by the LADWP. Water levels during the more recent drought are generally higher than the 1986-1992 period due to full, ongoing implementation of the LTWA and a reduction in LADWP pumping during later droughts. All wells appear to have recovered or mostly recovered from the 2012-2016 drought or are showing increases in groundwater levels since January 2017. Where possible, Figures 4-4a through 4-4d are annotated with the aquifer zone (unconfined or confined) the well is believed to be screened in. Wells with screen intervals within 100 ft bgs or wells with dry observations were assumed to be screened in the shallow unconfined aquifer zone.

4.1.3 Owens Lake Management Area

Groundwater levels in the Owens Lake management area are highly dependent on spatial location and screened interval of the well. This is due to a combination of effects such as the highly stratified ("layer cake") geology that results in five separate aquifers, the asymmetric depth of this portion of the basin which results in a great deal of lithostatic pressure exerted on the lower aquifers on the western side of the management area, and this area being the natural terminus of the groundwater basin. This results in water level elevations that can vary over 80 ft within the same aquifer unit (see Figure 19 in MWH, 2013b). However, within a given well, water levels show relatively minor fluctuations. Locations of representative monitoring wells are shown in Figure 4-5, with water level trends for each aquifer system discussed below.

Figure 4-6a shows water level elevations for a single well screened from 30-40 ft bgs and three shallow piezometers screened between 3 and 10 ft bgs. Water levels appear to be in a dynamic steady state condition, showing both seasonal fluctuations and multi-year trends. Water levels decrease during dry years and increase during wet periods. Pumping stress in this management area is relatively constant and low. While the piezometer data is only available through early 2010, water levels in T588 quickly recovered following the 2012-2016 drought. For the time period data are available, water levels in the shallow aquifer system have fluctuated about 16 feet in T588 (Lone Pine) and about 4 feet in the shallow piezometers.

Water level data for Aquifers 1-5 are presented in Figures 4-6b through 4-6f. Assignment of wells to a specific aquifer is the same as that presented in the LADWP's Owens Lake Updated Conceptual Model Report (see Appendix H of MWH [2013b]). Of the 58 wells assigned to Aquifers 1-5, 31 had water level data available. Water level trends are generally consistent across the aquifers, with levels decreasing during the 2012-2016 drought and then recovering during the following wet period. These fluctuations are relatively minor, typically ranging between 2 and 8 feet total for the period of record. Groundwater elevations in the lower aquifers are greater than those in the upper aquifers, resulting in a general upward gradient in the playa area of the old lake bed.

Wells T901 (Aquifer 1) and T899 (Aquifer 5) show much more stable water levels compared to the other wells screened in Aquifers 1-5. The timing of the increased groundwater levels following the 2012-2016 drought is consistent for these two wells, suggesting similar hydrologic processes are influencing their groundwater elevations. The presence of Inyo Mountain Front Fault to the east of these wells (Figure 4-5) may restrict groundwater flow and/or compartmentalize the aquifers in this portion of the management area.

The two wells that show the greatest fluctuations in water levels are River Site Lower (Aquifer 2) and SFIP MW (Aquifer 3). The high frequency and short duration of the fluctuations is attributed to pumping from wells located nearby the monitoring wells. Despite the relatively large drawdown, water levels quickly recover to their pre-pumping levels and do not show long-term decline.

Another spatially localized trend is visible in the DVF South Upper, Middle and Lower wells that correspond to Aquifers 1-3, respectively. Water levels showed larger declines during the summer of 1999 and 2000 compared to years prior and following. This is likely due to increased pumping from the LADWP in the nearby Lone Pine well field from spring 1998 through 2000. Water levels recovered the following winter in both instances. This indicates that groundwater pumping from the Lone Pine well field influences water levels in the northern portion of the Owens Lake aquifer system, but recent management of pumping has kept groundwater levels in a dynamic steady state equilibrium as evidenced by recent water levels in nearby wells T904 (Aquifer 1), River Site Lower (Aquifer 2), and T917 (Aquifer 3).

4.2 Spring Flow

Annual volumetric discharge from the gaged spring as well as total runoff from Fish Slough is shown in Figure 4-7. Flow data collected from the Fish Slough northeast spring (SW3208) show discharge has steadily decreased since the early 1990s at a rate of approximately -18 AF/yr. The rate of decline tends to increase during dry years and decrease during wet years. These data correspond with reductions of Fish Slough total annual runoff (SW3216; Figure 4-7, bottom) of about -87 AF/yr since at least 1980. Since there are no surface-water features that terminate within Fish Slough and estimated runoff from precipitation within the subbasin is only about 50 AF/yr (Appendix 10 OVGA GSP), the majority of runoff must be sourced from groundwater discharge. Since total runoff has steadily declined, either inputs (e.g., groundwater discharge) to the subbasin have decreased or outputs from the subbasin (e.g., ET) have increased. Increased ET is an unlikely explanation, as decreasing groundwater levels observed in the subbasin would ultimately lower ET rates as water would become increasingly inaccessible for use by phreatophytic plants. Therefore, the most plausible explanation for the decrease in total runoff is a decrease in groundwater discharge within the basin that ultimately becomes runoff. This is supported by the observed decrease of flow from the northeast spring (SW3208).

Gaged spring flow data from outside of the adjudicated portions of the OVGB has not been identified. As a result, no trend analysis was performed on springs located in other portions of the groundwater basin.

4.3 Groundwater Quality

The sections below contain water quality trend analyses for the three management areas of the Owens Valley groundwater basin. Constituents of general concern in the groundwater basin are arsenic, nitrate, total dissolved solids (TDS), chloride, and sodium. Both arsenic and nitrate have legally enforceable maximum contaminant levels (MCLs) of 10 micrograms per liter (μg/L) and 10 milligrams per liter as nitrogen (mg/L as N), respectively. Secondary, non-enforceable standards for TDS and chloride have been set at 500 mg/L and 250 mg/L, respectively. Sodium was included in the analysis because it is part of the conditional use permit issued by Inyo County for the Crystal Geyser Roxane water bottling plant expansion in the Owens Lake management area, although no state or federal standard has been set for it.

4.3.1 Fish Slough and Tri-Valley Management Area

Representative wells with recent water quality data in the Fish Slough and Tri-Valley management area are shown in Figure 4-8. Groundwater quality is generally good, with only CH-MW3 exceeding the secondary standard for TDS (Figure 4-9). CH-MW3 is a landfill monitoring well, so the elevated solute concentrations are likely due to proximate infiltration of leachate. The other constituents evaluated do not appear to show any significant trend, suggesting the observed concentrations are generally indicative of natural conditions in the basin. No water quality data is available for the Fish Slough subbasin as of 2018, but since there is no development in that area water quality is assumed to be consistent with natural conditions.

4.3.2 Owens Valley Management Area

Representative wells with recent analytical data in the Owens Valley management area (Figure 4-10) show groundwater quality is generally very good, with none of the representative wells exceeding any of the primary or secondary MCLs (Figures 4-11a through 4-11d). Concentrations in the representative monitoring wells for the five constituents evaluated generally appear to be stable over the last three decades. Nitrate concentrations, which are a common concern for many California groundwater basins, are typically less than 2 mg/L as N and therefore well below the MCL of 10 mg/L as N.

Elevated concentrations of arsenic above the MCL of 10 µg/L are observed in some wells (OV-32, 1400036-001, COB 1, F131, OVU-02, and OV-35) within and adjacent to the Owens Valley management area. These are naturally occurring due to the numerous volcanic deposits present in this portion of the basin which commonly contain high arsenic concentrations. Municipal wells with elevated concentrations above the MCL for a given constituent are typically operated on a stand-by basis only (City of Bishop, 2008).

4.3.3 Owens Lake Management Area

Locations of representative monitoring wells for the Owens Lake management area are shown in Figure 4-12. Each of the five aquifers has at least one well with recent water quality data for all five contaminants of concern (Figures 4-13a through 4-13e). In general, water quality in the vicinity of the lake itself is very poor due to evaporative concentration of solutes. Concentrations of most constituents evaluated appear to increase from north to south, suggesting concentrations vary more in the horizontal direction than they do in the vertical direction. While the limited number of data points makes this far from a definitive trend it is consistent with the conceptual model of groundwater flow and evaporative discharge for this portion of the basin. Concentrations of TDS, chloride, and sodium are relatively stable within a given well. Arsenic is the only constituent that shows erratic concentrations that fluctuate between non-detectable to nearly an order of magnitude greater than the MCL of 10 µg/L. Nitrate was not detected in any of the representative monitoring wells, and is typically observed at concentrations well below the MCL of 10 mg/L as N.

Analysis of Potential Data Gaps

A data (or knowledge) gap is defined in the SGMA regulations as a "lack of information that significantly affects the understanding of the basin setting or evaluation of the efficacy of Plan implementation, and could limit the ability to assess whether a basin is being sustainably managed" [23 CCR §351 (l)]. Data gaps are addressed in the SGMA regulations regarding Assessment and Improvement of Monitoring Network (a)-(e) contained in 23 CCR §354.38 (reproduced below):

(a) Each Agency shall review the monitoring network and include an evaluation in the Plan and each five-year assessment, including a determination of uncertainty and whether there are data gaps that could affect the ability of the Plan to achieve the sustainability goal for the basin.

(b) Each Agency shall identify data gaps wherever the basin does not contain a sufficient number of monitoring sites, does not monitor sites at a sufficient frequency, or utilizes monitoring sites that are unreliable, including those that do not satisfy minimum standards of the monitoring network adopted by the Agency.

(c) If the monitoring network contains data gaps, the Plan shall include a description of the following:

(1) The location and reason for data gaps in the monitoring network.

(2) Local issues and circumstances that limit or prevent monitoring.

(d) Each Agency shall describe steps that will be taken to fill data gaps before the next five-year assessment, including the location and purpose of newly added or installed monitoring sites.

(e) Each Agency shall adjust the monitoring frequency and density of monitoring sites to provide an adequate level of detail about site-specific surface water and groundwater conditions and to assess the effectiveness of management actions under circumstances that include the following:

(1) Minimum threshold exceedances.

(2) Highly variable spatial or temporal conditions.

(3) Adverse impacts to beneficial uses and users of groundwater.

(4) The potential to adversely affect the ability of an adjacent basin to implement its Plan or impede achievement of sustainability goals in an adjacent basin.

The term “potential” data gap is used in this Section since the determination of “information that significantly affects the understanding of the basin setting or evaluation of the efficacy of Plan implementation” is largely subjective. Comparison of data collection cost with respect to significance to GSP preparation, implementation, and periodic reevaluation should be

Table 5-1. Fish Slough and Tri-Valley well location and construction data

	Well Location and Construction Data	
Reported Data Type	**Number of Wells**	**Percentage of Wells (%)**
Coordinates	287	100
Accurate coordinates	58	20.2
Total depth	39	13.5
Depth to top of screen	214	74.6
Depth to bottom of screen	218	76.0
Pump depth	0	0

considered when prioritizing the filling of data gaps. In addition, not all data gaps must be filled at the time the GSP is submitted in order to produce a SGMA compliant GSP. However, flow additional data points will likely inform subsequent GSP 5-year assessments (i.e., updates). The chart depicted in Figure 5-1 is from BMP #2 and lays out the path GSA's should follow to identify and address data gaps in their sustainability planning [DWR, 2016b].

Data available in the Owens Valley groundwater basin reviewed while preparing this Tech Memo are generally of high quality, but spatial and temporal coverage vary depending on the management area. Potential data gaps are present in the historical groundwater datasets presented in Section 2 and in existing monitoring networks summarized in Section 3. A number of potential data gaps grouped by management area and data type are presented in this Section. Recommended prioritization for filling identified data gaps can be found in Section 6.

5.1 Fish Slough and Tri-Valley Management Area

5.1.1 Well Geographic Location and Construction

Data related to the location and construction of wells in the Fish Slough and Tri-Valley management area are mixed in terms of completeness. Table 5-1 summarizes the number and percentage of wells with various location and construction data relevant to developing sustainable management criteria for the GSP. Although a large percentage (nearly 75%) of wells have reported screen intervals, few wells have accurate coordinates associated with them. Minimum values for some unreported data can be inferred from other sources. For example, only 13.5% of wells have a reported total depth, but 75.7% wells have a reported depth to bottom of screen. Therefore, the bottom of screen depth could be used as a minimum value for the total depth of the well.

Unfortunately, the lack of a precise location for most wells makes the screen depth information largely unusable. This is because the high degree of topographic relief in the valley means that ground surface elevation may range by tens of feet or more within the possible area most wells are located. This level of uncertainty makes a meaningful well vulnerability assessment difficult.

5.1.2 Groundwater Level Data

Groundwater level data availability in the Tri-Valley area is generally highly localized. In the Benton Valley, only five wells associated with a landfill collect groundwater level data on a quarterly basis. Although the data from these wells is considered very high quality and dates back to the early 1990s, their lateral spacing is so close that at the scale of the valley they can be considered a single monitoring point (Figure 4-1). Currently, the OVGA database contains water levels in the Hammil Valley collected from two private wells, one (Hammil 1) with seven observations collected irregularly since July 2007 and the other (Hammil 2) with a single observation from May 2019. Monitoring wells with groundwater level data have a much greater spatial distribution in the Chalfant Valley compared to the Benton and Hammil Valleys. This is largely due to data collection by the LADWP which has installed several wells in this portion of the management area (Figure 4-1). Additional water level observations (locally known as the "Hutton" dataset) for the Tri-Valley exist, but these have not been provided to the OVGA as of the date of this report.

The lack of spatially distributed water levels in the Benton and Hammil Valleys is a significant data gap because the configuration of the water table cannot accurately be determined. Although observed water level declines have been remarkably consistent at locations where data has been collected, projecting water levels beyond the immediate vicinity of these wells is highly uncertain because local or valley-specific water table gradients cannot be calculated using only a single spatial location. Using wells across multiple valleys to calculate groundwater gradients is not advised due to the stepped topographic profile of the Tri-Valley area.

Groundwater level data availability for Fish Slough is generally good. Three wells (T397, FS-1, and Zack) have been completed and screened in the Bishop Tuff and provide an estimate of regional groundwater levels from the deeper aquifer. Two other wells (FS-2 and FS-4) are screened in the alluvial aquifer of Fish Slough. FS-4 is a very shallow well (8 ft) and has been reported dry since 2009, but FS-2 generally shows seasonal fluctuations in the alluvial aquifer with a slightly decreasing trend. Additionally, four new monitoring wells (two clusters containing a shallow and deep pair) have been installed by LADWP since 2018 in the southern portion of Fish Slough. It is anticipated that data from these wells will be added to the ICWD and OVGA databases regularly.

Table 5-2. Owens Valley well location and construction data

	Owens Valley Management Area Well Location and Construction Data	
Reported Data Type	Number of Wells	Percentage of Wells (%)
Coordinates	938	100
Accurate coordinates	297	31.7
Total depth	240	25.6
Depth to top of screen	507	54.1
Depth to bottom of screen	516	55.0
Pump depth	0	0

5.1.3 Groundwater Quality Data

Wells where groundwater quality has been recently sampled multiple times is limited to the Benton and Chalfant Valleys (Figure 4-8). Although spatial coverage of water quality data is limited, anthropogenic (human-caused) sources of groundwater contamination are considered to be limited due to the rural nature of the area. Since agriculture and ranching are the dominant land uses, nitrate would be the most likely constituent with non-naturally elevated concentrations. However, nitrate concentrations are well below the MCL of 10 mg/L as N for all samples collected (Figure 4-9). These observed concentrations are consistent with the dominant crop type being alfalfa, which does not require significant N-fertilizer application as it fixes is own nitrogen in the soil. Trends for the five evaluated constituents appear to be generally stable, and indicative of naturally occurring conditions.

5.1.4 Groundwater Extraction Data

No groundwater extraction data have been provided for wells within the Fish Slough and Tri-Valley management area. Estimates of groundwater pumping are typically calculated using an assumed application rate (typically 3-5 ft/yr) and the irrigated area (about 3,900 to 4,200 acres). Groundwater pumping in the Hammil Valley appears to be greater than in the Benton and Chalfant Valleys based on irrigated acreage [Harrington, 2016] and rate of groundwater level decline (Figure 4-2).

5.2 Owens Valley Management Area

5.2.1 Well Construction and Geographic Location

Nearly 940 wells have been identified within the Owens Valley management area, although this number is overestimated due to artifacts in the DWR adjudicated lands shapefile (see Section

2.1.1). Approximately one-third of these wells have accurate spatial coordinates, with half of the wells being located at section centroids. Screen depths are reported for a little over half of the wells, but as discussed in Section 5.1.2 the lack of accurate spatial data combined with the high degree of topographic relief and varying well construction over time in the valley currently precludes a meaningful well vulnerability assessment.

5.2.2 Groundwater Level Data

Spatial observations of groundwater levels within the Owens Valley management area are generally sparse since the majority of the groundwater monitoring is conducted by the LADWP on adjudicated (SGMA-exempt) lands. The LADWP groundwater monitoring network includes a small number of wells located within or immediately adjacent to the GSP area on the west side of the management area from Aberdeen to Lone Pine Creek (Figures 4-4c and 4-4d). Although the sampling frequency of these wells is quite high, they are spaced about 2.5 miles or greater apart. Most of Round Valley, located northwest of the City of Bishop, and numerous small segments of the basin along the western margin of the GSP area do not have nearby water level data. The largest portion of the management area without any groundwater level information is the eastern side, particularly near Crooked Road Canyon, along Death Valley Road, and Harkless Flat. However, this area contains isolated public lands which are undeveloped.

5.2.3 Groundwater Quality Data

The majority of wells used as representative monitoring points for groundwater quality in the Owens Valley management area are typically located either outside of the GSP area or near the down-gradient boundary with adjudicated lands. The lack of water quality observations within the GSP area is not necessarily a problem, since the constituents being evaluated will be transported in the same direction as groundwater flow. Therefore, if a representative monitoring point is along a flow path coming from the GSP area, then concentrations in that well will be a reflection of concentrations in the GSP area upstream if there is no significant mixing of water coming from another source.

The spatial and temporal coverage of the water quality data from the representative wells is generally good for the western portion of the management area, with multiple samples collected at most wells for each of the constituents evaluated. The population centers of the City of Bishop, Big Pine, and Independence all have relatively dense water quality observations. The largest portion of the management area lacking water quality information is the eastern side where no water quality data has been identified, either within the GSP area or down-gradient of it. This data gap is largely due to the lack of development and use of groundwater from this area.

5.2.4 Groundwater Extraction Data

The vast majority of groundwater extraction in the Owens Valley management area occurs from pumping or flowing artesian wells on adjudicated lands owned by the LADWP. Pumped volumes for each well are measured on a monthly basis, and provide an accurate assessment of total groundwater pumping in the basin. Annual groundwater extractions from the entire Owens Valley (including adjudicated lands) range from about 52,000 acre-ft/yr to 92,000 acre-ft/yr (LADWP Annual Operations Plan). Assuming uses within the Owens Valley management area total about 9,000 acre-ft/yr (see Section 2.1.5.2), pumping by the LADWP accounts for approximately 80 to 90% of groundwater extractions in the Owens Valley.

Pumping within the Owens Valley management area is assumed to be localized to population centers (e.g., City of Bishop, Big Pine, Independence, etc.) given the low population density of the basin, lack of available private land, few industrial users, and the low acreage of private agricultural fields. Two of the municipal water providers in northern portion of the management area, the City of Bishop and Indian Creek-Westridge Community Services District, have provided the volume of groundwater pumped on a monthly basis since about 2013. Groundwater used by Laws, Big Pine, and Independence is provided by LADWP wells and therefore metered, but those wells appear to be used for purposes in addition to local municipal supply. The few remaining municipal water suppliers in the management area that have either not provided pumping data or do not measure it represent a small number of connections and therefore have relatively limited extraction volumes.

5.3 Owens Lake Management Area

5.3.1 Well Construction and Geographic Location

The Owens Lake management area has been the focus of numerous hydrogeologic investigations since the mid-1990s due to it being one of the largest sources of dust pollution in the U.S. Documentation and reporting of new wells drilled or piezometers installed for these projects is generally very good, particularly by MWH [2013a] where they identified wells screened within each of the five stratified aquifers. Generally, the distribution of wells both horizontally and vertically appears to be sufficient for developing SMCs for the management area.

Table 5-3. Owens Lake well location and construction data

Owens Lake Management Area Well Location and Construction Data		
Reported Data Type	**Number of Wells/Piezometers**	**Percentage of Wells/Piezometers (%)**
Coordinates	506	100
Accurate coordinates	204	40.3
Total depth	152	30.0
Depth to top of screen	316	62.5
Depth to bottom of screen	316	62.5
Pump depth	0	0

5.3.2 Groundwater Level Data

Prior to 2010, most groundwater level data in the Owens Lake management area was collected by the GBUAPCD. Pressure transducers that recorded water levels at 15-minute intervals were installed in numerous shallow piezometers and wells starting in mid-1997. In 2010, groundwater level monitoring was transferred from the GBUAPCD to the LADWP. Although water levels continued to be monitored in these wells, the data were stored in a different database than the one LADWP routinely provides to the ICWD as part of the LTWA. This was not realized until after GSP data assimilation tasks had been completed, and the format of the water level data for these wells requires significant manual processing. As of the date of this report these data are not included in the OVGA database nor in any statistical analyses used to develop sustainable management criteria (SMCs). However, their addition into the OVGA database will be given high priority and included in the 5-year update. Additional wells in the Owens Lake management area have been added to the LADWP monitoring network since 2010, and water level observations recorded in these new wells have been assimilated into the OVGA database. Water level trends pre- and post-2010 for the Owens Lake management area appear to be similar and stable, so the omission of post-2010 data for some wells is not anticipated to significantly change interpretations or statistical analyses performed in this area.

With the exception of Aquifer 4, each of the Owens Lake management area aquifers has multiple wells spatially distributed around the playa. There is only one well (DVF North MW) currently identified as being screened in Aquifer 4 and is located on the northern edge of the playa. However, water level trends are correlated with spatial position of the well as opposed to which aquifer the well is screened with in, so other wells may be used as proxies for conditions in Aquifer 4. Furthermore, if conditions in Aquifers 3 and 5 are known then conditions in Aquifer 4 can be reasonably estimated.

5.3.3 Groundwater Quality Data

Prior to 2010 water quality was monitored on an approximately annual basis at multiple wells in Aquifers 1-4, and at a single well in Aquifer 5. The trend analysis in Section 4.4.3 shows that solute concentrations are naturally elevated but stable. Since monitoring was transferred to the LADWP in early 2010, water quality results that include the five constituents evaluated for the GSP are only available near the population centers of Lone Pine and Olancha.

According to a report titled "Baseline Groundwater Quality at Owens Lake" [LADWP, 2020a], water quality sampling has been conducted in 2011, 2014, 2016, 2017, and 2019. These data have not been incorporated into the OVGA database because sampling dates were not included in the report. This report also identifies "shallow," intermediate," and "deep," depth classes for wells instead of assigning wells to a specific aquifer, possibly because they are screened across multiple aquifers.

5.3.4 Groundwater Extraction Data

Measured groundwater extractions near Owens Lake are only available at LADWP production wells located on adjudicated lands. There are no groundwater extraction data for any wells within the Owens Lake management area. Known groundwater extractions include pumping by Crystal Geyser just north of Olancha for export as bottled water, irrigation of a small number of agricultural fields to the south of Olancha, municipal and domestic use for the small number (<500) of people that live in the area, and recreational use at a 6 acre water ski pond. Pumping volumes from Crystal Geyser have been requested multiple times with no response.

Groundwater pumping volumes for LADWP wells outside of the GSP area are available for several wells located near Lone Pine and a single well located near Olancha. Pumping brackish water from the aquifers beneath Owens Lake for use in dust control management has been proposed by the LADWP and would be evaluated in a CEQA EIR. While this project is still in the evaluation phase, groundwater pumping in the area will increase significantly if it is ultimately approved. If this happens, re-evaluation of the current groundwater monitoring network is recommended.

Data Gaps Summary and Priority Ranking

This final Section summarizes and prioritizes recommendations on how refinement and or expansion of the existing monitoring networks in the basin might minimize or eliminate data gaps. GSP preparation and submittal to the DWR by January 2022 is will utilize to the extent possible the previously collected data described in this Tech Memo. Due to financial and logistical constraints, the recommendations offered here are not anticipated to be included in the initial version of the GSP. However, they can be used to inform the required 5-year update assessments and annual reporting. Direct actions to fill data gaps include:

- Increasing monitoring frequency. For example, increasing water level measurements at a specific well from twice per year (typically spring and fall) to four per year (quarterly) or more.
- Increasing the spatial distribution and density of the monitoring network. For example, install new monitoring wells or add monitoring data from existing wells in locations that currently have sparse coverage.
- Increasing the quality of data through improved collection methods and data management methods.

A number of data gaps and potential existing monitoring network enhancements were identified in Section 5. Prioritization levels are used to rank OVGA monitoring program recommendations included herein. Priority ranking is “value added” such that the improved ability to understand the basin setting, determine SMCs, or evaluate basin sustainability is weighed against the cost of collecting the data. For example, it could be advantageous to only use groundwater data collected from properly constructed, multiple-well monitoring sites with completions in each of the aquifer zones in the GSP area and monitored on a daily basis. This would greatly decrease GSP analysis uncertainty and would be consistent with the DWR’s data quality recommendations. However, the additional installation and monitoring cost would be extremely prohibitive for the members of the OVGA and the relatively small number of rate payers they represent, especially given the current “Low” prioritization status of the basin and the frequency of observed groundwater level fluctuations.

The sections below describe the data gaps ordered from “High” to “Low” priority ranking, a justification for the assigned ranking, and a recommendation for filling the data gap. These are summarized in Table 6-1.

Table 6-1. Summary of data gaps and prioritization

Priority Ranking	Management Area	Data Gaps Summary	Recommended Action
High	Fish Slough and Tri-Valley	Limited spatial distribution of water levels for Benton and Hammil Valleys.	Implement a well registration and reporting program. Conduct single monitoring campaign at as many wells as possible. Use information obtained from sampling campaign to inform which wells should be added to the existing monitoring network.
High	Fish Slough and Tri-Valley	Limited well coordinate accuracy for Tri-Valley wells.	Obtain better well location information or GPS coordinates of wells measured during monitoring campaign.
High	Fish Slough and Tri-Valley	Lack of subsurface flow information.	Development of a physically based numerical groundwater flow model of the Fish Slough and Tri-Valley area.
Medium	Fish Slough and Tri-Valley	Limited information regarding groundwater extraction volume.	Development of an agricultural water demand model, installation of flow meters on agricultural production wells, or estimation of pumping rates and volumes using power consumption.
Medium	Owens Valley	Limited well coordinate accuracy and well construction data for private domestic wells.	Field inspections by ICWD staff as time allows to update well location and construction information.
Medium	Owens Lake	Most recent water quality observations in the OVGA database are pre-2010.	Assimilate water quality data collected by LADWP since 2010 into OVGA database.
Medium	Owens Lake	Missing Crystal Geyser Roxane bottling plant groundwater extractions.	Obtain groundwater extraction volumes from Crystal Geyser Roxane.
Medium	Owens Valley and Owens Lake	Lack of subsurface flow information.	Obtain groundwater flow models from the LADWP or relevant information from selected model input and output files.
Low	Fish Slough and Tri-Valley	Limited spatial distribution of water quality data.	Additional water quality sampling if grant or other funds become available.
Low	Owens Valley	Limited groundwater elevation data for some portions of the	Additional water level sampling if grant or other funds become available.

Table 6-1. Summary of data gaps and prioritization (cont.)

Priority Ranking	Management Area	Data Gaps Summary	Recommended Action
Low	Owens Valley	Limited groundwater quality data for some portions of the management area.	Additional water quality sampling if grant or other funds become available.
Low	Owens Valley	Groundwater extractions from some municipal water system within the GSP area.	Obtain missing groundwater extraction data for municipal water suppliers if available. Install flow meters on municipal production wells if grant or other funds become available.
Low	Owens Lake	Limited well coordinate accuracy and well construction data for private domestic wells.	Field inspections by ICWD staff as time allows to update well location and construction information.
Low	Owens Lake	Limited water level data for Aquifers 2 and 4 since 2010.	Assimilate water level data collected by LADWP since 2010 into OVGA database.

6.1 High Priority Data Gaps

High priority data gaps are those that significantly limit the understanding of the basin setting, the ability to establish SMCs, or to evaluate basin sustainability. While these data gaps are unlikely to be addressed in the GSP that will be submitted to the DWR in January 2022, it is highly recommended they are addressed within the first 5-year required update of the GSP.

6.1.1 Benton and Hammil Valley Water Levels

The current water level monitoring network in the Benton and Hammil Valleys is insufficient for mapping the water table surface within each respective valley. Without a reasonable estimation of the location of the water table, a meaningful well vulnerability assessment is difficult and heavily reliant on assumed conditions. This adds considerable challenges and uncertainties when developing SMCs, especially since water levels have been slowly but consistently declining in the Tri-Valley area for decades.

Filling of this data gap is recommended in two stages. The first would be to conduct a single monitoring campaign at as many existing wells (Figure 6-1) as possible in order to construct a detailed map of water level elevations within each valley. Using this information, the optimum number of monitoring wells to add and their locations can be determined. A minimum of three wells spaced sufficiently far apart is required for determining the orientation of a sloped surface.

Therefore, it is recommended a minimum of two additional wells be added to each of the monitoring networks in the Benton and Hammil Valleys if the water table surface is not overly complex. Additional monitoring wells may be necessary to characterize the water table surface if the geometry is more complicated than a simple sloped surface.

6.1.2 Tri-Valley Well Construction and Geographic Location

Although there is a relatively high percentage of wells with screen depths reported in the Tri-Valley, as discussed in Section 5.1.1 the lack of accurate location data limits accuracy of a well vulnerability assessment Furthermore, well locations and measurement points must be known within a reasonable degree of accuracy for any water level observations collected from them to be of use. Collecting water level data from existing wells is the most expedient and cost-effective solution for filling the data gap discussed in Section 6.1.1. Therefore, any wells added to the Tri-Valley groundwater monitoring network (either temporarily or permanently) should have more accurate location information than the centroid of the section the well is located within. With most smart phones having the ability to display and/or record GPS coordinates, reasonably accurate spatial locations can be easily determined during sampling. Depending on availability and completeness, driller's logs could then be used to cross reference existing wells in the OVGA database with these new coordinates.

6.1.3 Fish Slough and Tri-Valley Numerical Groundwater Flow Model

Correlations in water level declines observed in Fish Slough and Tri-Valley (Figure 4-2), the intersection of the Fish Slough fault zone with the southern portion of the Hammil Valley [Jayko and Fatooh, 2010], geochemical identification of Fish Slough source water [Zdon and others, 2019], geophysical data [Pakiser 1964; Hollet 1991], and the general topography of the area strongly indicate that some portion of water discharged within Fish Slough is sourced from the Tri-Valley area. The lack of a groundwater flow model prevents further investigation of the proportion of water Fish Slough receives from the Tri-Valley area compared to the portion received from the northwest portion of the watershed (Long Valley) through the Volcanic Tablelands. Understanding the degree of connectivity between these two source areas and Fish Slough is necessary for future refinement of SMCs that protect the unique habitat of Fish Slough while not being overly restrictive on Tri-Valley users and stakeholders.

The development of a physically based numerical groundwater flow model of the Fish Slough and Tri-Valley area is highly recommended. Two land surface models that simulate precipitation, ET, runoff, and recharge are available for the area. The first was developed by the USGS using the Basin Characterization Model (BCM) as part of a statewide modeling effort, and the second was a finer resolution, basin-specific effort developed by DBS&A using the Distributed Parameter Watershed Model (DPWM; Appendix 10 OVGA GSP). These land surface models can be used to inform boundary conditions required for a groundwater flow model, specifically the seasonal and inter-annual groundwater recharge that is spatially distributed across the basin.

6.2 Medium Priority Data Gaps

Medium priority data gaps are those where information is available but limited in spatial coverage and/or sampling frequency. Filling of these data gaps would either strengthen the monitoring network used to demonstrate basin sustainability, or help refine SMCs in some management areas. While these data gaps are unlikely to be addressed in the GSP that will be submitted to the DWR in January 2022, it is recommended that they are addressed within the first 5-year required update of the GSP if funding sources are available.

6.2.1 Tri-Valley Groundwater Extractions

Measured values of groundwater extractions in the Tri-Valley area either do not exist or have not been provided by the TVGMD. Agricultural pumping is assumed to be the predominant use of groundwater given the very low population density of the area. Estimations of annual pumped volume have been made using a simplified approach that multiplies the irrigated acreage in Tri-Valley by an assumed application rate of 5 ft/yr [Harrington, 2016]. While this provides a general estimate that is useful for long-term average water budgets, it does not account for the numerous complicating factors involved with agricultural irrigation (e.g., mixed water sources, soil properties, irrigation method, crop rotation patterns, precipitation timing, etc.) that can result in different pumped volumes from year to year. Furthermore, development of a numerical groundwater flow model of the Tri-Valley would require assignment of groundwater pumping to specific wells.

More detailed estimation of groundwater pumping, or metering of pumping volumes from agricultural wells, is recommended. This would help refine inter-annual water budgets and boundary conditions for a groundwater flow model. The most cost-effective way to achieve more detailed pumping estimates would be to use an agricultural crop-water demand model that simulates plant demands on a daily basis. These models are relatively inexpensive to develop and can provide well-specific estimates of groundwater pumping. An advantage of this method is that future crop demands that take into account climate change can also be estimated.

Another approach for refining groundwater extraction data in the Tri-Valley area would be to install flow meters on agricultural wells. While this would provide more accurate pumping data compared to the modeling approach, it is likely cost-prohibitive and several years of data collection would be required to observe any inter-annual changes in groundwater pumping, if they exist. Alternatively, power usage at wells combined with knowledge of the depth to water can be used to estimate the volume of groundwater pumped. The lack of water level observations in the Tri-Valley would add additional uncertainty to the power usage analysis. Using either approach, additional work would be required to estimate the effects of climate change on future pumping rates. Therefore, the modeling approach is currently recommended as it provides the best value for filling the groundwater extraction data gap.

6.2.2 Owens Valley Management Area Well Construction and Geographic Location

Private wells in the Owens Valley management area are the most likely to have the greatest location uncertainty as the coordinates provided by the DWR are typically the centroid of the section they are located within. As discussed in Section 5.1.1, the high degree of topographic relief in the valley precludes a meaningful well vulnerability analysis for inaccurately located wells. While a well vulnerability assessment is important and should be completed, this data gap has been classified as a medium priority due to water levels in the area being either stable or showing inter-annual trends consistent with water year type. That is, water levels generally decrease during dry periods and increase during wet years. Deviations from this trends are attributable to LADWP pumping, which is constrained by the LTWA. Therefore, defensible SMCs can be developed using the lowest water levels from the 2012-2016 drought as the minimum threshold as a substitute for a full vulnerability analysis. Accurate well locations can be determined by field inspections as staff time allows before the first 5 year plan review. These SMCs can be refined if needed at that time.

6.2.3 Owens Lake Groundwater Quality

Prior to 2010, before monitoring was transferred from the GBUAPCD to the LADWP, water quality data was generally collected at multiple wells in each aquifer on an approximately annual basis. Groundwater quality observations in the OVGA database sampled post 2010 have been collected primarily from wells with mostly unreported screen depths. Without a reported screen interval depth it is impossible to assign the well, and observations obtained from it, to a specific aquifer. The water quality trends for the Owens Lake area presented in Section 4.3.3 indicate concentrations are relatively stable and generally correlated with horizontal position on the playa rather than with a specific aquifer. Similar behavior was observed with water level trends (see Section 4.1.3) and indicates compartmentalization of the aquifer due to restriction of flow across faults in the area. Better descriptions of the well construction information may be available and should be pursued by the OVGA before the first 5 year update.

Groundwater quality observations that are not currently in the OVGA database have been identified in a recent LADWP report [2020a], and states that water quality data have been collected in 2011, 2014, 2016, 2017, and 2019. Wells identified in that report appear to be some of the same wells as those sampled by the GBUAPCD, so assimilation and cross checking well names and locations and the data contained within it will likely fill the current data gap of not having water quality observations in the representative monitoring wells post 2010 (see Figures 4-13a through 4-13e). The complete dataset of water quality results sampled post 2010 should requested from the LADWP and incorporated into the OVGA database. If these wells are routinely sampled by the LADWP and the data made available to the OVGA, then additional water quality sampling would not be considered necessary.

6.2.4 Owens Lake Groundwater Extractions

Since groundwater extraction in the Owens Lake management area is assumed to be relatively small due to the low population density and lack of agriculture, the volume of groundwater pumped by the Crystal Geyser Roxane bottling plant near Olancha likely represents a significant portion of total groundwater extractions in the area and could better inform the groundwater budget. As mentioned in Section 2.1.5.3, requests for these pumping data from Crystal Geyser Roxane have not been responded to. Filling this data gap would require minimal investment of resources as it is assumed to have already been collected by Crystal Geyser Roxane as part of their operations.

6.2.5 Owens Valley and Owens Lake Numerical Groundwater Flow Models

As discussed in Section 1.3, groundwater flow models that collectively cover the majority of the Owens Valley and Owens Lake management areas have been developed by the LADWP. Review of the model documentation provided by the LADWP indicates that these models would be useful for certain GSP elements that are currently poorly defined or unknown, such as historical groundwater budgets and simulated water level elevations in areas with few monitoring wells. In addition, these models could potentially be used to estimate future water budgets using climate change factors provided by the DWR. The LADWP declined an initial request for the model files. A subsequent request for model output files along with selected input files that contain relevant aquifer geometry and which aquifer wells are screened in was not responded to.

6.3 Low Priority Data Gaps

Low priority data gaps are those where additional data collection would only marginally improve the understanding of the basin setting, ability to establish SMCs, or evaluate basin sustainability. This is generally because the existing monitoring networks and historical data sets are generally sufficient and other sources of information (e.g., land use, population, etc.) can be used to make reasonable assumptions about conditions that affect the hydrologic system. These data gaps will not be addressed in the GSP that will be submitted to the DWR in January 2022. It is recommended these data gaps only be filled if funding sources are available and the high and medium data gaps discussed above have already been addressed.

6.3.1 Fish Slough and Tri-Valley Water Quality

Water quality data in the Fish Slough and Tri-Valley management area is only available at a small number of clustered wells in the Benton and Chalfant Valleys. Groundwater flow is generally from north to south with a fork near Hammil Valley. This results in two regional flow paths that both begin in Benton Valley: one that flows toward Hammil Valley and then towards Fish Slough, and the other which flows toward Hammil Valley and then continues south toward Chalfant Valley. Solute concentrations in Chalfant Valley are similar to those in Benton Valley (except for TDS which is discussed in Section 4.3.1), indicating there is no significant source in Hammil Valley or Fish Slough for the five constituents evaluated. This is consistent with the rural nature of the area and the primary agricultural crop being alfalfa, which does not require nitrogen fertilization. Additional water quality sampling could be performed in Hammil Valley and Fish Slough, but would likely show similar concentrations as those observed in Benton and Chalfant Valleys.

6.3.2 Owens Valley Management Area Groundwater Levels

There are relatively few monitoring wells located within the GSP area, and those that are within the GSP area are typically located just inside near the boundary with the adjudicated (SGMA exempt) lands. In order to develop SMCs for the area a combination of existing monitoring well, land use, population density data, and hydrologic expertise is required. Since the majority of the Owens Valley management area is owned by federal and state agencies (Figure 6-2) and therefore lacking in private (i.e., developable) land, the uncertainty typically associated with predicting the effects of groundwater pumping in areas with limited data is significantly reduced. Additional monitoring points within the GSP area would provide more direct evidence that the area is being managed sustainably.

Filling this data gap can be accomplished by adding existing wells to the monitoring network, or drilling new monitoring wells. Adding existing wells is generally the most cost-effective way to expand a monitoring well network, as there is considerable expense associated with drilling new wells. Figure 6-3 shows the locations of existing wells that could potentially be added to the monitoring network. The lack of existing wells identified in the GSP area suggests that groundwater use in most of the Owens Valley management area is likely limited, consistent with inferences drawn from land use and population data.

6.3.3 Owens Valley Management Area Groundwater Quality

A large portion of the wells used to assess groundwater quality conditions in the Owens Valley management area are located outside or just within the GSP area. Groundwater in this area generally flows from the alluvial fans along the margin to the axis of the valley, and then to the south. The wells used as representative monitoring points are located at or near the end of flow paths coming from the GSP area, and therefore water quality results from them are a culmination of the processes happening within the GSP area. The low solute concentrations observed in the representative monitoring wells indicate there are so significant sources of the five constituents of concern evaluated within the GSP area. This is consistent with the hydrologic conceptual model of the basin where high quality water derived from Sierra Nevada snowmelt recharges groundwater as tributaries flow across alluvial fans along the margin of the basin. This, combined with a lack of development and therefore potential sources of contamination, is strong evidence that water quality within the Owens Valley management area is high. Additional water quality sampling could be performed within the GSP area, but would likely produce similar results as wells located outside the GSP area.

6.3.4 Owens Valley Management Area Groundwater Extractions

Pumping by the LADWP represents the vast majority of groundwater extractions that occur within the groundwater basin. The two water suppliers within the GSP area that have provided recent pumping volumes, the City of Bishop and the Indian Creek-Westridge Community Services District, represent a large portion of the population within the GSP area that relies on groundwater. Pumped volumes from the remaining public water suppliers are unlikely to significantly alter our understanding of the groundwater budget, since the extracted volume is expected to be small relative to the pumping volumes already collected. Communities within the valley are unlikely to expand in the future because either LADWP or other public agencies (state or federal) own the surrounding land, so increased demand due to population growth is not considered to be a significant concern. The lack of chronic groundwater declines indicates that current pumping rates do not exceed long-term recharge rates. Therefore, historical or future pumping data collected from wells collected as part of a water supplier's internal operations can be easily incorporated into the GSP, but installation of new equipment to monitor groundwater pumping is not considered to be cost-effective at this time.

6.3.5 Owens Lake Well Construction and Geographic Location

Recent geologic, hydrologic, and geophysical investigations in the Owens Lake management area, particularly those performed by the GBUAPCD and MWH as part of the Owens Lake Groundwater Evaluation Project (OLGEP), have resulted in a number of monitoring wells screened within each of the five stratified aquifers. Several of these wells are nested, allowing for both horizontal and vertical comparison of water level and quality data. Private wells with inaccurate coordinates are less of a concern in the Owens Lake area because water levels are generally very stable and near or above the land surface (flowing artesian conditions), and the topographic relief of the area is much lower compared to the rest of the GSP area. A simple inventory of any wells that went dry during the 2012-2016 drought (OVGA staff are unaware of any dry wells) could be done in lieu of a more formal well vulnerability assessment required for the other GSP management areas.

6.3.6 Owens Lake Groundwater Levels

Groundwater level monitoring data post 2010 in the OVGA database is primarily from Aquifers 1 and 5 and conducted on a monthly basis. With current levels of groundwater pumping, which are minimal, additional monitoring of water levels in Aquifers 2-4 is not considered to be necessary. This is because the current and natural state of the aquifer system is generally upward vertical flow. Groundwater levels in the middle aquifers must therefore be some elevation between those found in Aquifers 1 and 5. Significant pumping from Aquifers 2-4, such as that proposed by the LADWP as part of their Owens Lake Groundwater Development Project (OLGDP), could change this so re-evaluation of the monitoring network would be necessary.

Additional water level data not present in the OVGA database have been identified in a quarterly monitoring report from the LADWP [2020b]. These data appear to be from the same monitoring well and piezometer network established by the GBUAPCD, whose locations are in the OVGA database. These water level data should be requested from the LADWP and assimilated into the OVGA database.

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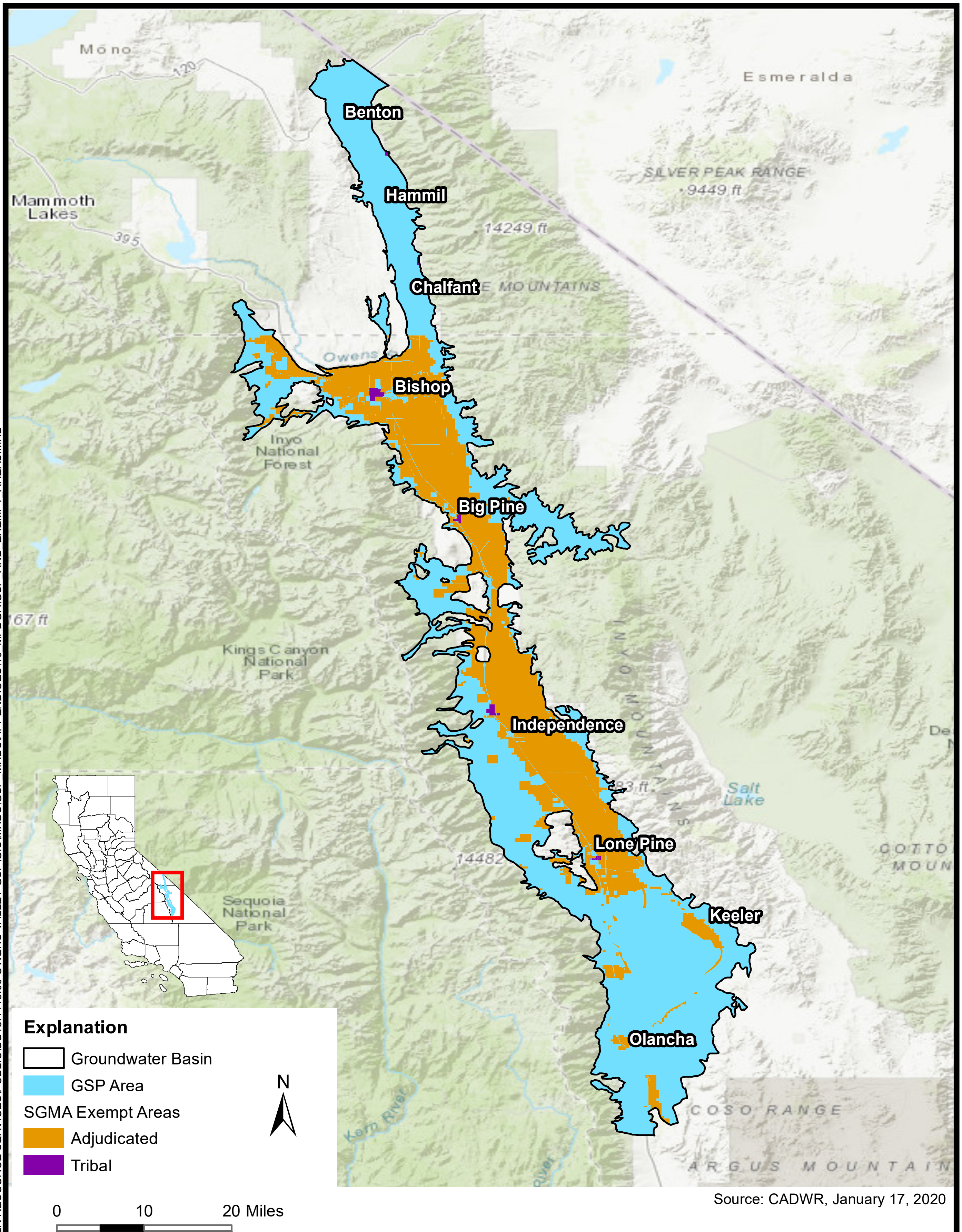

Source: CADWR, January 17, 2020

MONITORING PLAN AND DATA GAPS ANALYSIS

Groundwater Sustainability Plan Area and Lands Exempt from SGMA

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Figure 1-1

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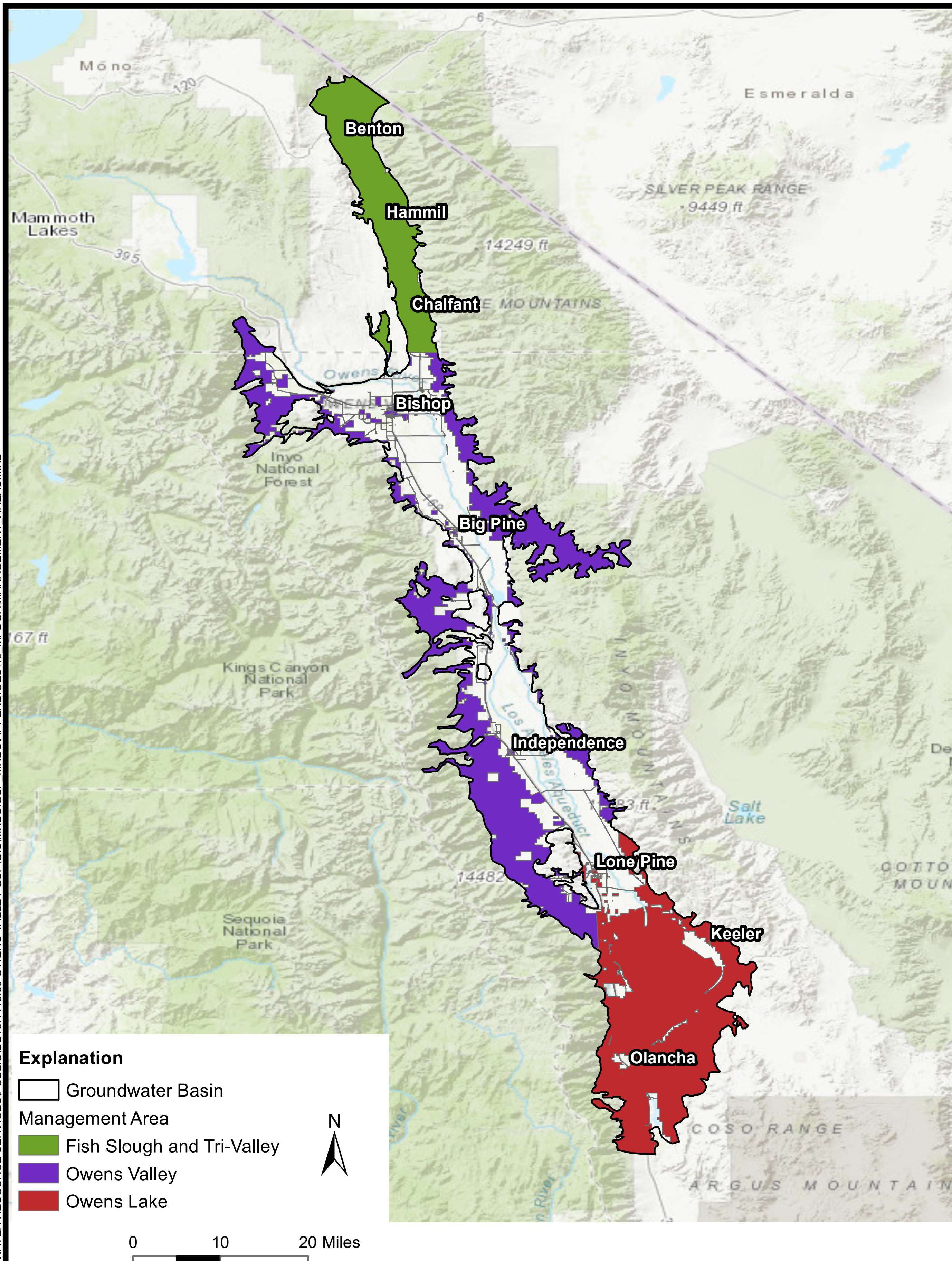

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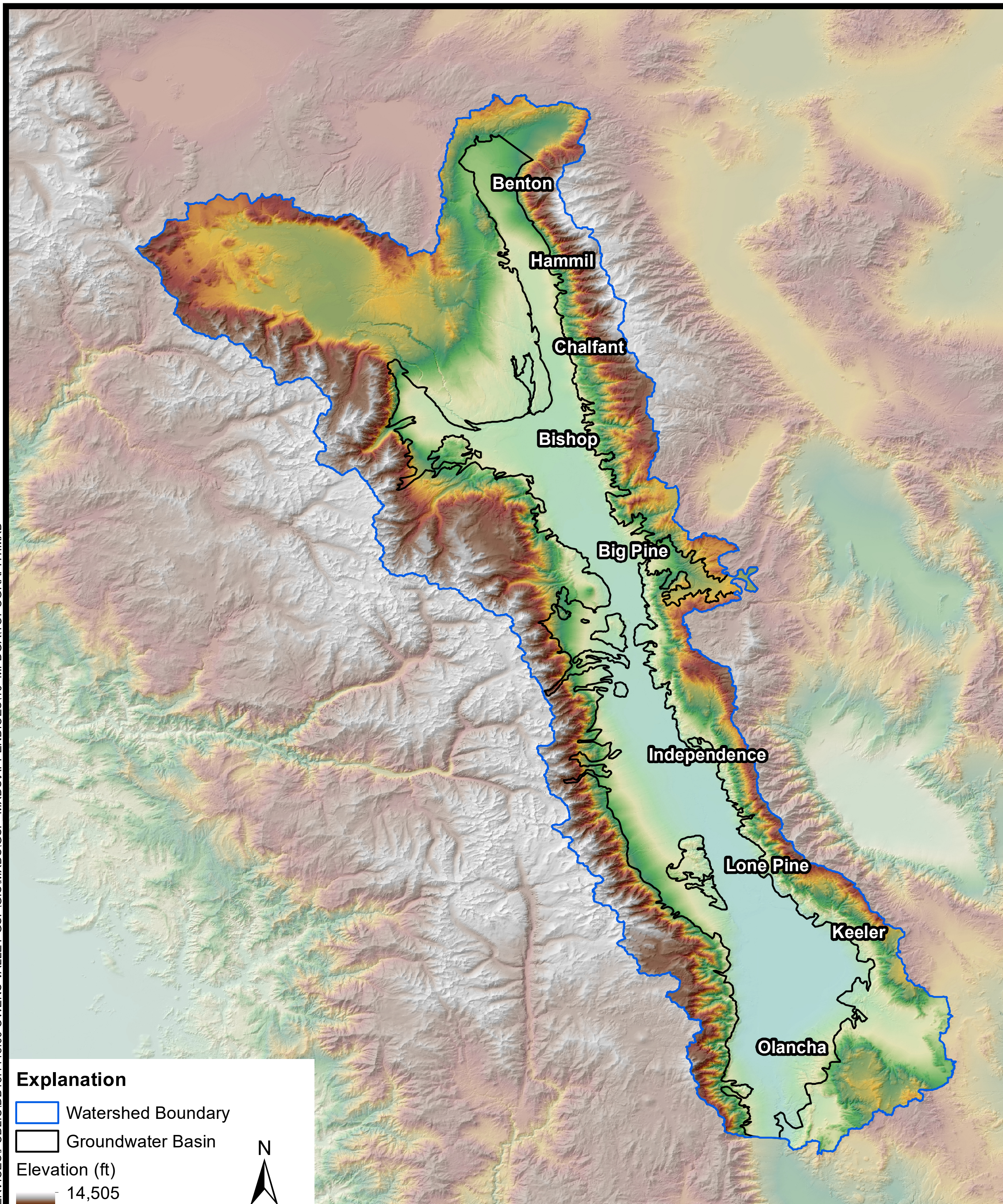
MONITORING PLAN AND DATA GAPS ANALYSIS

GSP Management Areas

Figure 1-2



Source: USGS National Elevation Dataset March 3, 2020

0 10 20 Miles

Notes:
1. Watersehd boundary modified to include entire groundwater basin.

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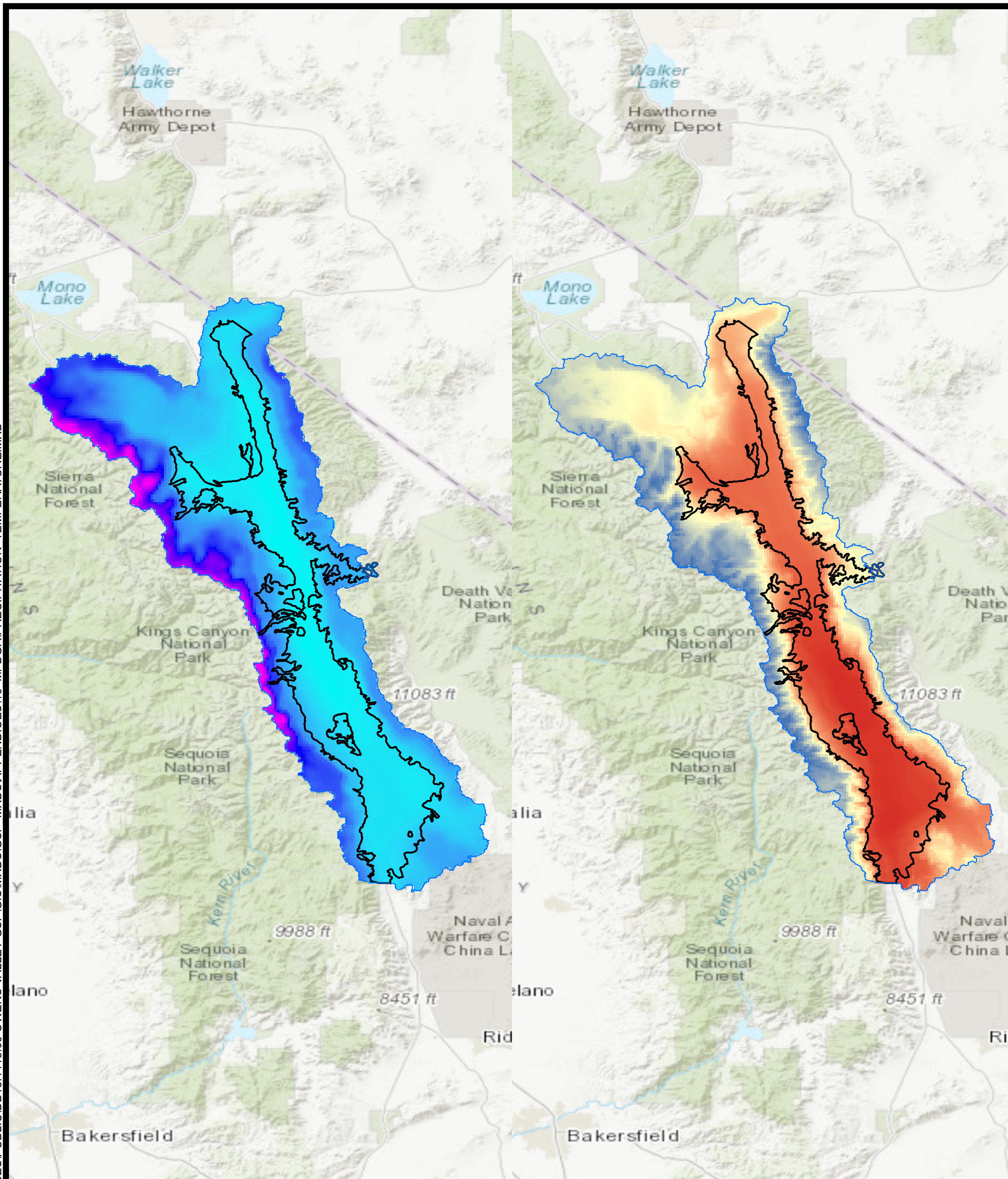
MONITORING PLAN AND DATA GAPS ANALYSIS
Owens Valley Watershed Topgraphy

Figure 1-3



Source: PRISM 30-year normals (1981-2010)

Explanation

Precipitation (in/yr)
57
4.5

Average annual temperature (degrees F)
61
25

Watershed Boundary
Groundwater Basin

N

0 10 20 Miles

MONITORING PLAN AND DATA GAPS ANALYSIS

Mean Annual Precipitation and Temperature

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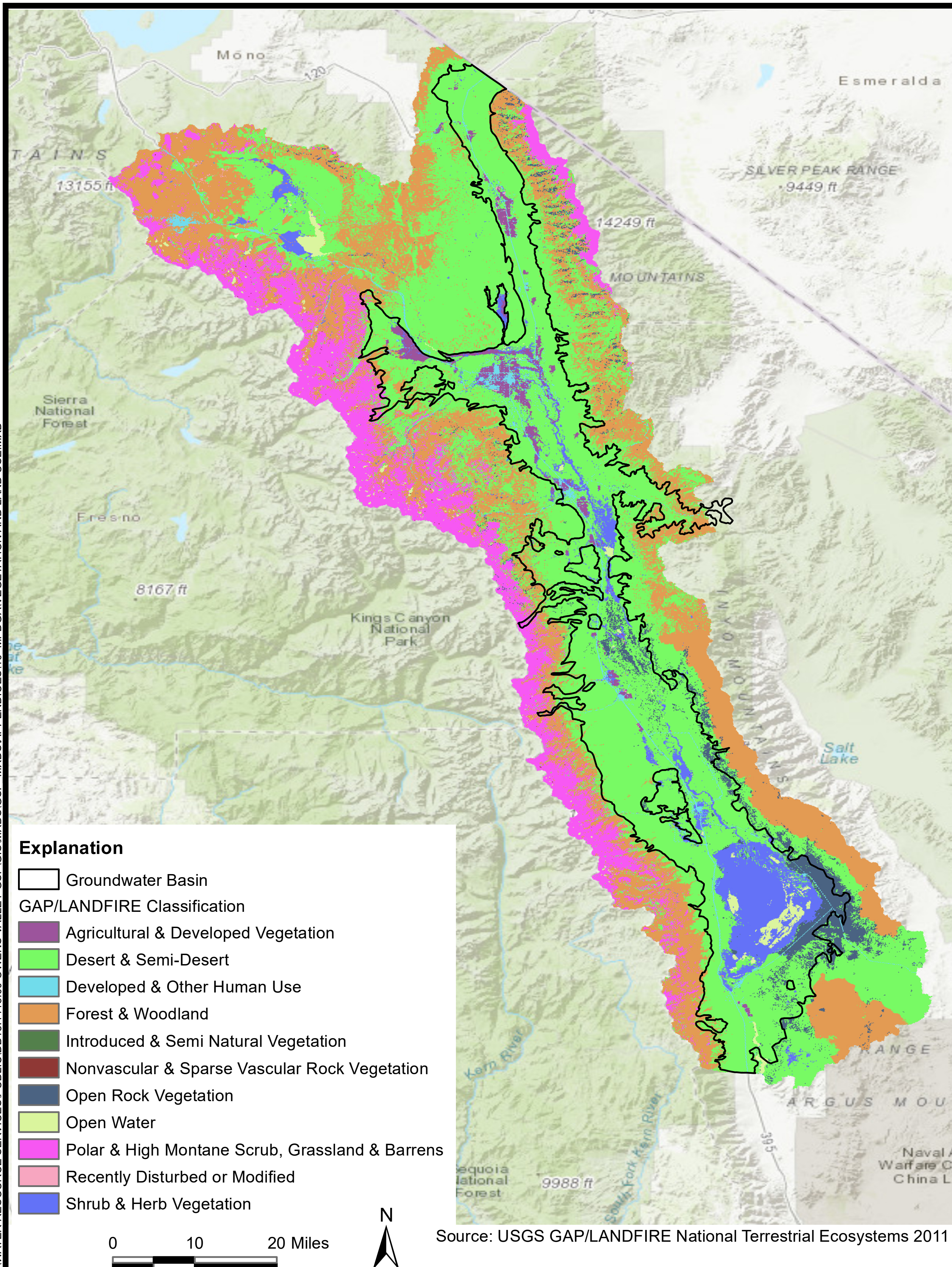
Figure 1-4



Source: USGS GAP/LANDFIRE National Terrestrial Ecosystems 2011

MONITORING PLAN AND DATA GAPS ANALYSIS

Vegetation and Land Use

Figure 1-5

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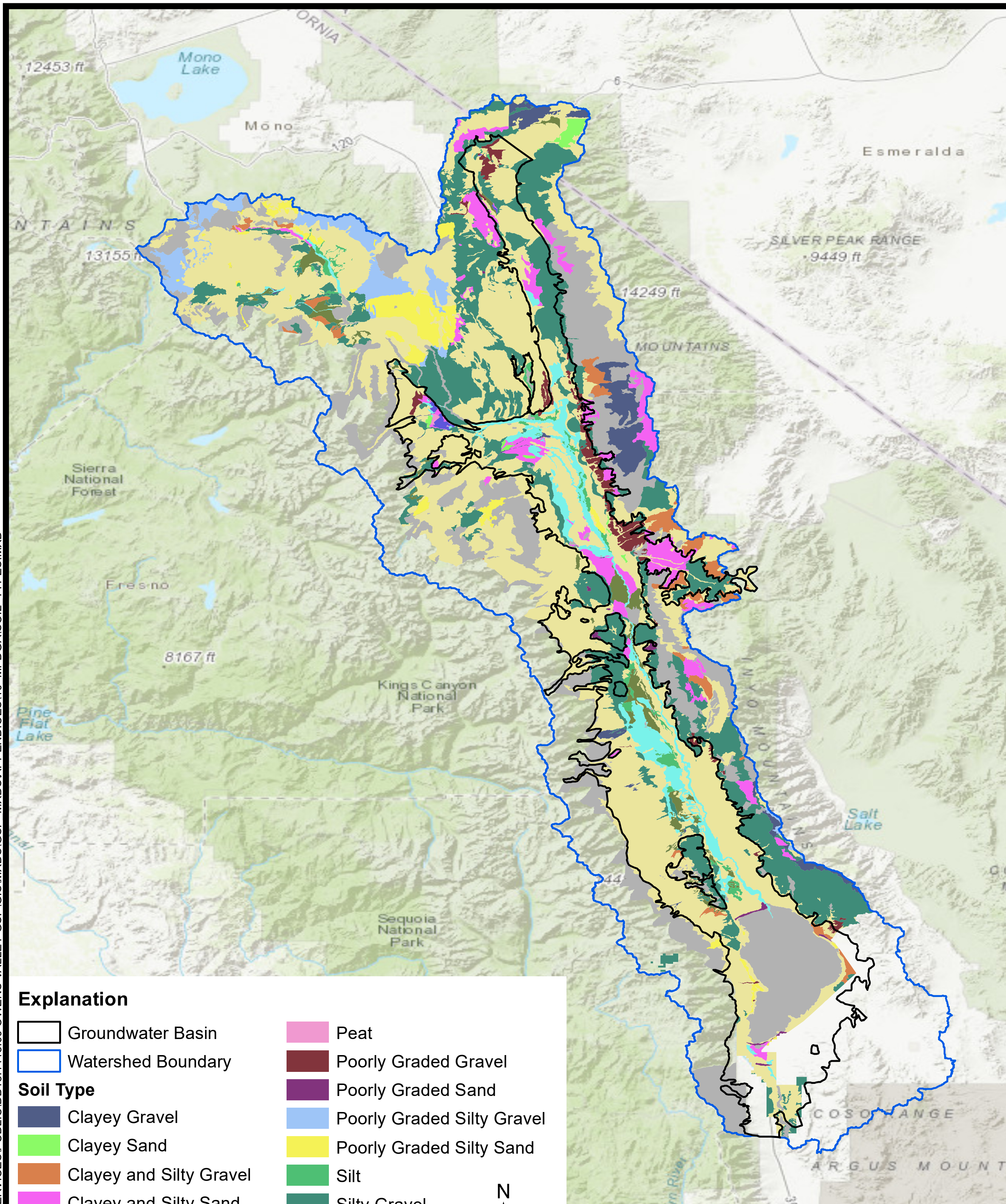

Source: NRCS SSURGO database September 16, 2019.

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MONITORING PLAN AND DATA GAPS ANALYSIS

Soil Types

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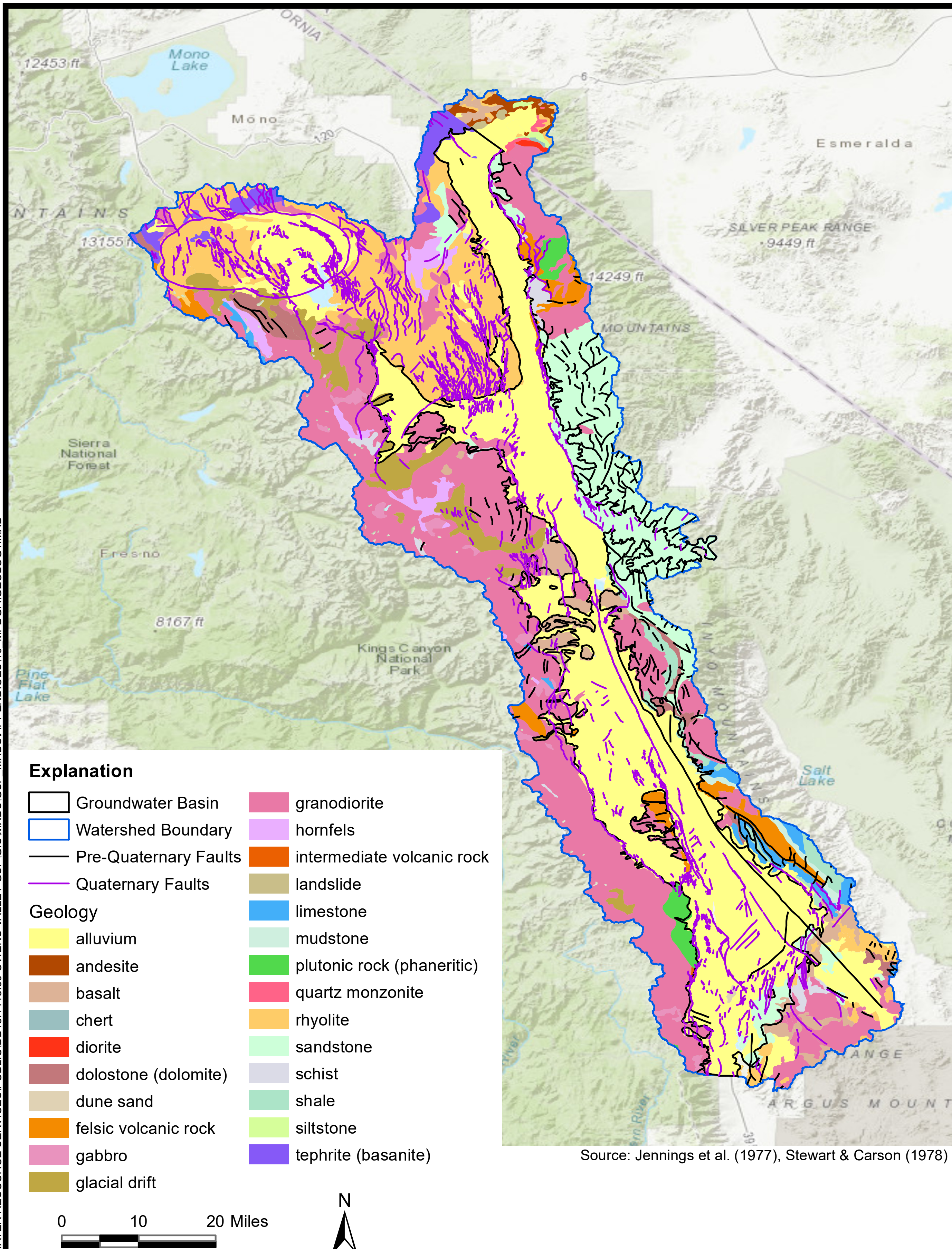
Figure 1-6



MONITORING PLAN AND DATA GAPS ANALYSIS

Geology

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Figure 1-7

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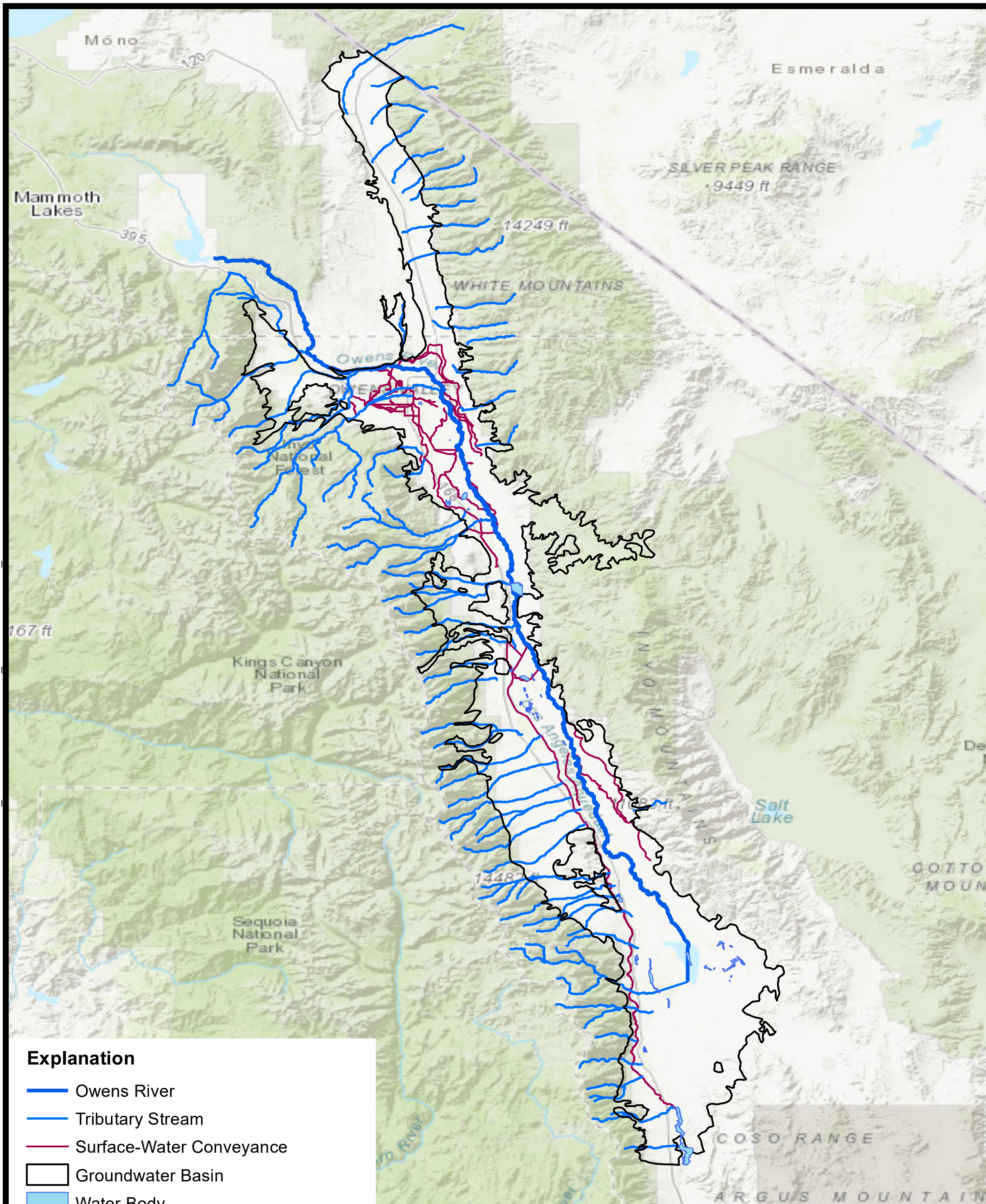

Source: National Hydrogprahy Dataset (2019); ICWD

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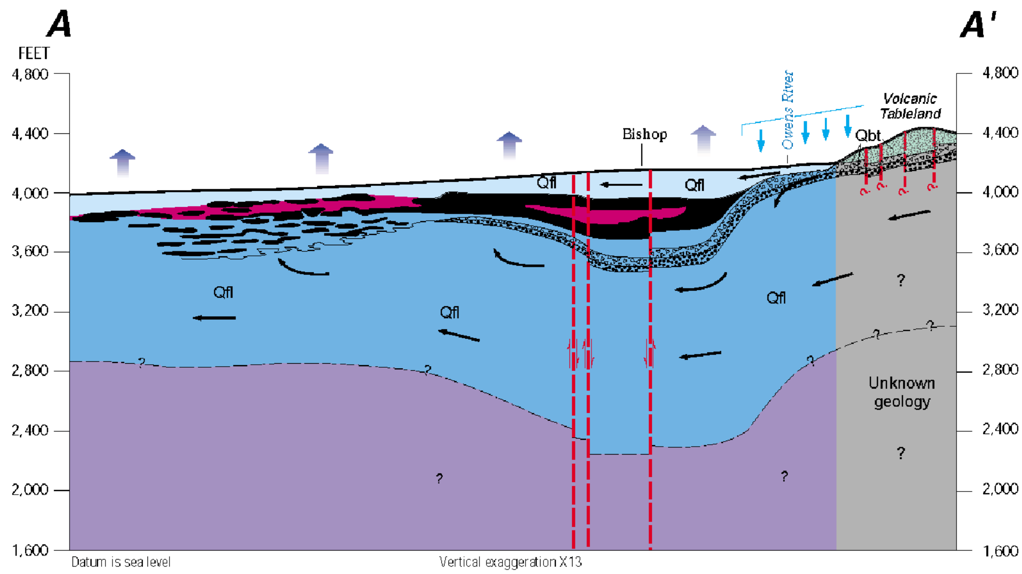
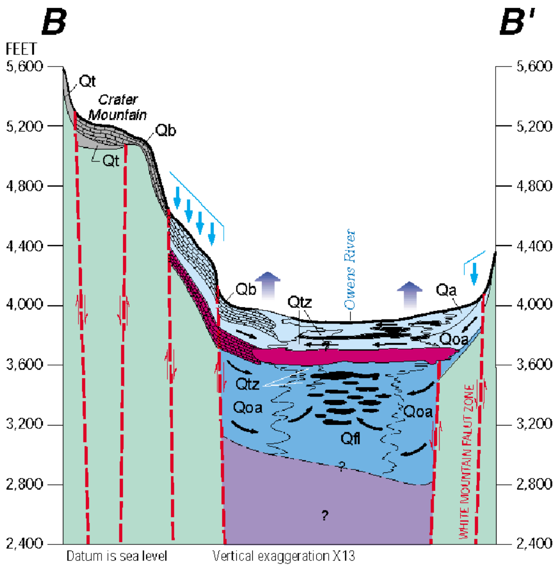
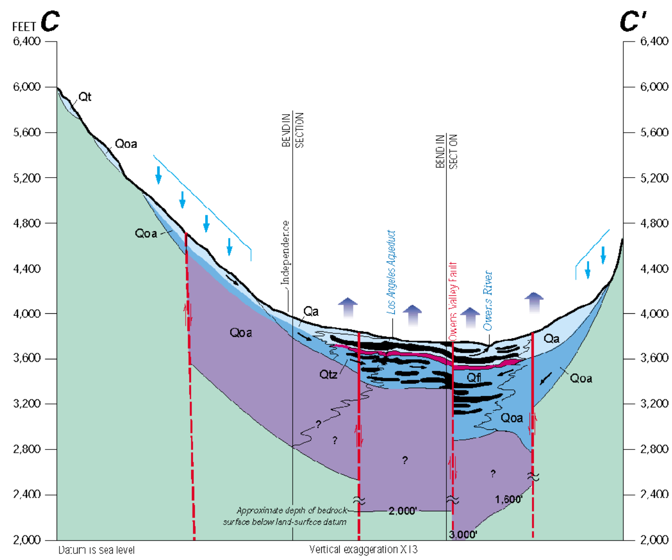
MONITORING PLAN AND DATA GAPS ANALYSIS

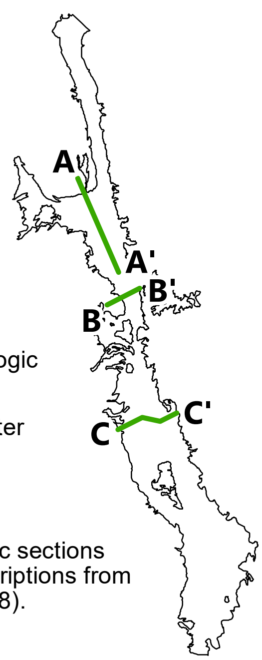
Surface-Water Features

Figure 1-8









Explanation

Hydrogeologic Section

Groundwater Basin

Notes:
1. Hydrogeologic sections and unit descriptions from Danskin (1998).

Generalized Geologic Units

QUATERNARY

Valley Fill

Qa — **Younger alluvial fan deposits** – Poorly sorted, unconsolidated gravel, sand, silt, and clay

Qoa — **Older alluvial fan deposits** – Very poorly sorted, unconsolidated to moderately consolidated gravel, sand, silt, and clay

Qtz — **Transition-zone deposits** – Moderately to well-sorted, unconsolidated sandy gravel, not exposed at land surface

Qt — **Glacial and talus deposits** – Poorly to moderately sorted, unconsolidated to consolidated silty-sandy gravels, some clay

Qfl — **Fluvial and lacustrine deposits** – Moderately to well-sorted, unconsolidated lenses and layers of sand, silty sand, and gravelly sand; layers, lenses, or massive beds of silty clay; shaded where massive or continuous bed

Qb — **Olivine basalt** – Flows and cones with extensive interflow breccia and clinker zones; collectively named the Big Pine volcanic field

QUATERNARY

Qbt — **Bishop Tuff** – Valley-fill members are composed of an upper member of friable ash, pumice, and tuff, shown with ▿-pattern, and a lower basalt member composed principally of pumice

Bedrock

Qbt — **Volcanic Tableland** – Bedrock unit of the upper Bishop Tuff member composed of welded or agglutinated ash and tuff that grades laterally and vertically to the upper valley fill member

PRE-QUATERNARY

Undifferentiated bedrock units – Includes granitic, metamorphic, volcanic, and sedimentary rocks

? — **Unknown geology**

Fault – Dashed where inferred; queried where uncertain; arrow indicates relative movement of fault block. ≈ indicates geologic mapping is truncated to show approximate depth of bedrock

Hydrogeologic Units

Unit 1 – Unconfined part of the aquifer system

Unit 2 – Confining unit of the aquifer system

Unit 3 – Confined and unconfined parts of the aquifer system

Unit 4 – Where present, the top serves as the base of the aquifer system

Permeable materials – Not part of the defined aquifer system

Generalized direction of ground-water flow

Approximate area of ground-water recharge or discharge

Recharge, mostly from tributary streams

Discharge, mostly to evapotranspiration

MONITORING PLAN AND DATA GAPS ANALYSIS

Hydrogeologic Cross Sections

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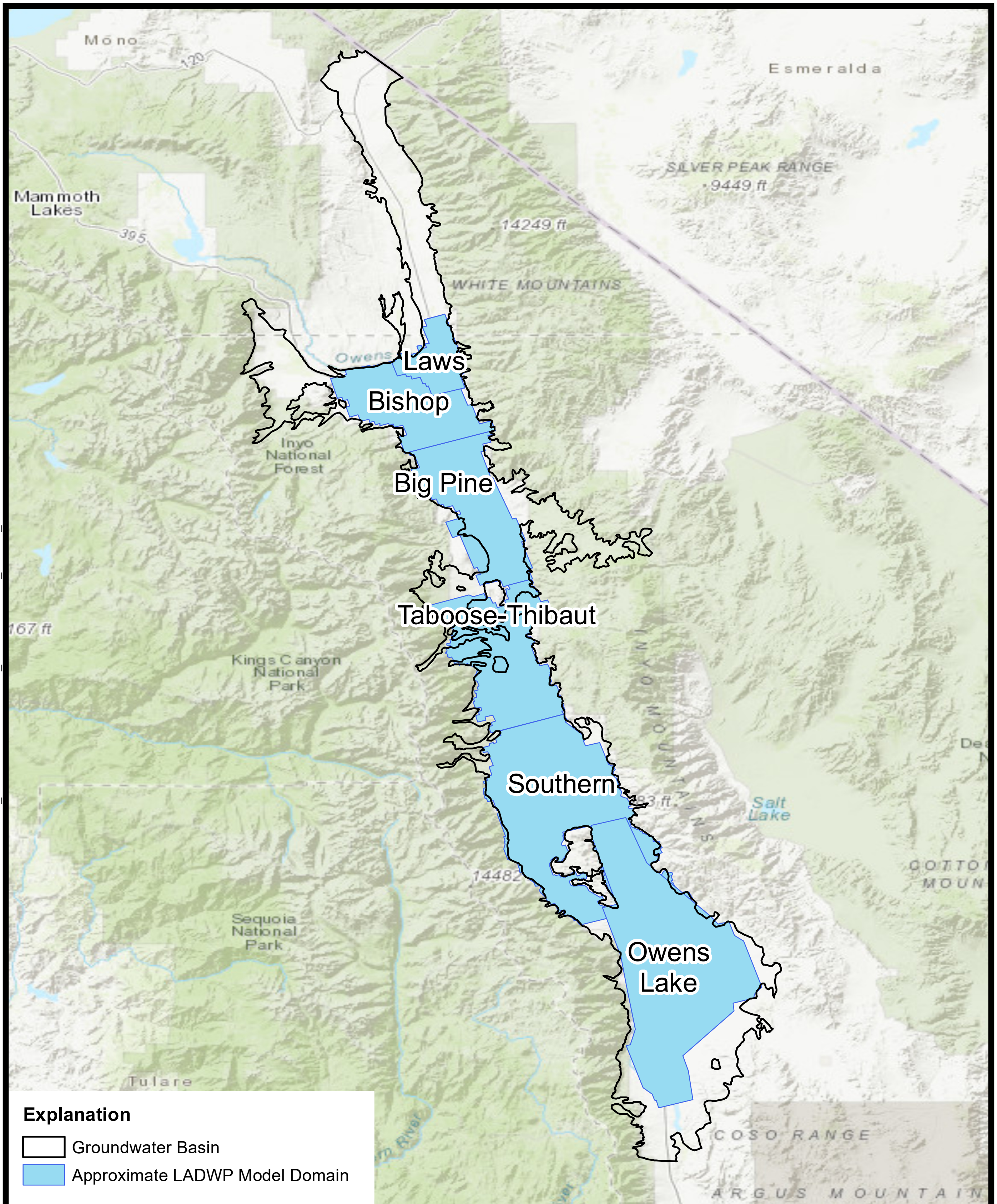
Figure 1-9



Notes:
1. Model domains digitized from maps in documentation reports

MONITORING PLAN AND DATA GAPS ANALYSIS
LADWP Groundwater Model Domains

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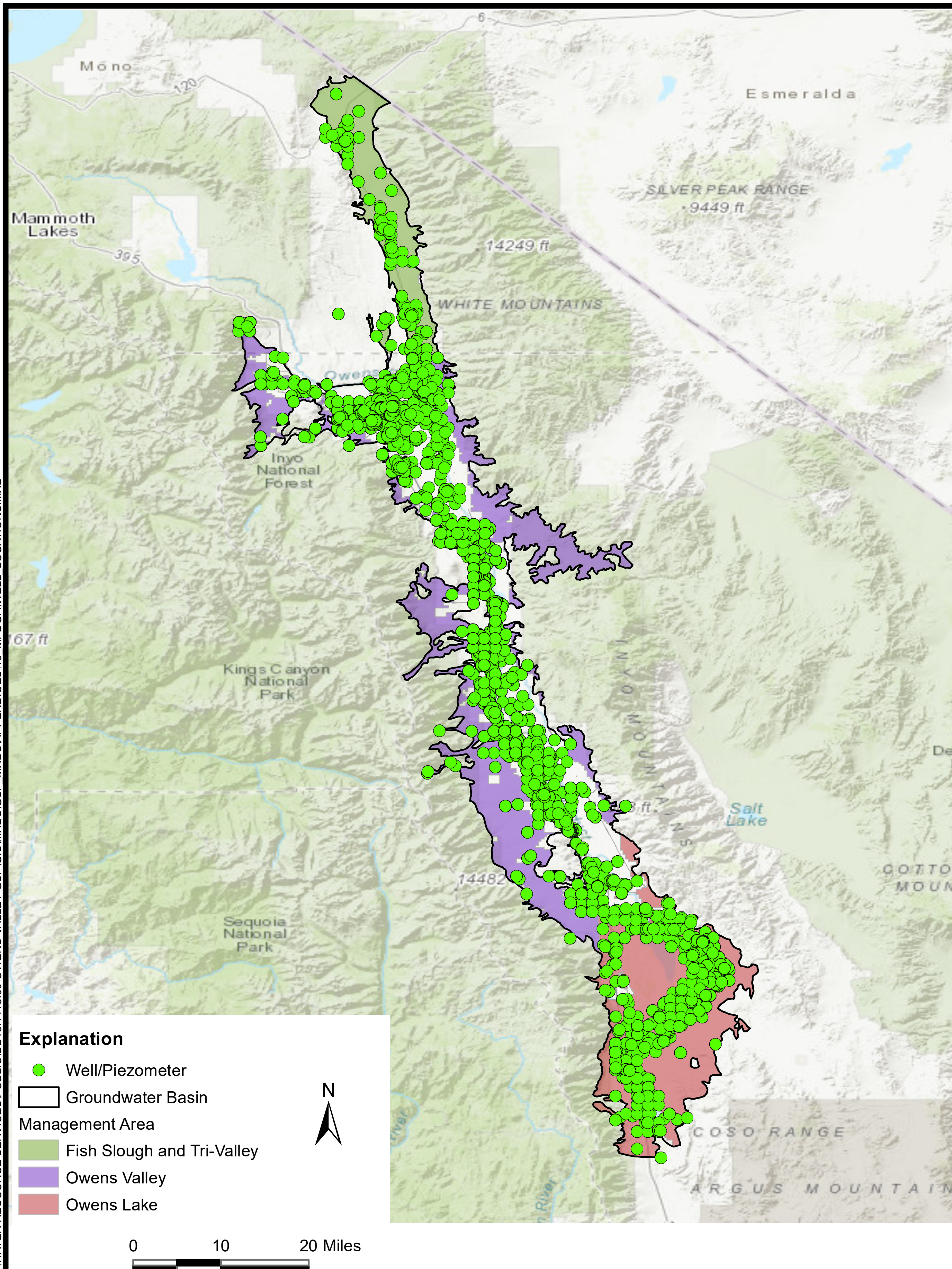
Figure 1-10

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP_MXDS\APPENDICES\10_MPDGA\LADWP_MODEL_DOMAINS.MXD



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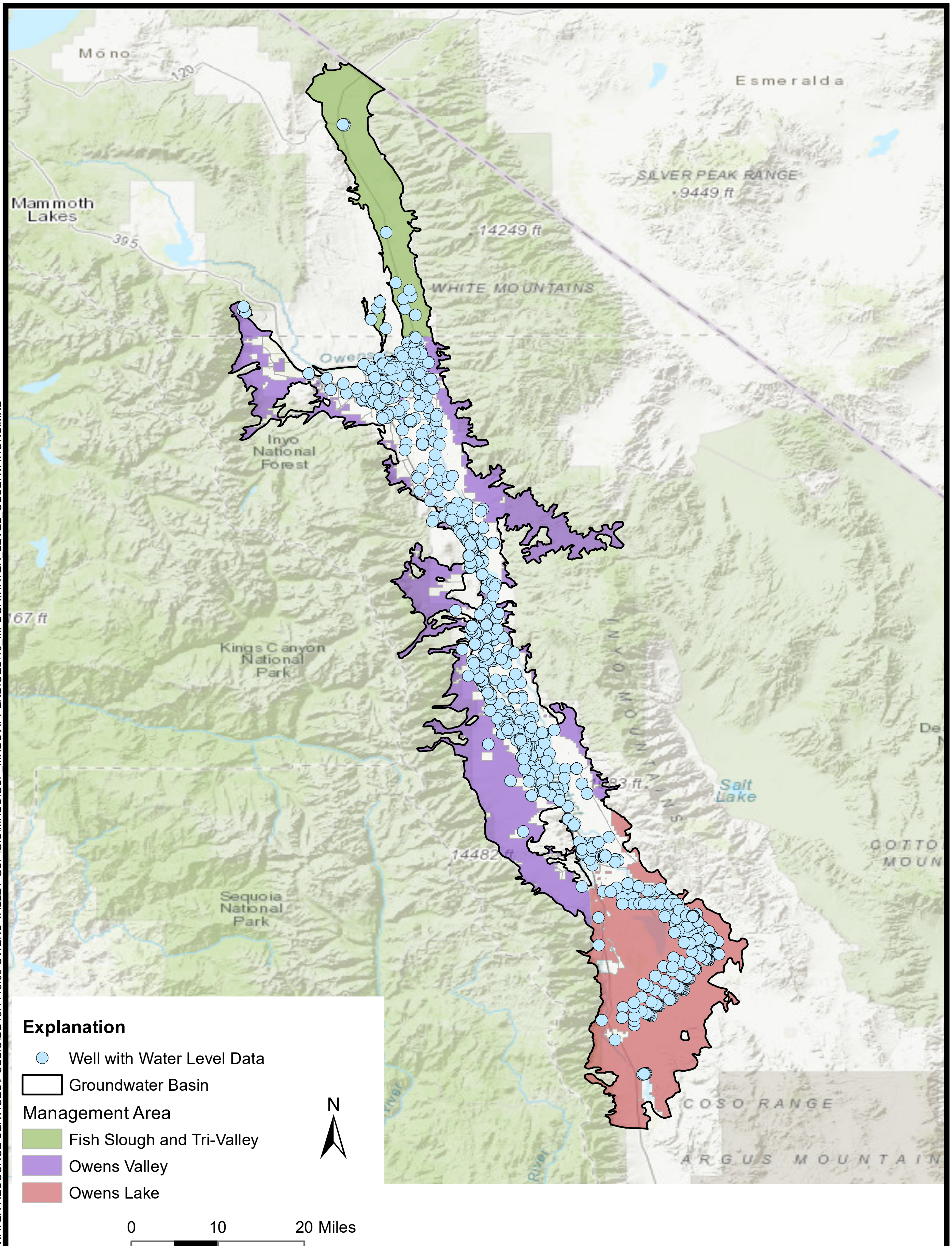
MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Valley Wells

Figure 2-1a



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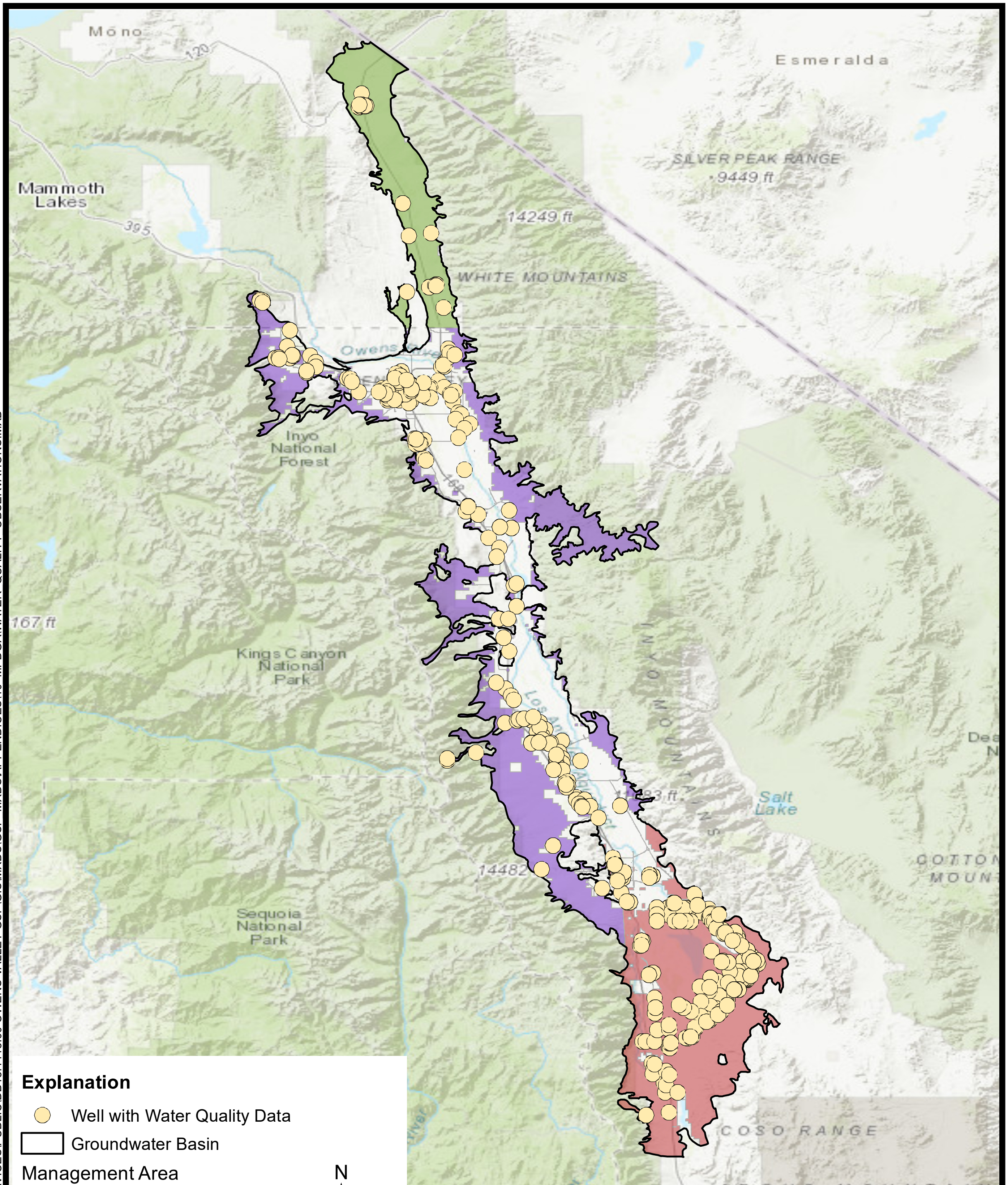
MONITORING PLAN AND DATA GAPS ANALYSIS

Wells with Water Level Data

Figure 2-1b



Notes:
1. Locations sampled for arsenic, chloride, sodium, nitrate, and total dissolved solids (TDS) shown

0 10 20 Miles

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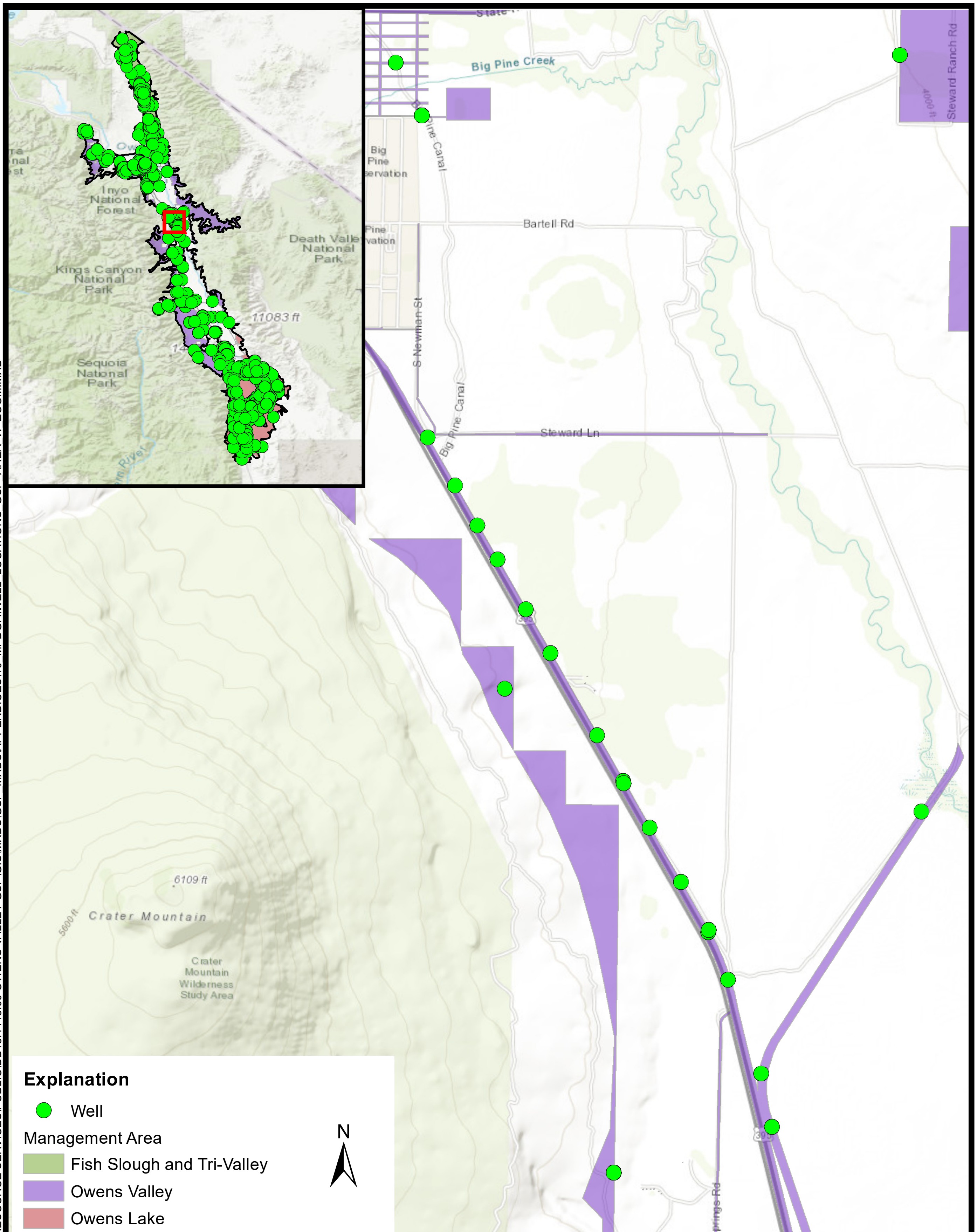
MONITORING PLAN AND DATA GAP ANALYSIS
Water Quality Data

Figure 2-1c

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP MXDS\APPENDICES\10 MPDGA\WATER QUALITY OBSERVATIONS.MXD



K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP_MXDS\APPENDICES\10_MPDGA\WELL_LOCATIONS_GSP_AREA_W_ZOOM.MXD

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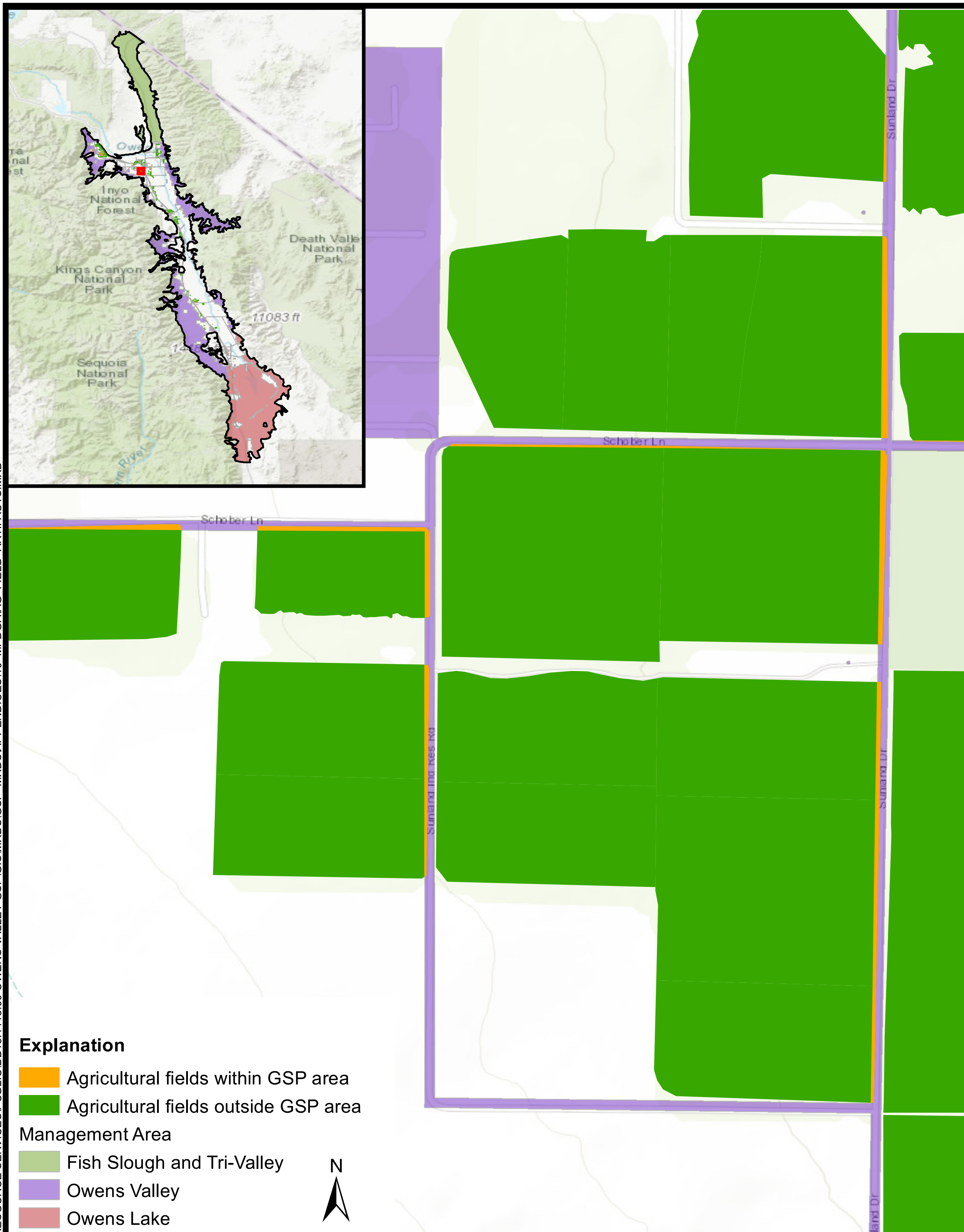
MONITORING PLAN AND DATA GAPS ANALYSIS

Wells located within GSP Area

Figure 2-2



Source: CADWR (2020)

MONITORING PLAN AND DATA GAPS ANALYSIS

Agricultural Field Clipping Artifacts

Figure 2-3

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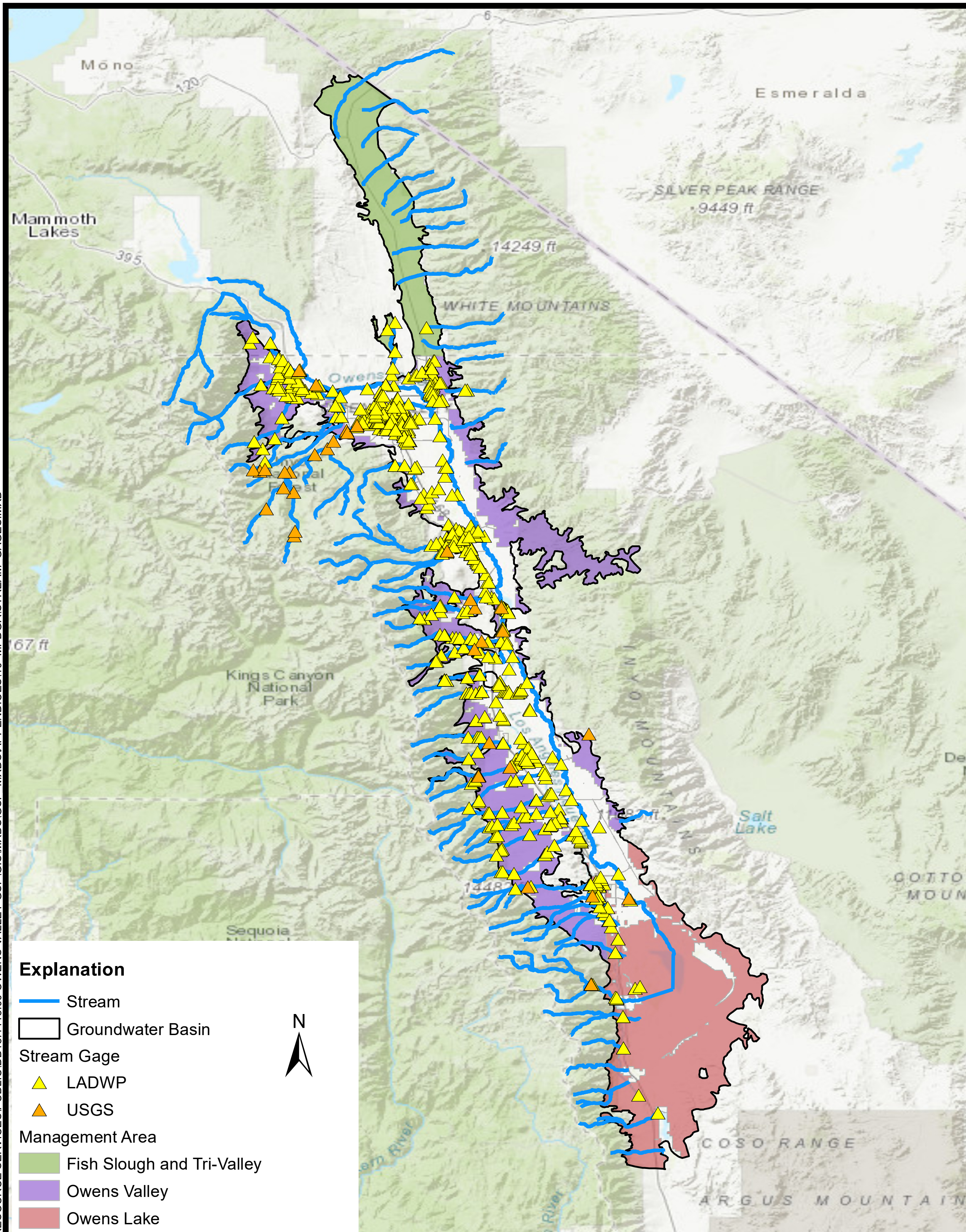
K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP MXDS\APPENDICES\10 MPDGA\AG FIELD ARTIFACTS.MXD



Source: National Hydrography Dataset (2020); LADWP; USGS

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Valley Surface-Water Gages

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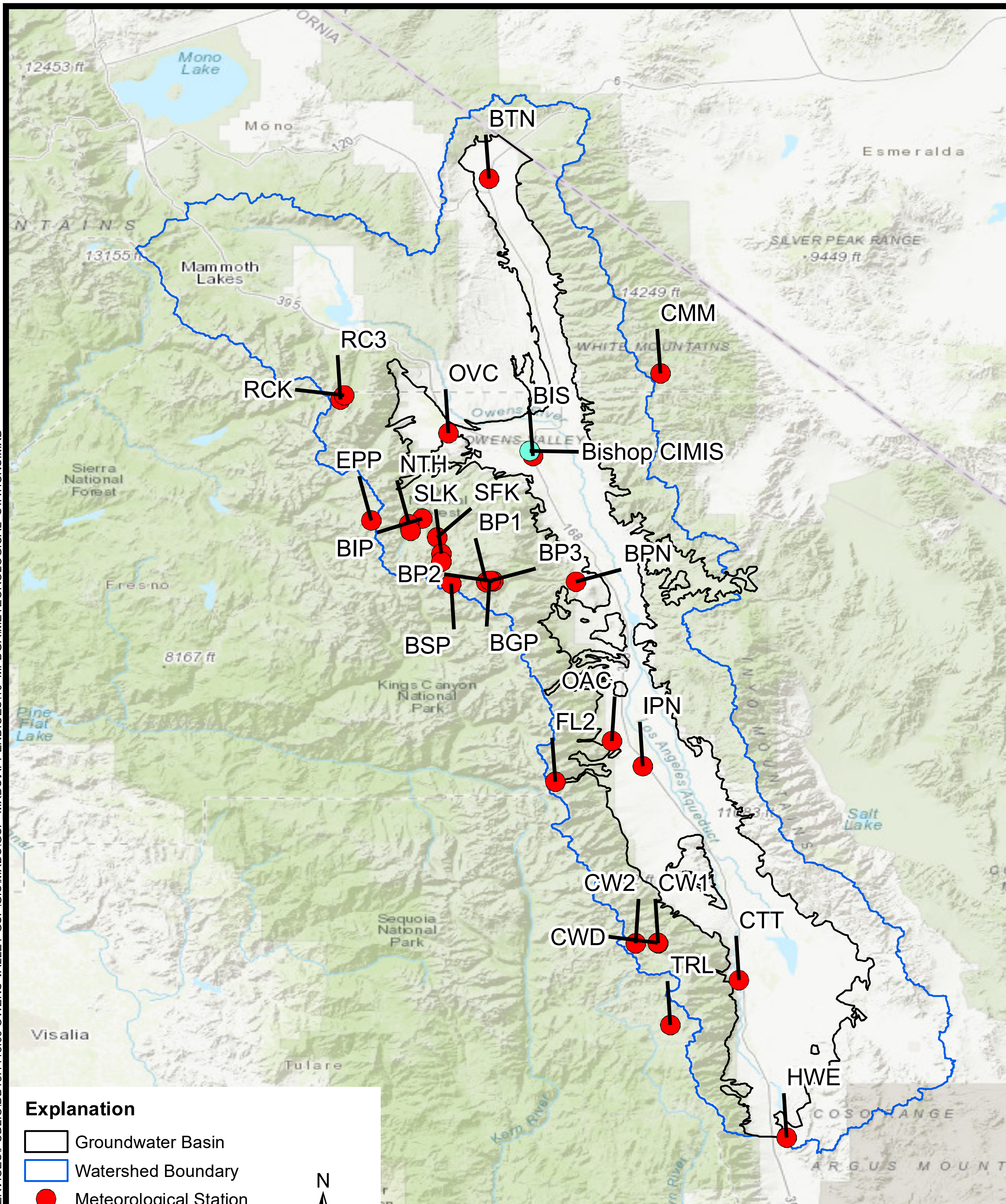
Figure 2-4

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP_MXDS\APPENDICES\10_MPDGA\STREAM_GAGES.MXD



Sources: CDEC, CIMIS

Notes:
1. Watersehd boundary modified to include entire groundwater basin.
2. CDEC = California Data Exchange Center
3. CIMIS = California Irrigation Management Information System

MONITORING PLAN AND DATA GAP ANALYSIS

Meteorological Stations

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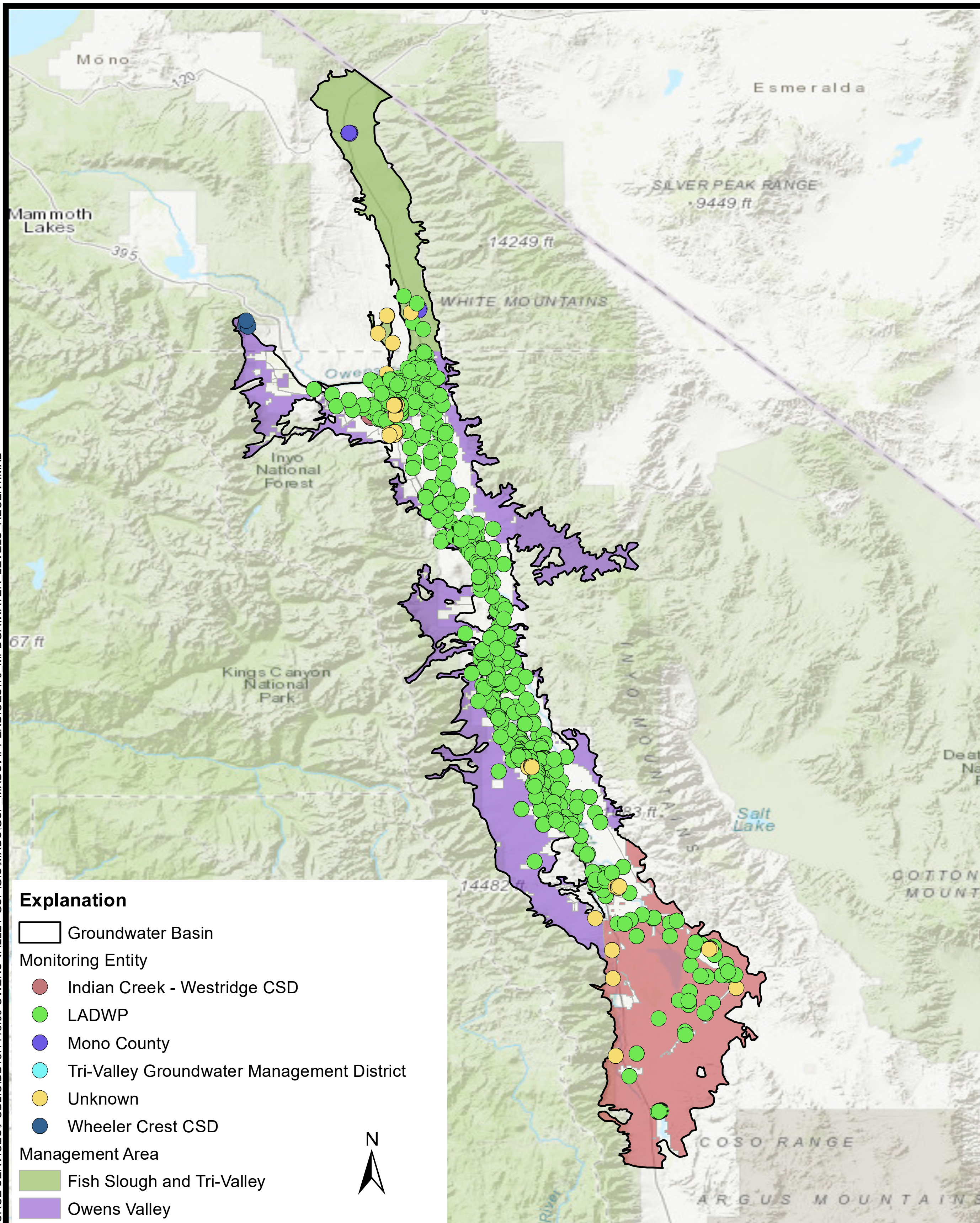
Figure 2-5

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP_MXDS\APPENDICES\10_MPDGA\METEOROLOGICAL_STATIONS.MXD



Notes:
1. Wells with water levels collected after January 1st, 2010 shown
2. Wells with more than three observations shown

MONITORING PLAN AND DATA GAPS ANALYSIS

Wells with Recent Water Level Data

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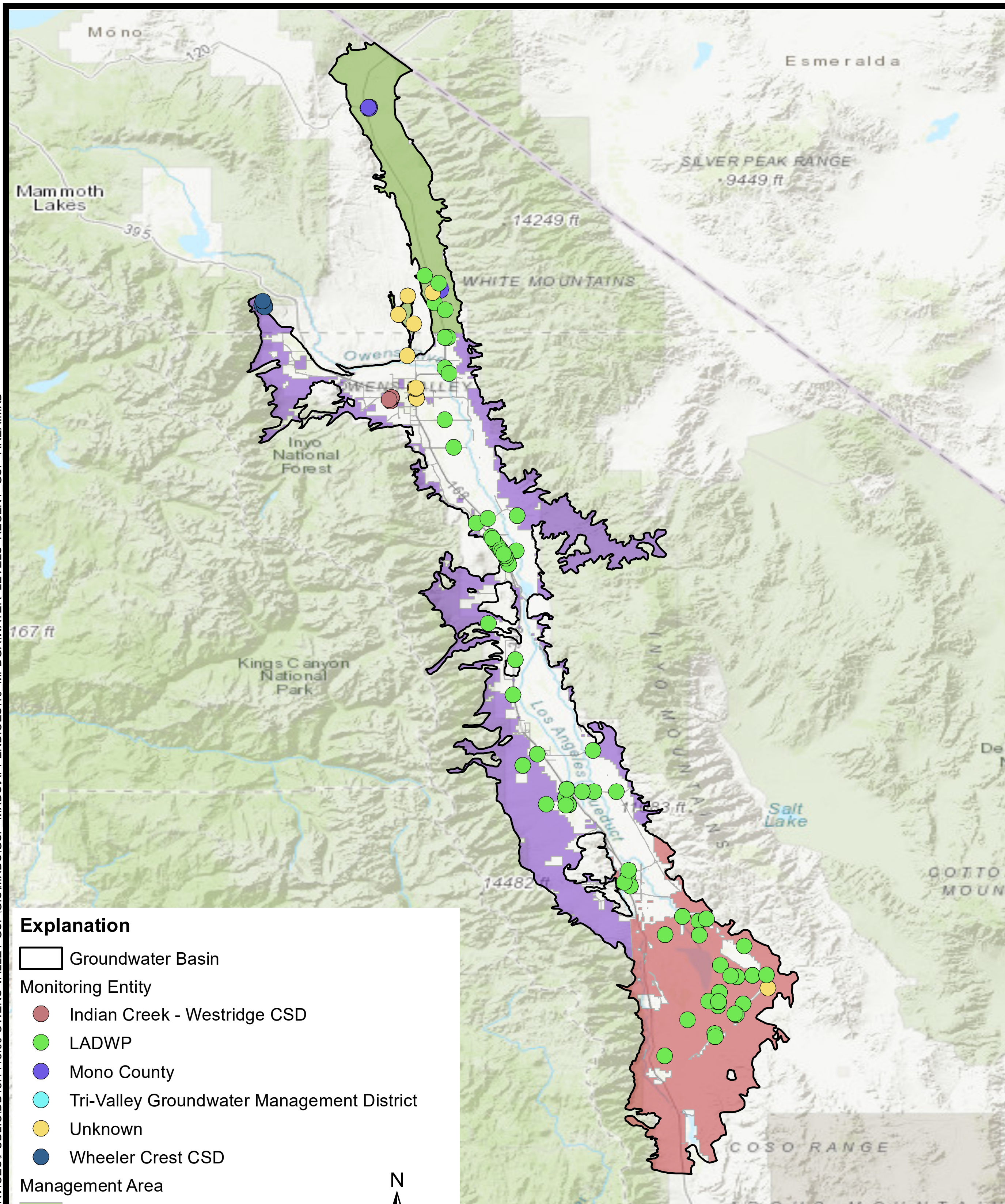
Figure 3-1a

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP_MXDS\APPENDICES\10_MPDGA\WATER_LEVELS_RECENT.MXD



Notes:
1. Wells with water levels collected after January 1st, 2010 shown
2. Wells with more than three observations shown

MONITORING PLAN AND DATA GAPS ANALYSIS

Wells with Recent Water Level Data GSP Area

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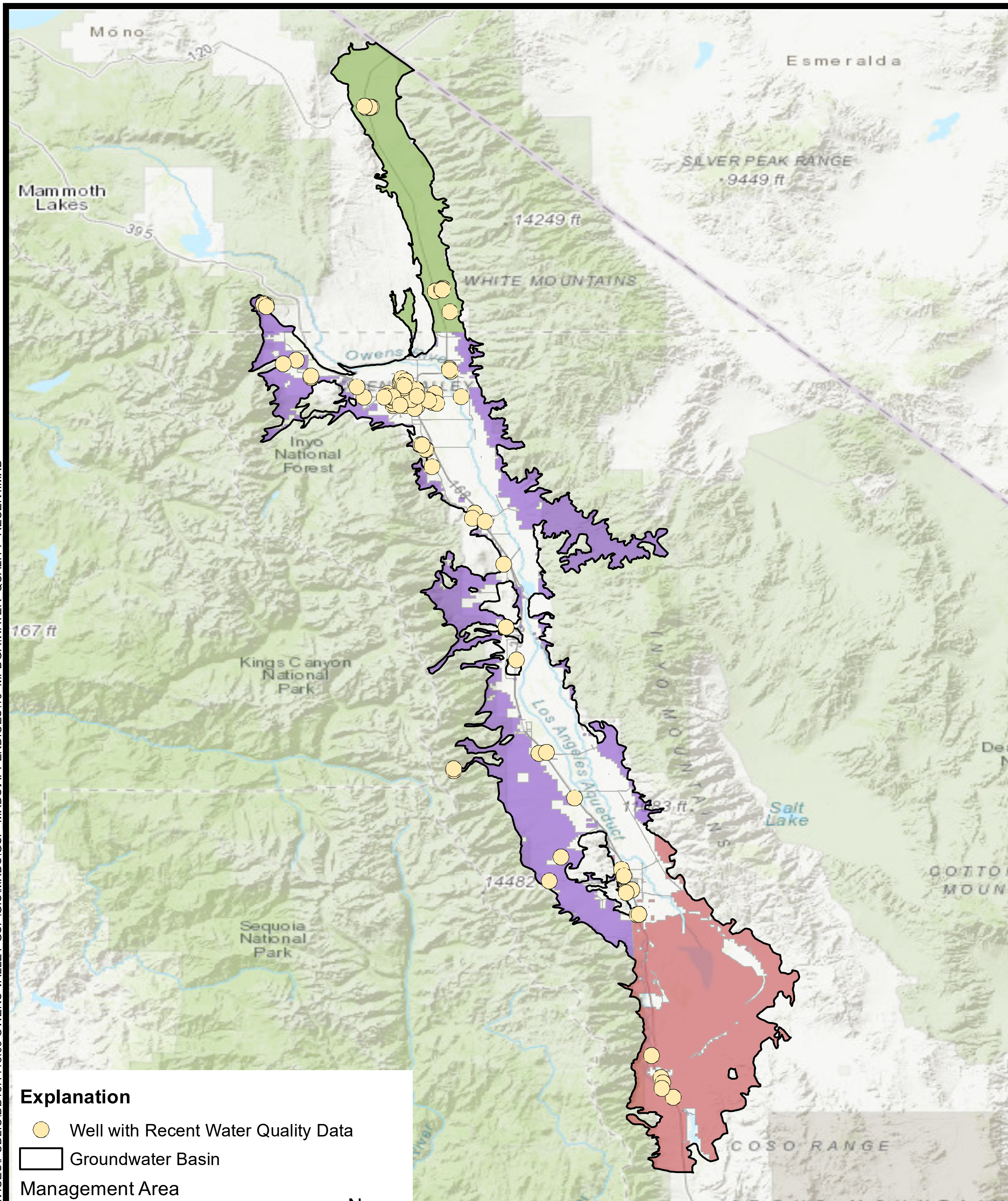
Figure 3-1b

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP_MXDS\APPENDICES\10_MPDGA\WATER_LEVELS_RECENT_GSP_AREA.MXD



Explanation

- Well with Recent Water Quality Data
- Groundwater Basin

Management Area

- Fish Slough and Tri-Valley
- Owens Valley
- Owens Lake

N

0 10 20 Miles

Notes:
1. Locations sampled for arsenic, chloride, sodium, nitrate, and total dissolved solids (TDS) shown
2. Wells with observations after January 1, 2010 shown
3. Wells with fewer than three observations omitted

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP_MXDS\APPENDICES\10_MPDGA\WATER_QUALITY_RECENT.MXD

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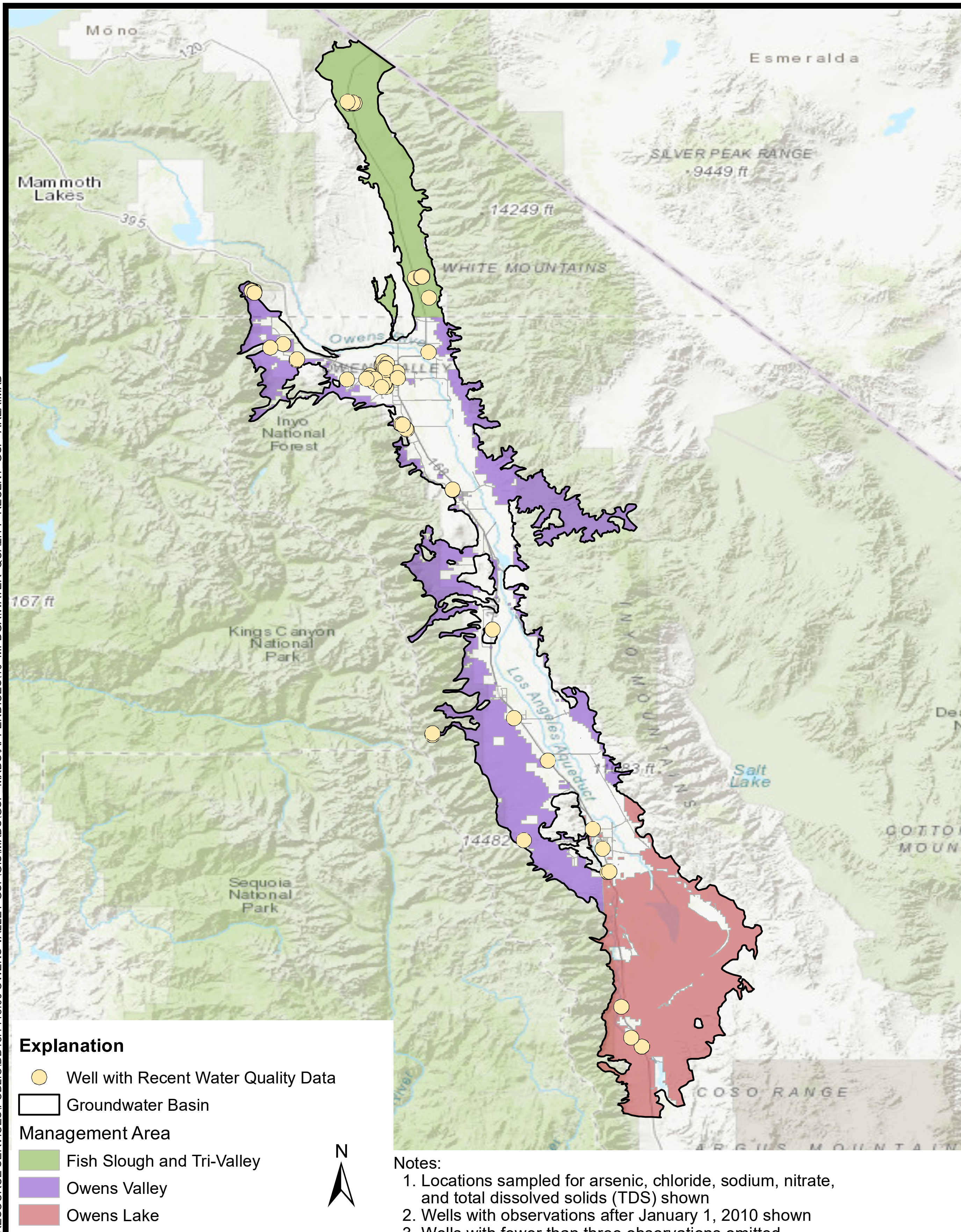
MONITORING PLAN AND DATA GAPS ANALYSIS

Recent Water Quality Data

Figure 3-2a



Notes:
1. Locations sampled for arsenic, chloride, sodium, nitrate, and total dissolved solids (TDS) shown
2. Wells with observations after January 1, 2010 shown
3. Wells with fewer than three observations omitted

MONITORING PLAN AND DATA GAPS ANALYSIS

Recent Water Quality Data GSP Area

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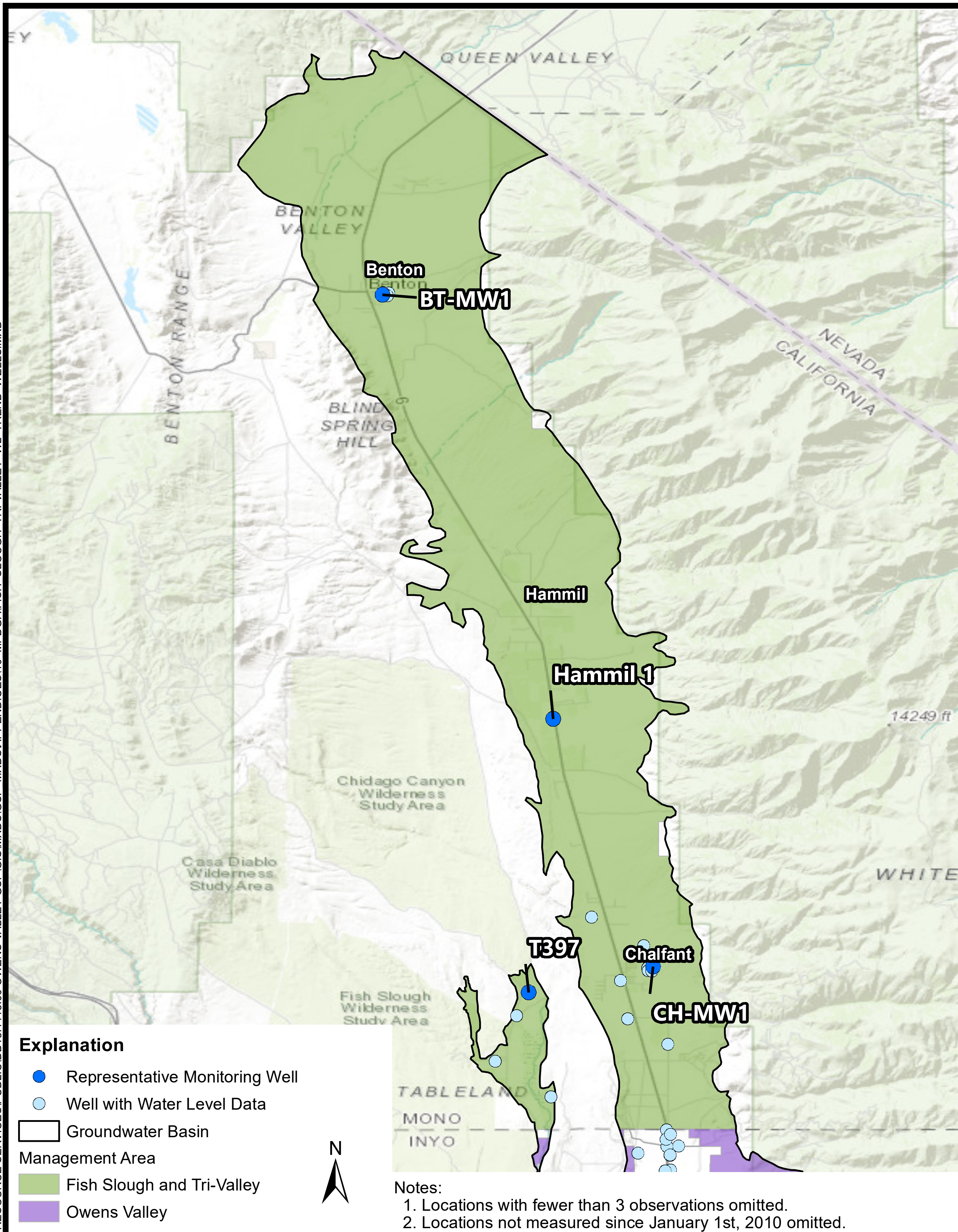
Figure 3-2b

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP MXDS\APPENDICES\10 MPDGA\WATER QUALITY RECENT GSP AREA.MXD



Notes:
1. Locations with fewer than 3 observations omitted.
2. Locations not measured since January 1st, 2010 omitted.

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP MXDS\APPENDICES\10 MPDGA\FISH SLOUGH TRI-VALLEY WL TREND WELLS.MXD

MONITORING PLAN AND DATA GAPS ANALYSIS

Fish Slough and Tri-Valley Water Levels
Representative Monitoring Wells

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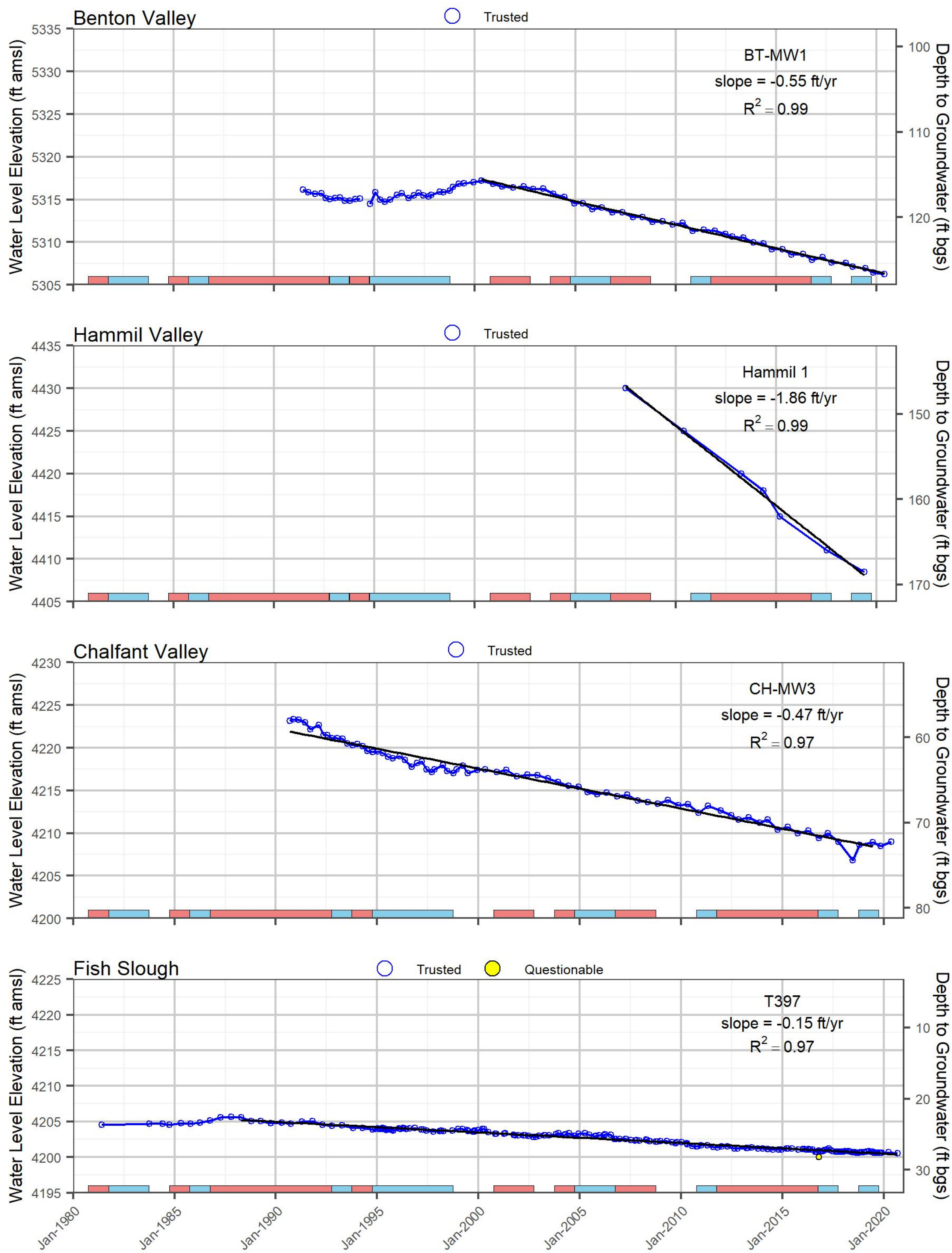
5/11/2021 DB18.1418

Figure 4-1



Notes:

1. Red and blue rectangles indicate dry and wet water years, respectively

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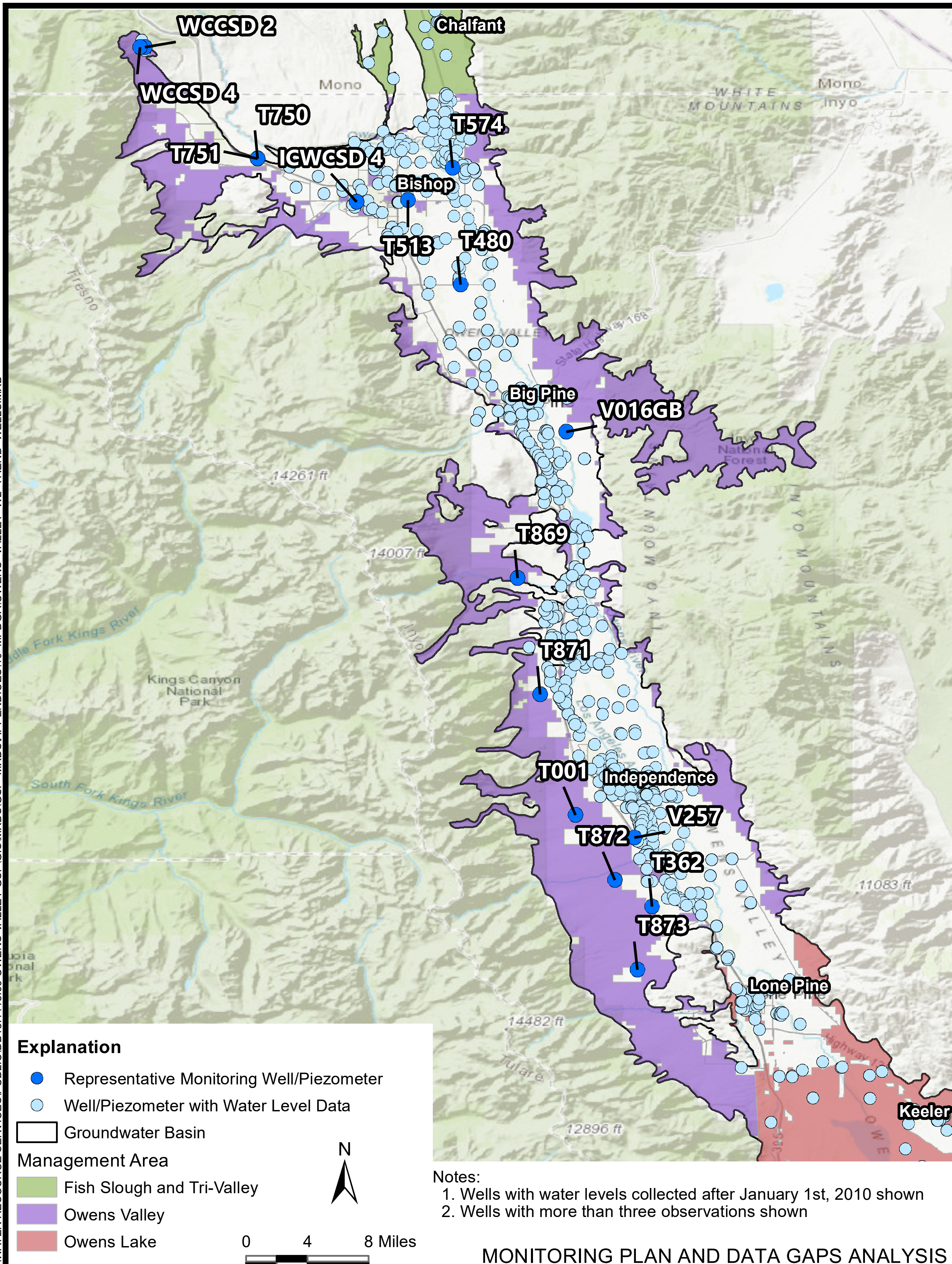
MONITORING PLAN AND DATA GAPS ANALYSIS

Fish Slough and Tri-Valley Management Area
Water Level Trends

Figure 4-2

K:\Projects\Water Resource Services\Public\DB18.1418.00 Owens Valley GSP\GSP\Appendices\7- Monitoring Plan and Data Gap Analysis\Figures\Fish_Slough_Tri-Valley_WL_trends.pdf



Notes:
1. Wells with water levels collected after January 1st, 2010 shown
2. Wells with more than three observations shown

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Valley Water Levels
Representative Monitoring Wells

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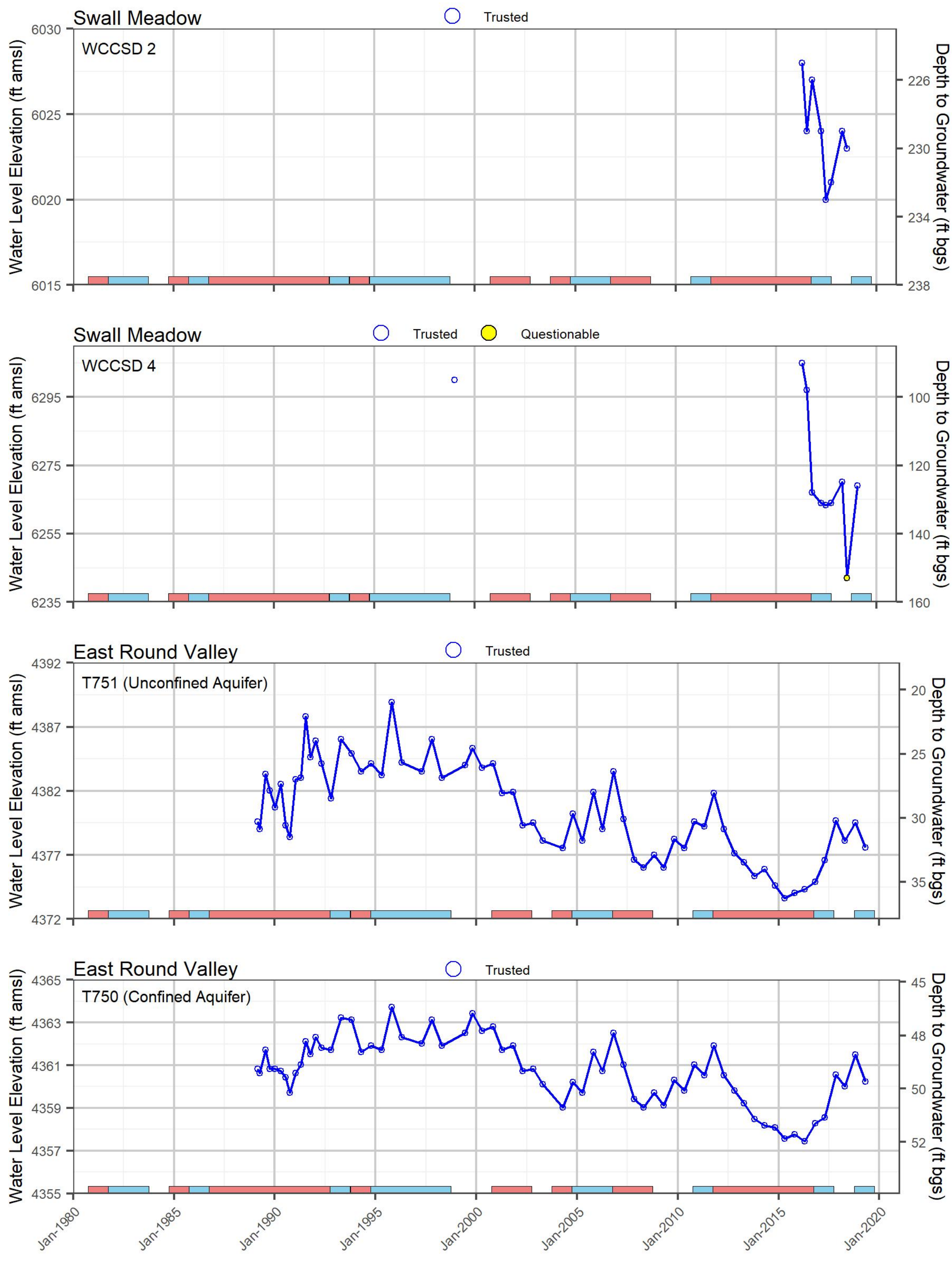
Figure 4-3

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP_MXDS\APPENDICES\10_MPDGA\OWENS_VALLEY_WL_TREND_WELLS.MXD



Notes:
1. Red and blue rectangles indicate dry and wet water years, respectively

MONITORING PLAN AND DATA GAPS ANALYSIS
Owens Valley Management Area
Water Level Trends

DBS&A
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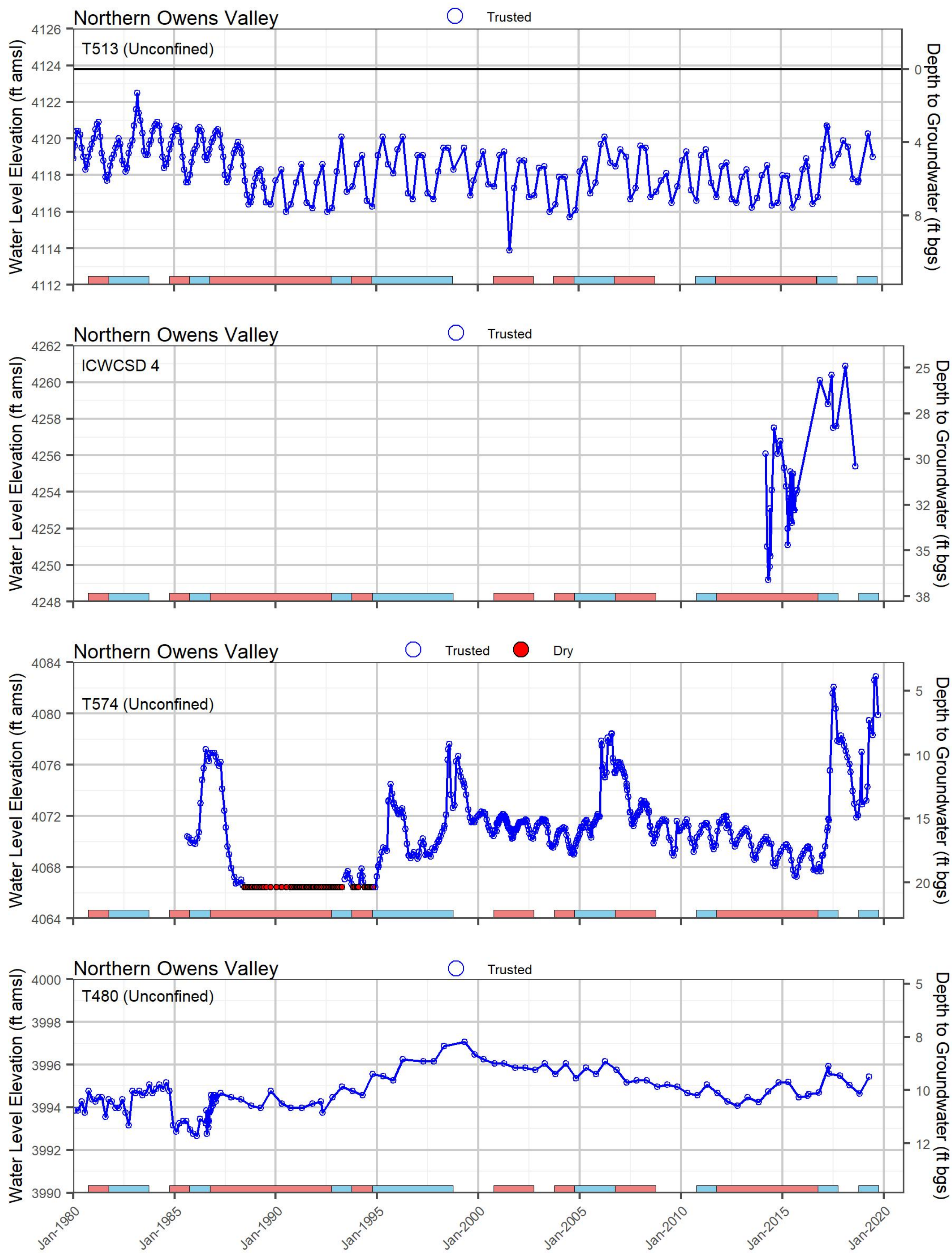
Figure 4-4a

K:\Projects\Water Resource Services\Public\DB18.1418.00 Owens Valley GSP\GSP\Appendices\7- Monitoring Plan and Data Gap Analysis\Figures\Round_Valley_WL_trends.pdf



Notes:

1. Red and blue rectangles indicate dry and wet water years, respectively

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Valley Management Area
Water Level Trends

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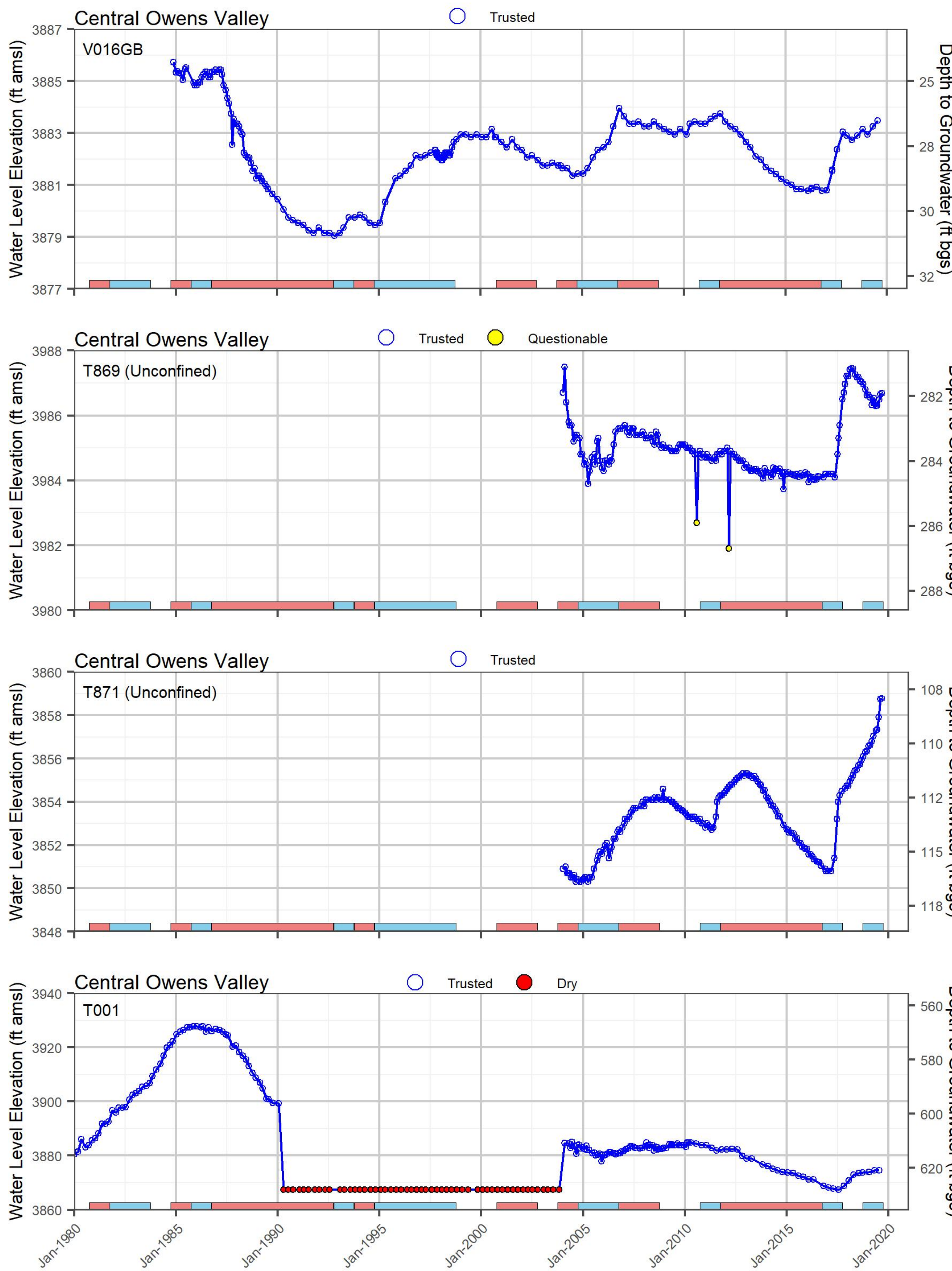
Figure 4-4b

K:\Projects\Water Resource Services\Public\DB18.1418.00 Owens Valley GSP\GSP\Appendices\7- Monitoring Plan and Data Gap Analysis\Figures\Owens_Valley_Northern_WL_trends.pdf



Notes:

1. Red and blue rectangles indicate dry and wet water years, respectively

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Valley Management Area
Water Level Trends

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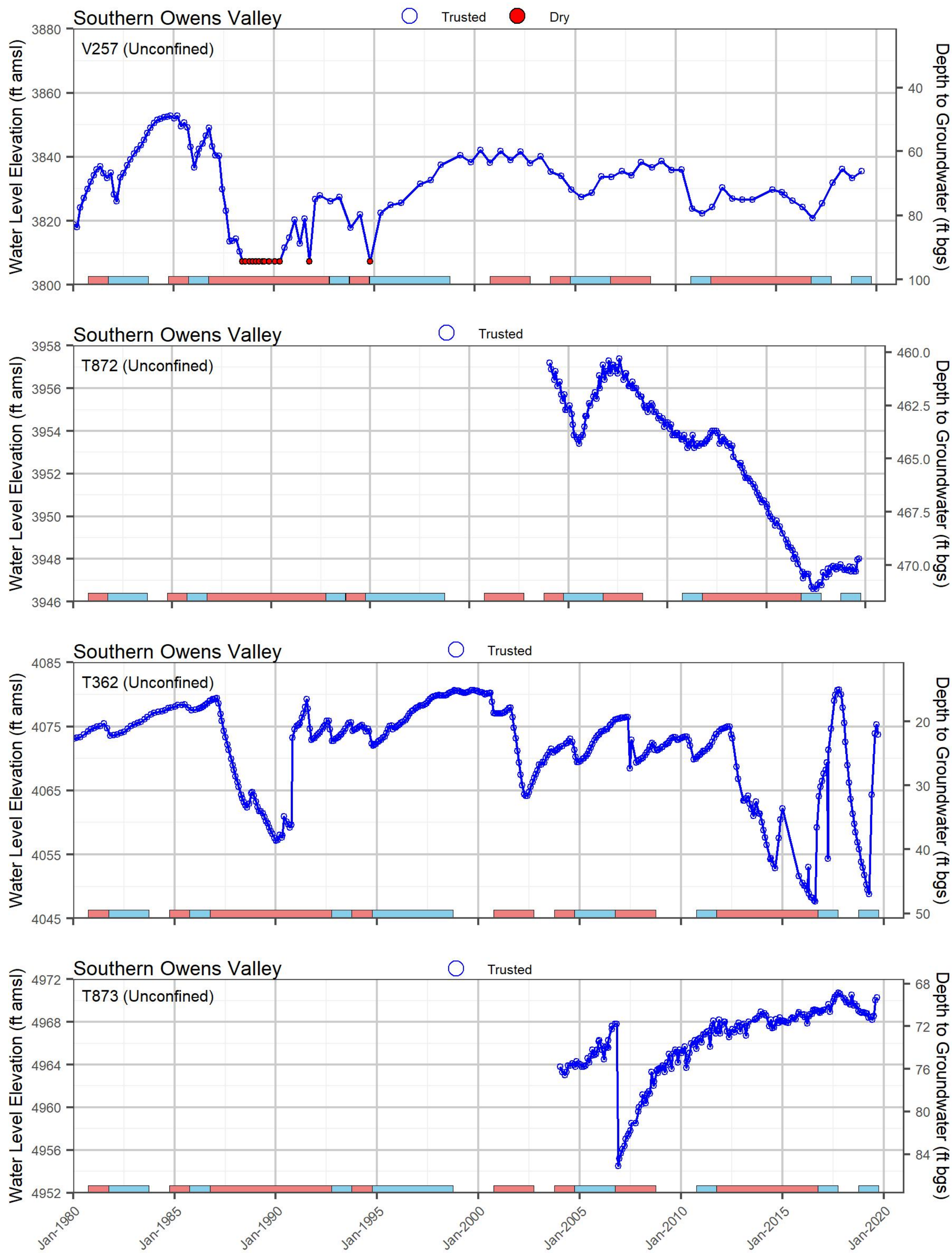
Figure 4-4c

K:\Projects\Water Resource Services\Public\DB18.1418.00 Owens Valley GSP\GSP\Appendices\7- Monitoring Plan and Data Gap Analysis\Figures\Owens_Valley_Central_WL_trends.pdf



Notes:

1. Red and blue rectangles indicate dry and wet water years, respectively

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Valley Management Area
Water Level Trends

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Figure 4-4d

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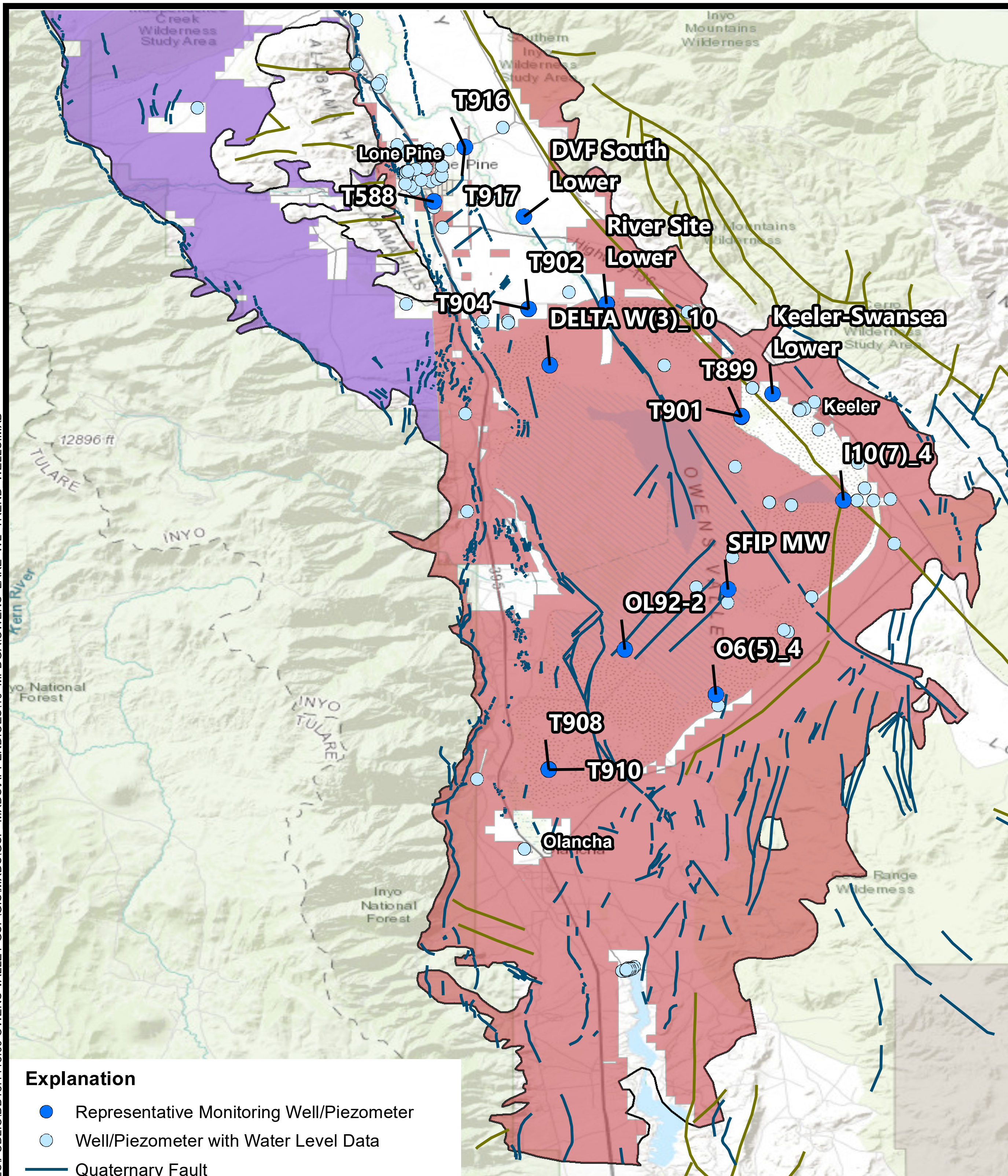

Explanation

- Representative Monitoring Well/Piezometer
- Well/Piezometer with Water Level Data
- Quaternary Fault
- Pre-Quaternary Fault
- Groundwater Basin

Management Area

- Owens Valley
- Owens Lake

N

0 2 4 Miles

Source: USGS Geologic Hazards Science Center

Notes:
1. Wells with water levels collected after January 1st, 2010 shown
2. Wells with more than three observations shown

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Lake Water Levels
Representative Monitoring Wells

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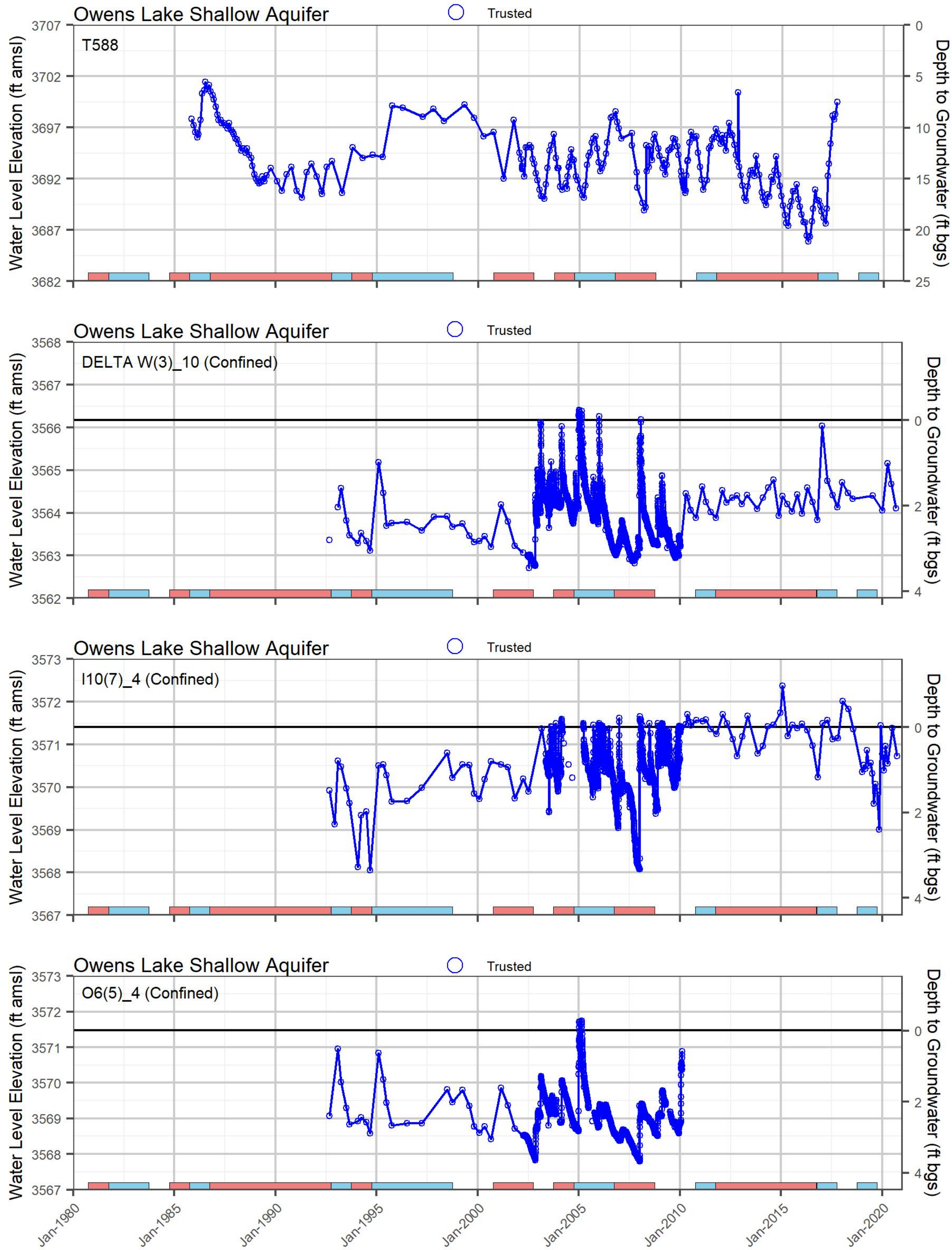
Figure 4-5

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP_MXDS\APPENDICES\10_MPDGA\OWENS_LAKE_WL_TREND_WELLS.MXD



Notes:

1. Red and blue rectangles indicate dry and wet water years, respectively

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Lake Management Area
Water Level Trends

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Figure 4-6a

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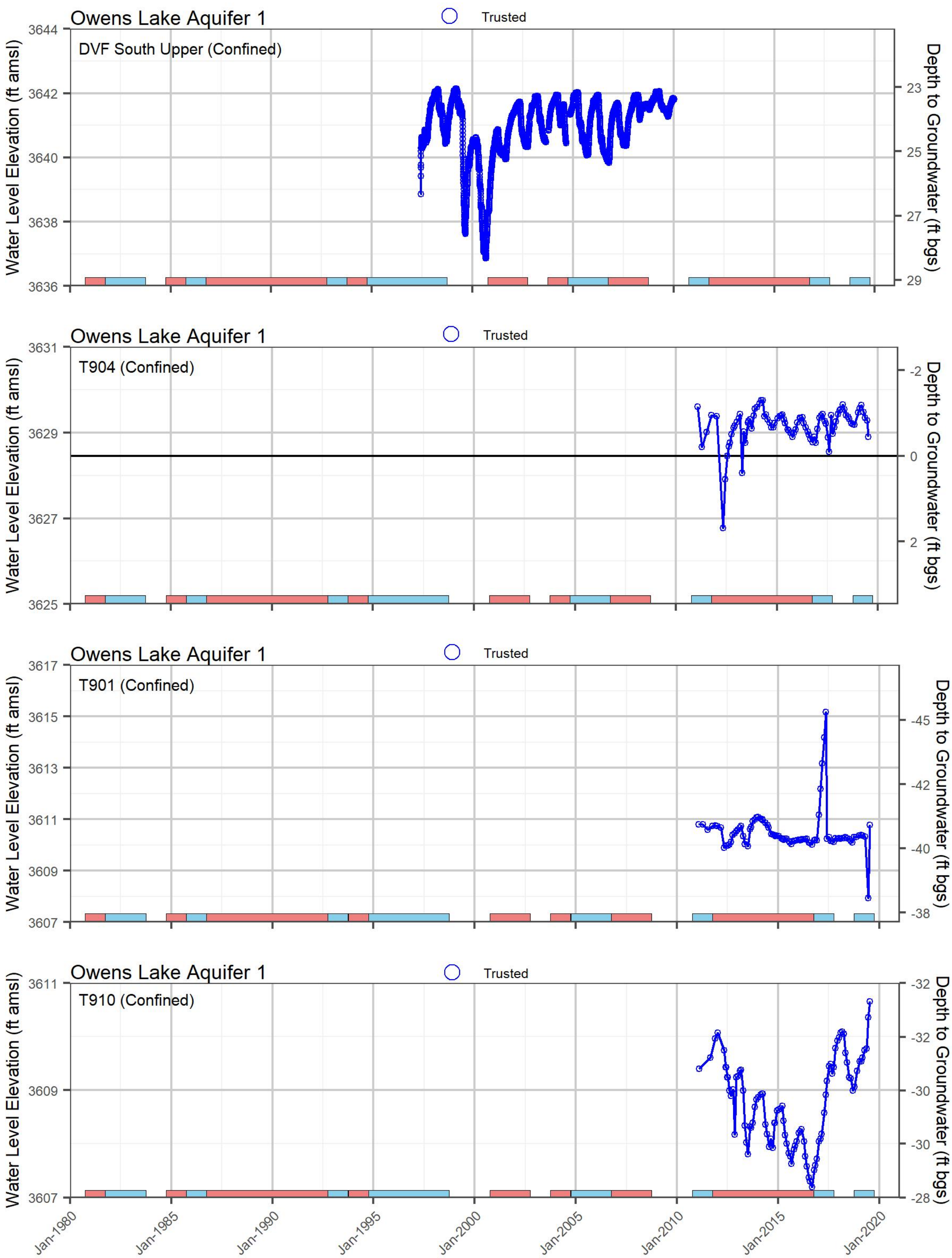

Notes:

1. Red and blue rectangles indicate dry and wet water years, respectively

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Lake Management Area
Water Level Trends

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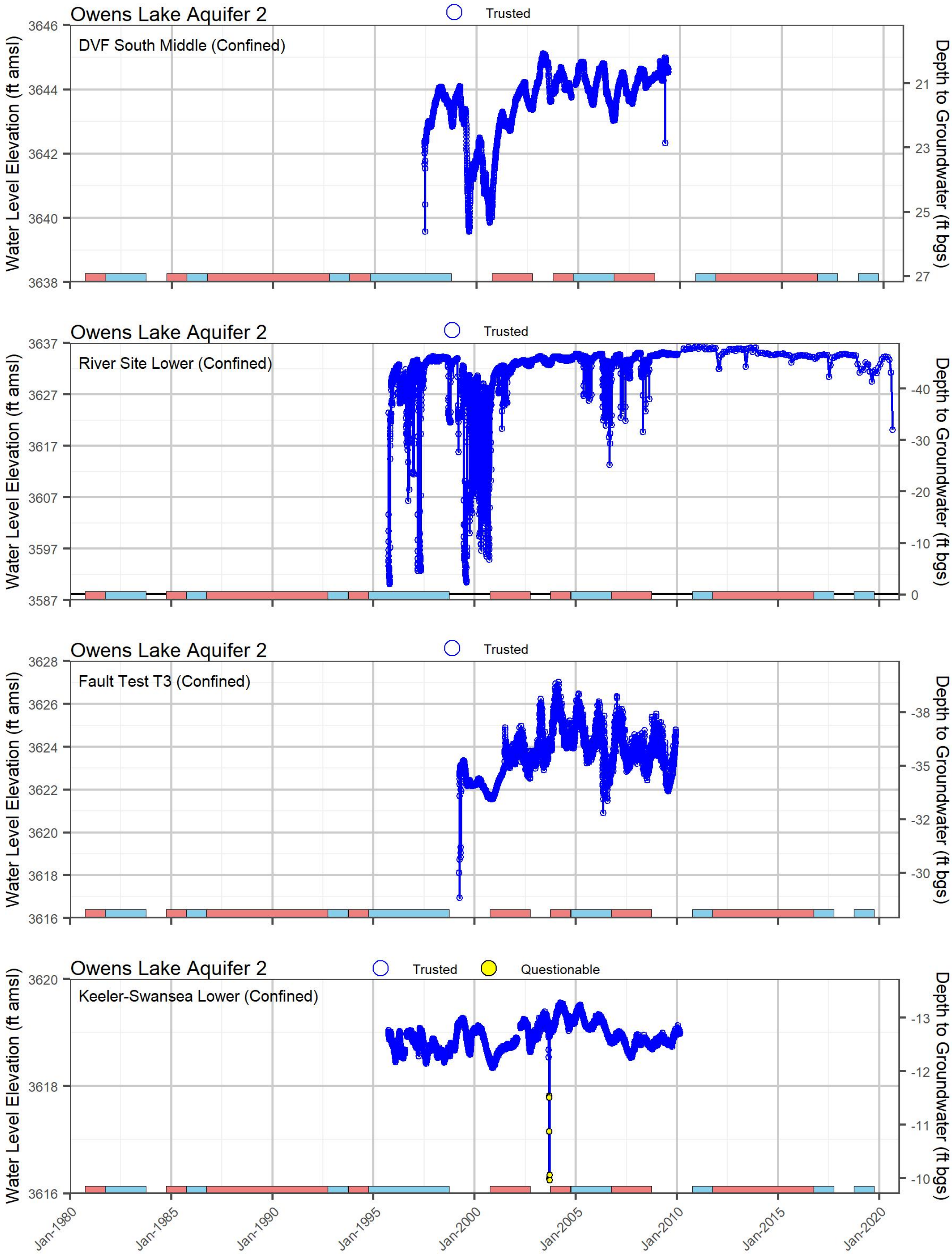
Figure 4-6b

K:\Projects\Water Resource Services\Public\DB18.1418.00 Owens Valley GSP\GSP\Appendices\7- Monitoring Plan and Data Gap Analysis\Figures\Owens_Lake_Aquifer_1_WL_trends.pdf



Notes:

1. Red and blue rectangles indicate dry and wet water years, respectively

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Lake Management Area

Water Level Trends

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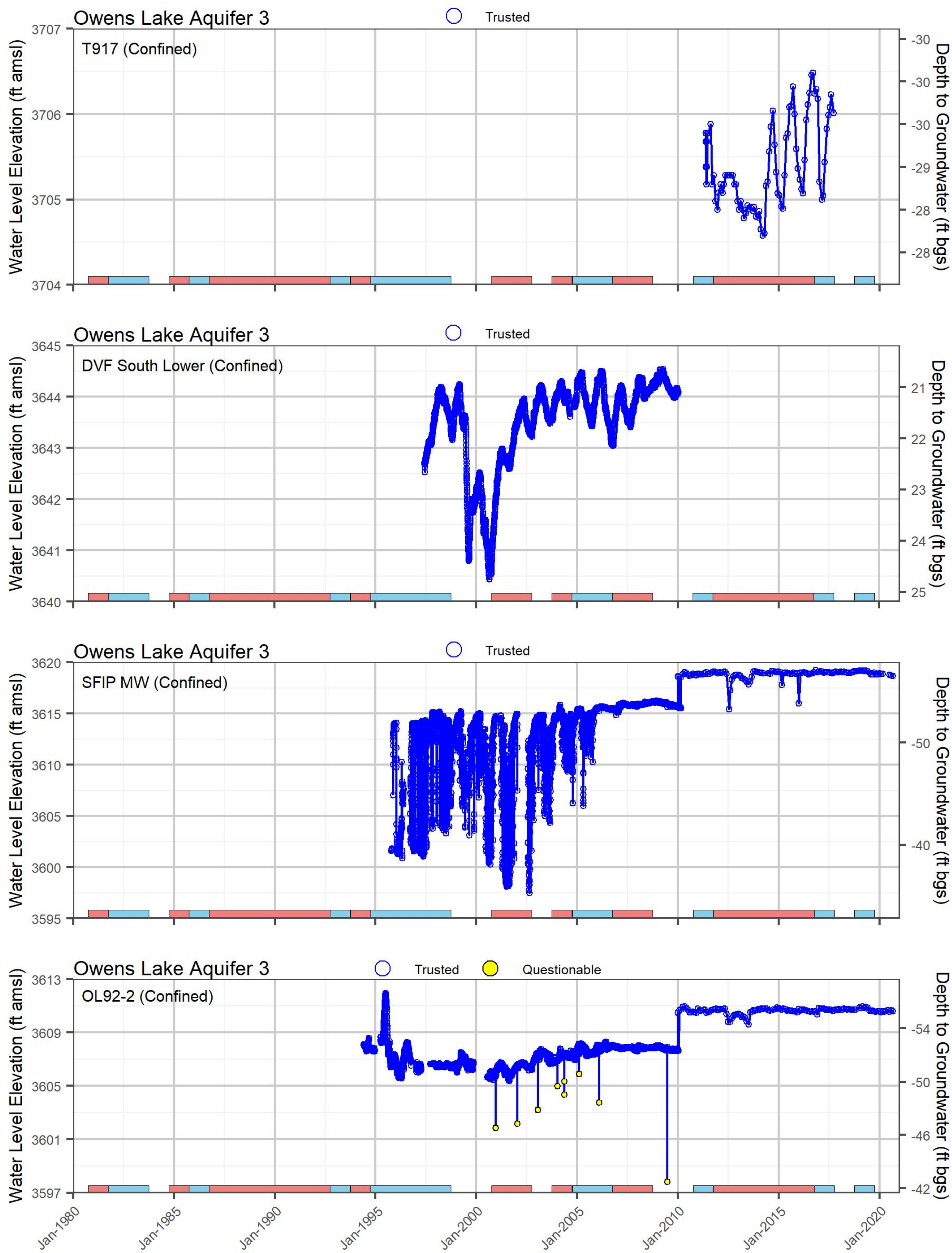
Figure 4-6c

K:\Projects\Water Resource Services\Public\DB18.1418.00 Owens Valley GSP\GSP\Appendices\7- Monitoring Plan and Data Gap Analysis\Figures\Owens_Lake_Aquifer_2_WL_trends.pdf



Notes:

1. Red and blue rectangles indicate dry and wet water years, respectively

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Lake Management Area
Water Level Trends

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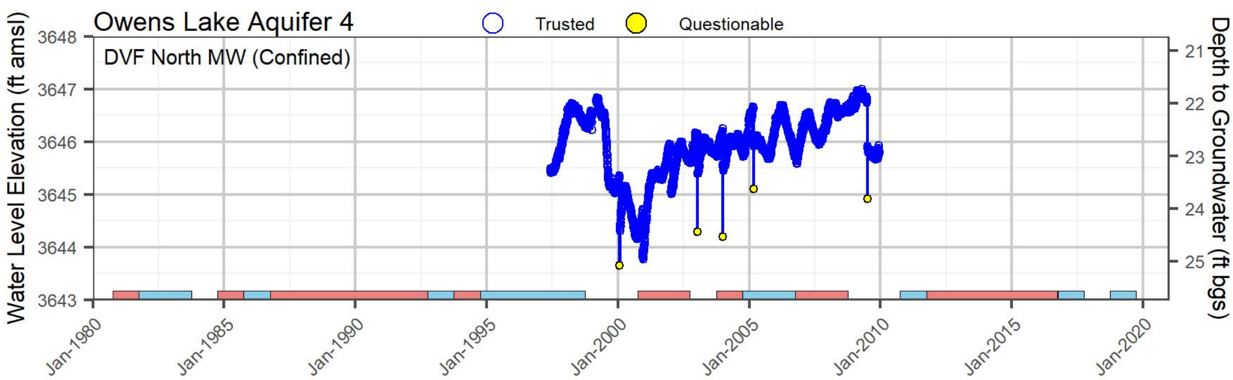
Figure 4-6d



Notes:

1. Red and blue rectangles indicate dry and wet water years, respectively

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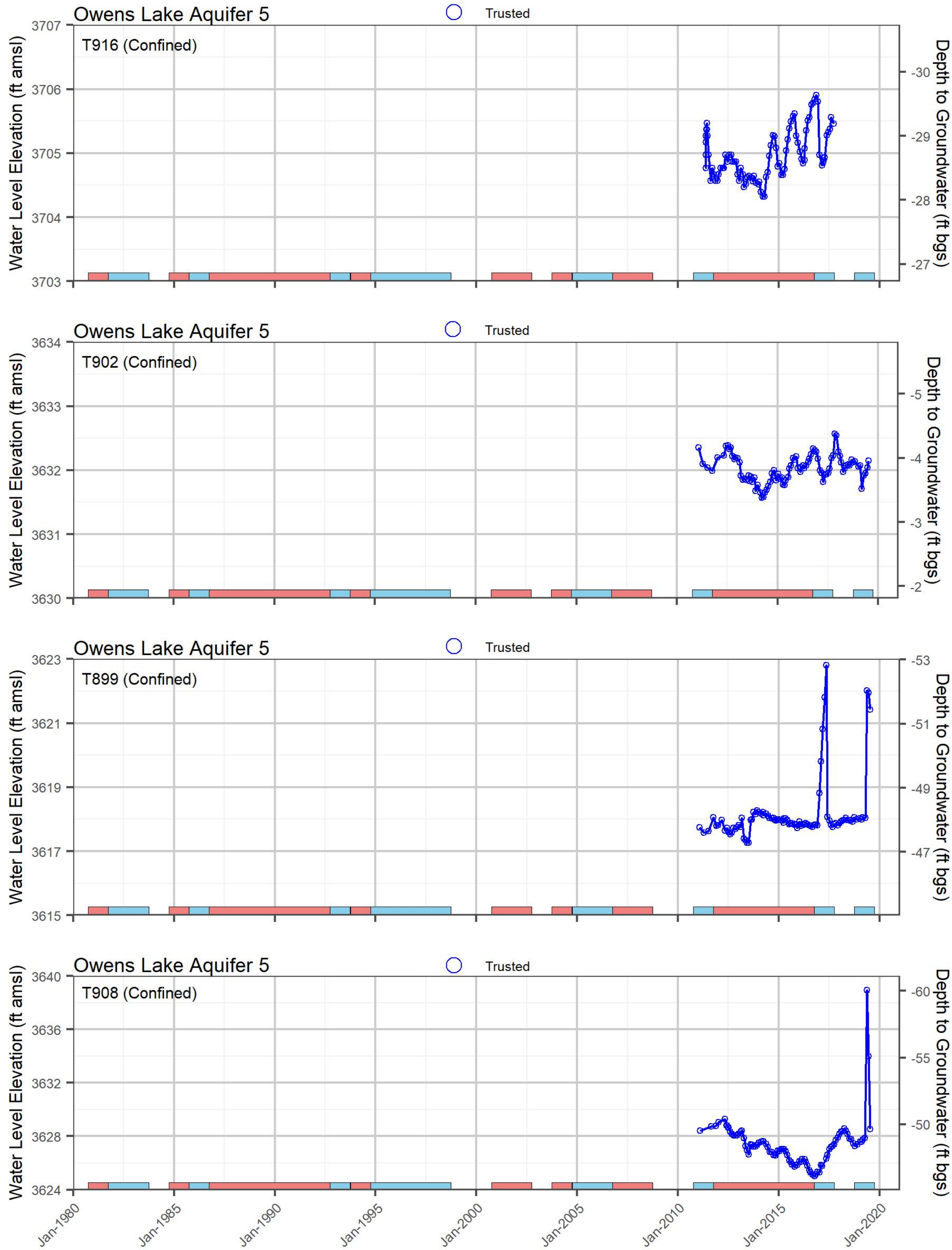
MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Lake Management Area

Water Level Trends

Figure 4-6e



Notes:
1. Red and blue rectangles indicate dry and wet water years, respectively

MONITORING PLAN AND DATA GAPS ANALYSIS
Owens Lake Management Area
Water Level Trends

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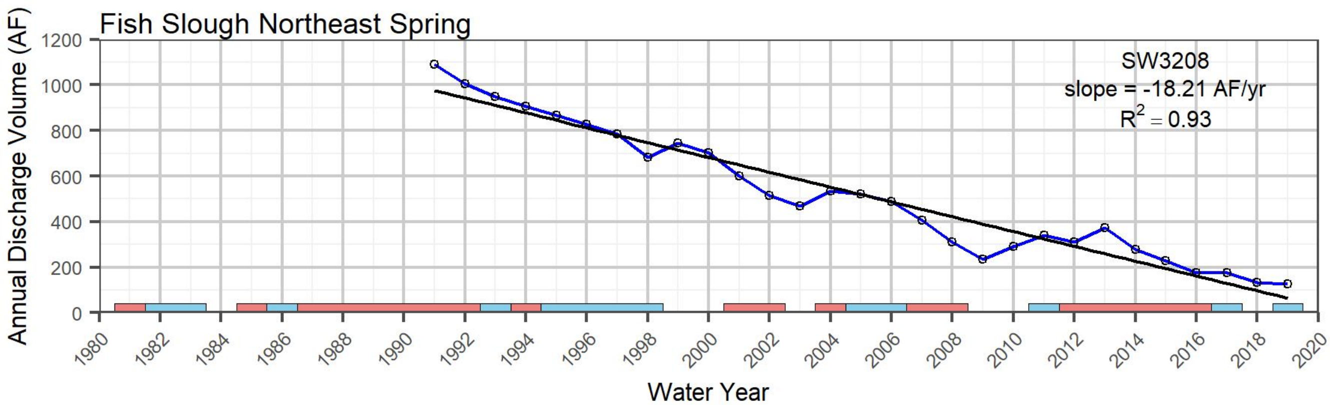
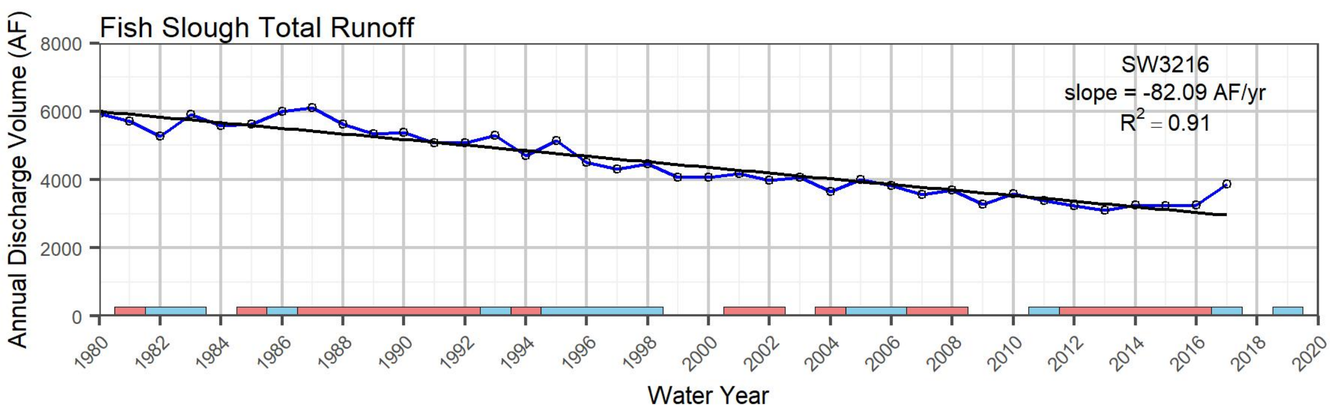
5/12/21

Figure 4-6f





Notes:

1. Red and blue rectangles indicate dry and wet water years, respectively

MONITORING PLAN AND DATA GAPS ANALYSIS

Fish Slough and Tri-Valley Management Area
Spring Flow and Runoff Trends

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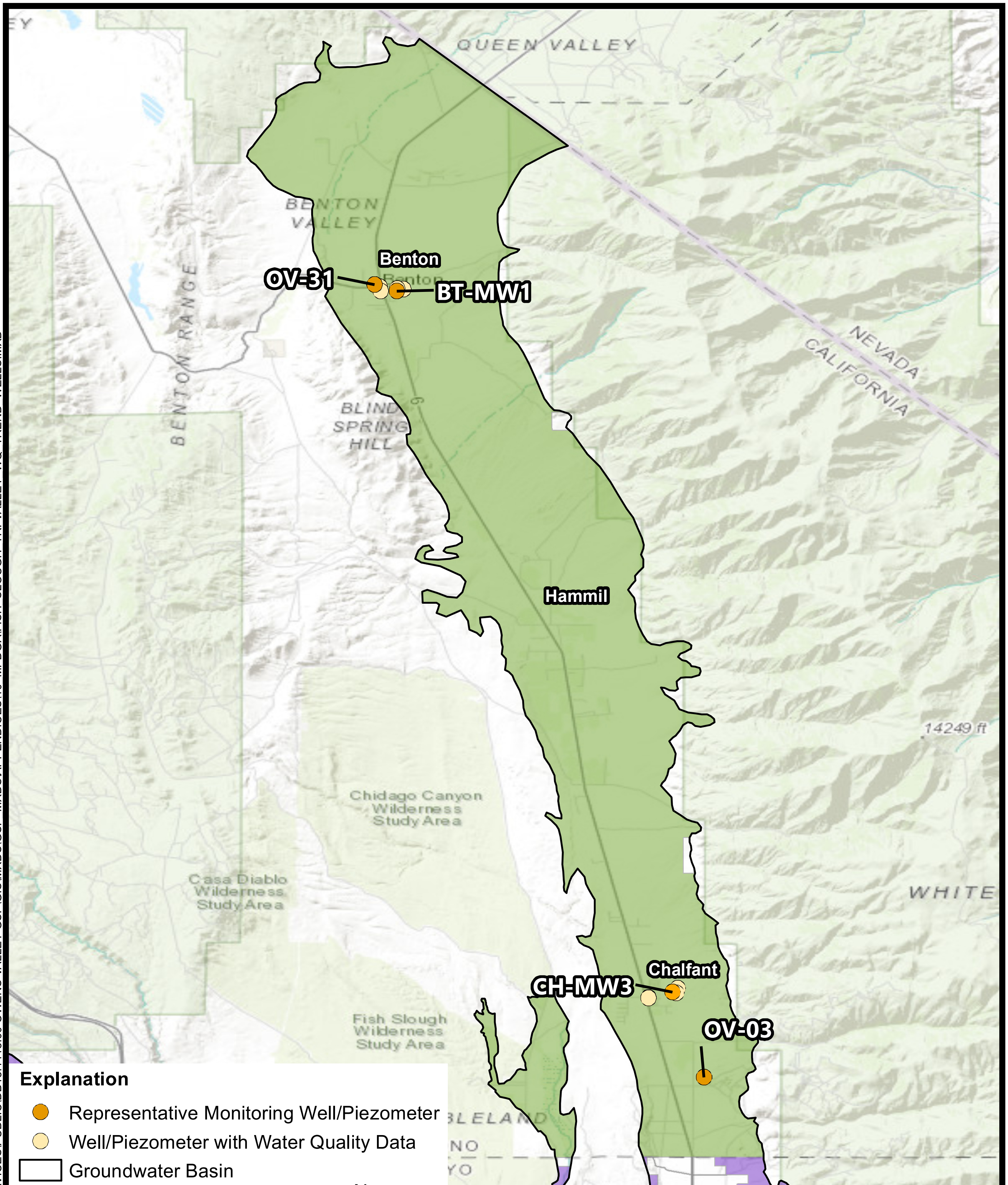
Figure 4-7

K:\Projects\Water Resource Services\Public\DB18.1418.00 Owens Valley GSP\GSP\Appendices\7- Monitoring Plan and Data Gap Analysis\Figures\Fish_Slough_Spring_Flow_and_Runoff.pdf



Explanation

- Representative Monitoring Well/Piezometer
- Well/Piezometer with Water Quality Data
- Groundwater Basin

Management Area

- Fish Slough and Tri-Valley
- Owens Valley

N

0 2 4 Miles

Notes:
1. Locations sampled for arsenic, chloride, sodium, nitrate, and total dissolved solids (TDS) shown
2. Wells with observations after January 1, 2010 shown
3. Wells with fewer than three observations omitted

MONITORING PLAN AND DATA GAPS ANALYSIS

Fish Slough and Tri-Valley Water Quality Representative Monitoring Wells

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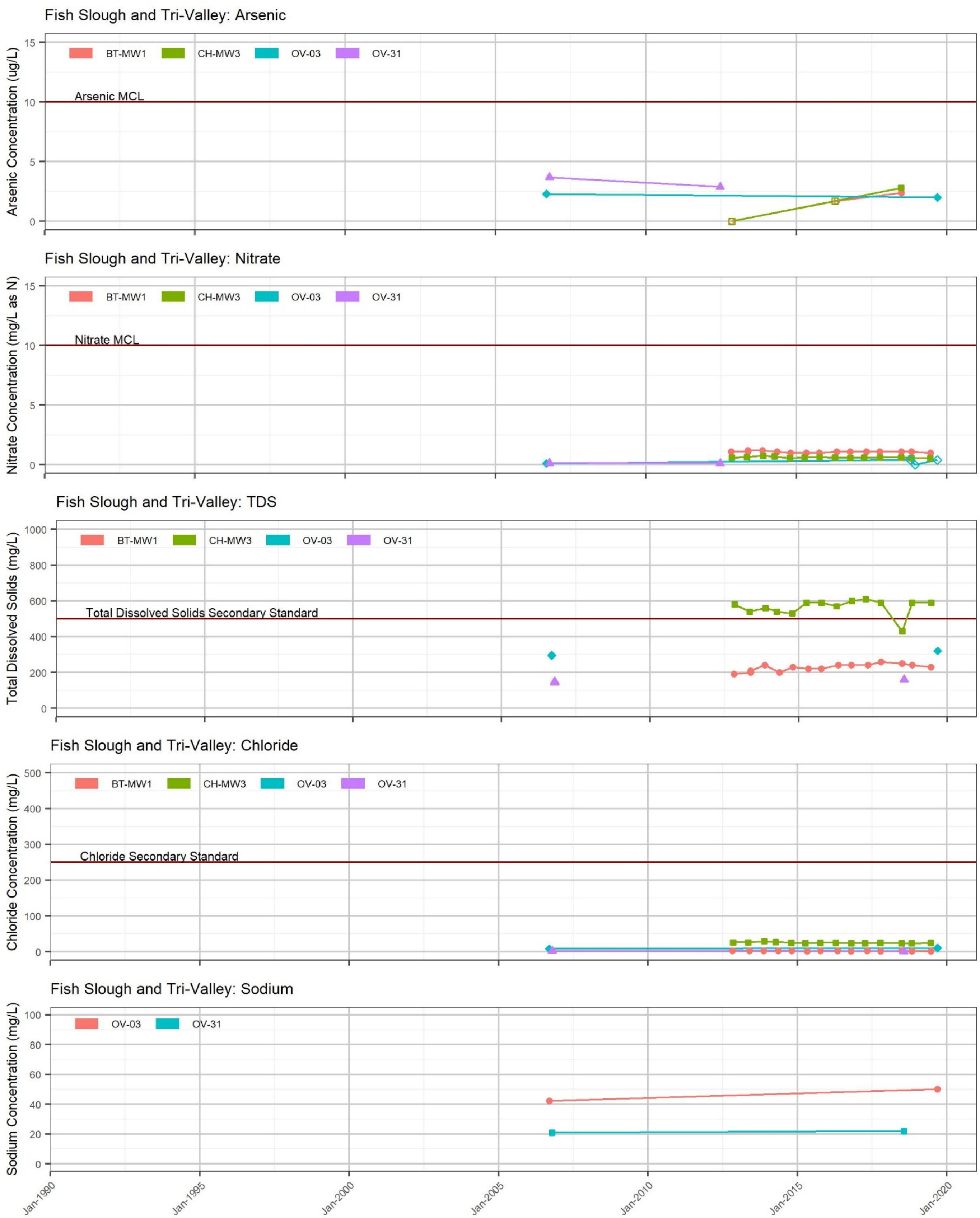
Figure 4-8

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP MXDS\APPENDICES\10 MPDGA\FISH SLOUGH TRI-VALLEY WQ TREND WELLS.MXD



Notes:

1. Non-detects plotted as open symbols at the reference limit

MONITORING PLAN AND DATA GAPS ANALYSIS

Fish Slough and Tri-Valley Management Area
Water Quality Trends

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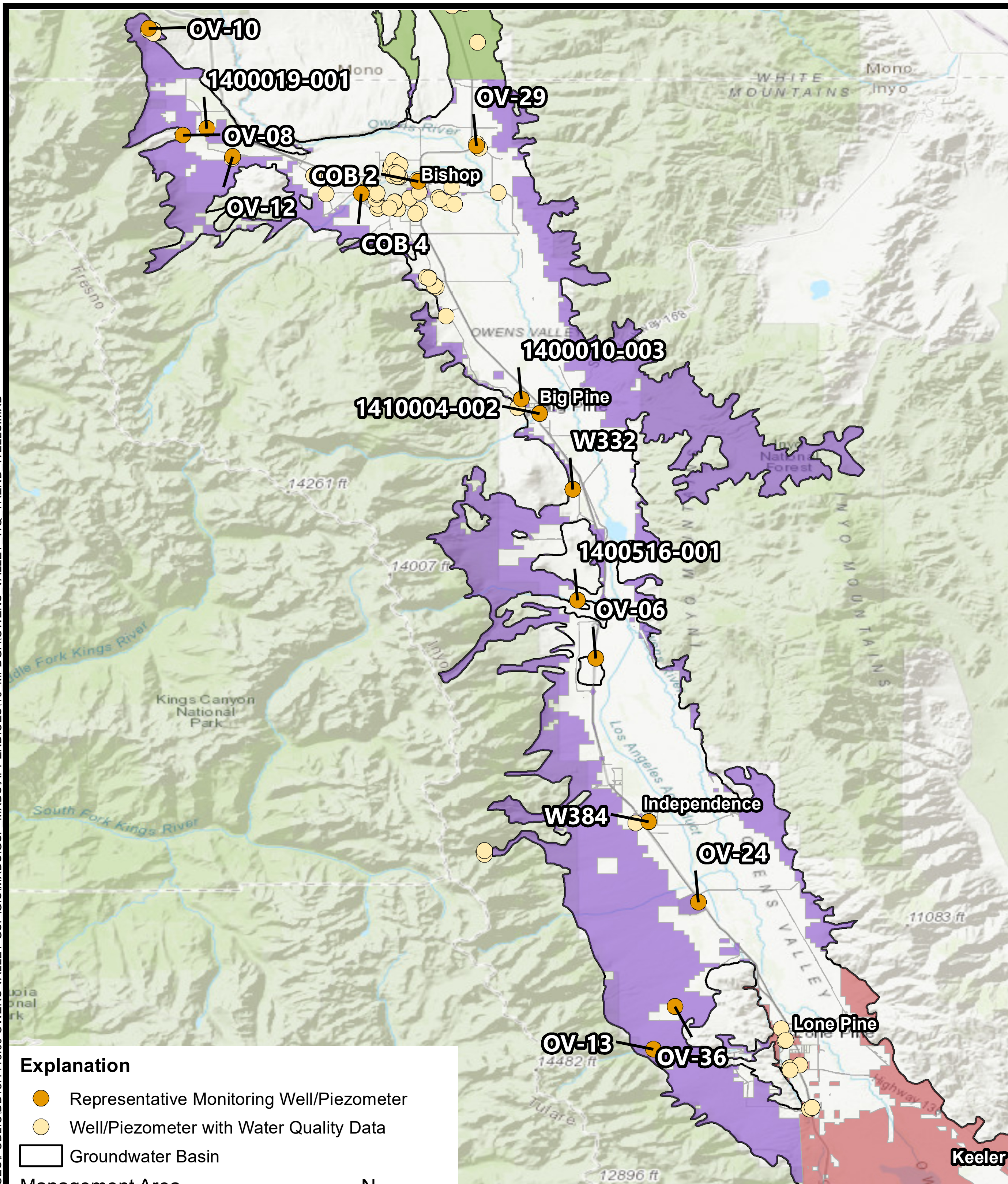
Figure 4-9

K:\Projects\Water Resource Services\Public\DB18.1418.00 Owens Valley GSP\GSP\Appendices\7- Monitoring Plan and Data Gap Analysis\Figures\Fish_Slough_Tri-Valley_WQ_trends.pdf



Notes:
1. Locations sampled for arsenic, chloride, sodium, nitrate, and total dissolved solids (TDS) shown
2. Wells with observations after January 1, 2010 shown
3. Wells with fewer than three observations omitted

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Valley Water Quality Representative Monitoring Wells

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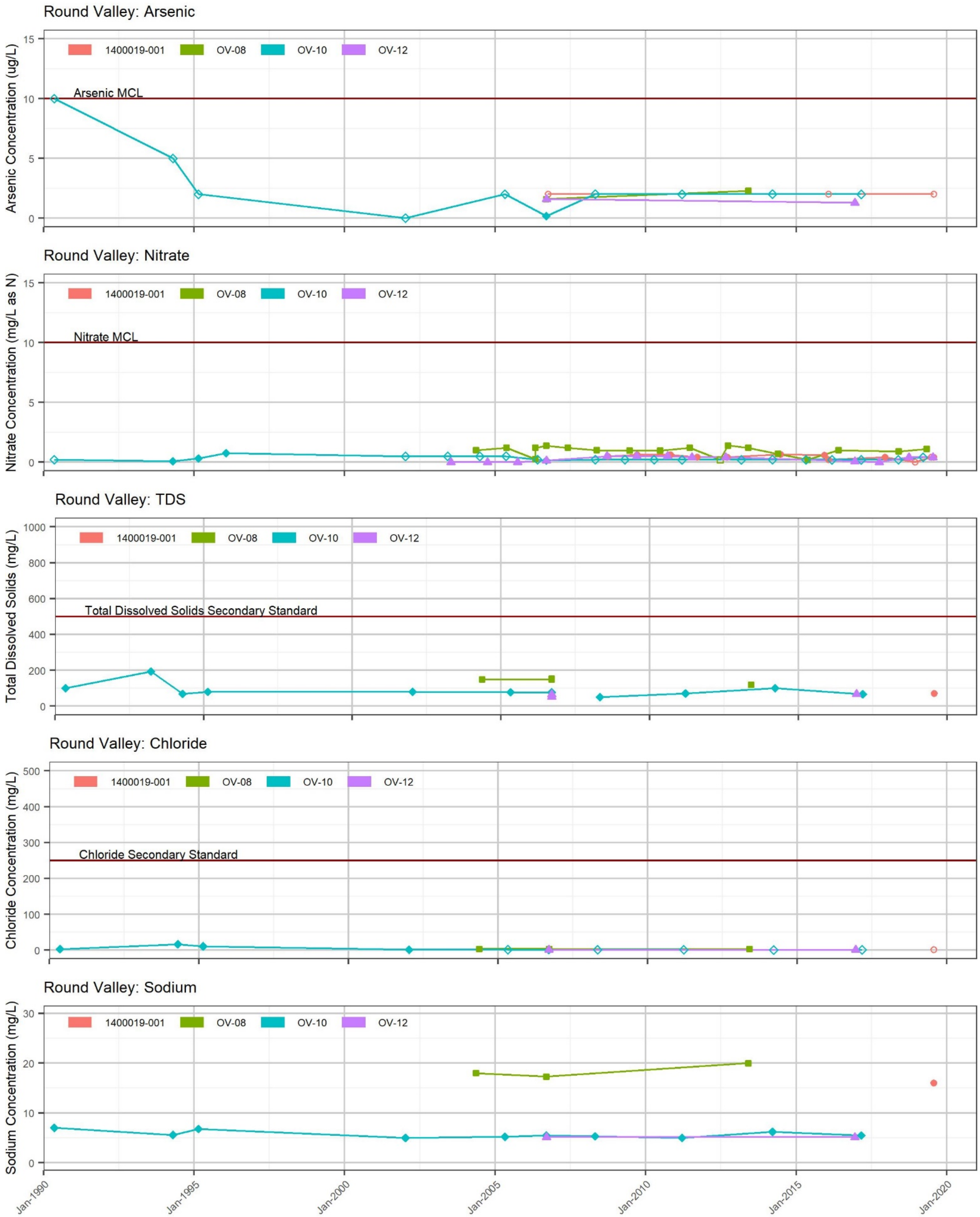
Figure 4-10

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP_MXDS\APPENDICES\10_MPDGA\OWENS_VALLEY_WQ_TREND_WELLS.MXD



Notes:

1. Non-detects plotted as open symbols at the reporting limit

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Valley Management Area
Water Quality Trends

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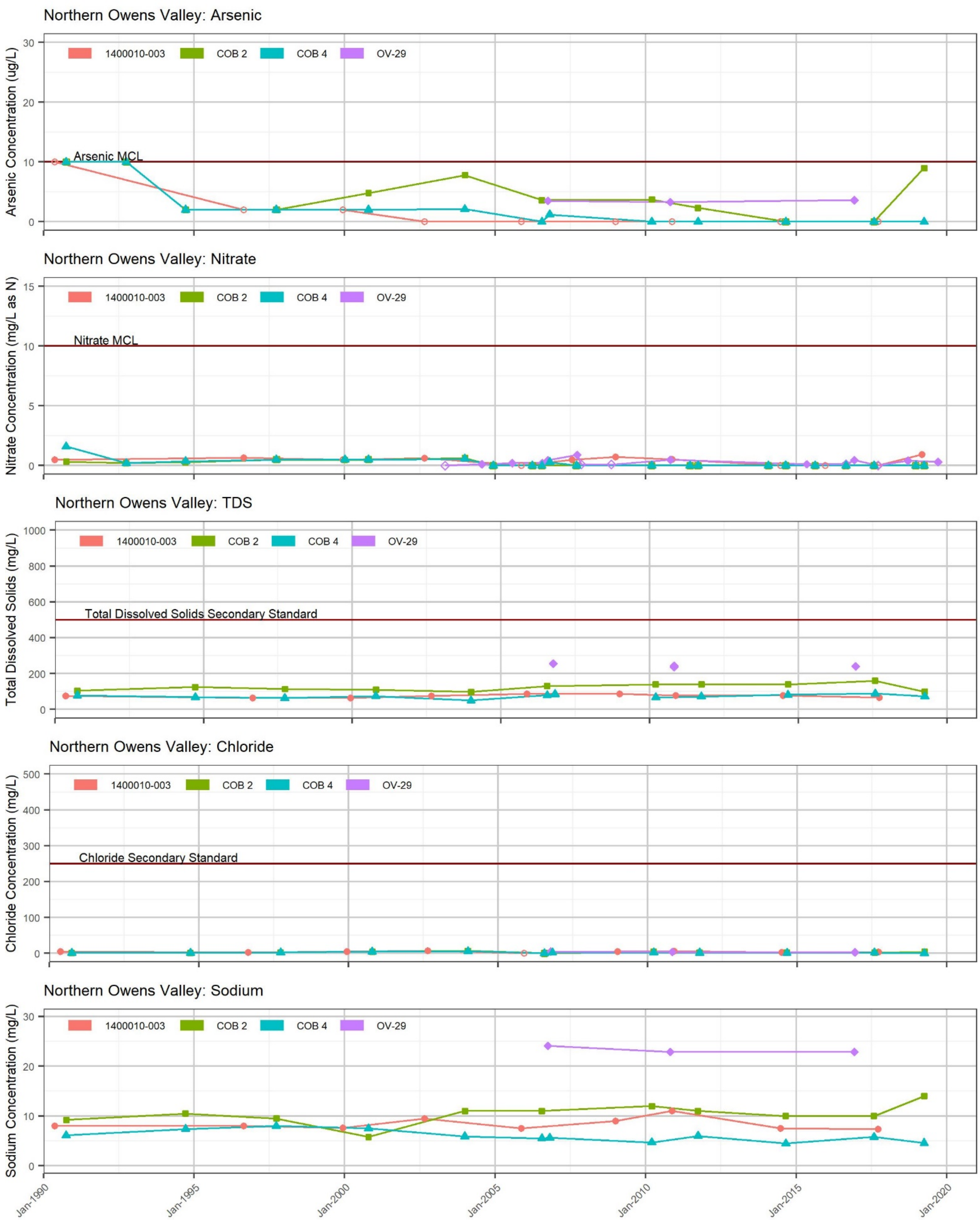
Figure 4-11a

K:\Projects\Water Resource Services\Public\DB18.1418.00 Owens Valley GSP\GSP\Appendices\7- Monitoring Plan and Data Gap Analysis\Figures\Round_Valley_WQ_trends.pdf



Notes:

1. Non-detects plotted as open symbols at the reporting limit

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Valley Management Area

Water Quality Trends

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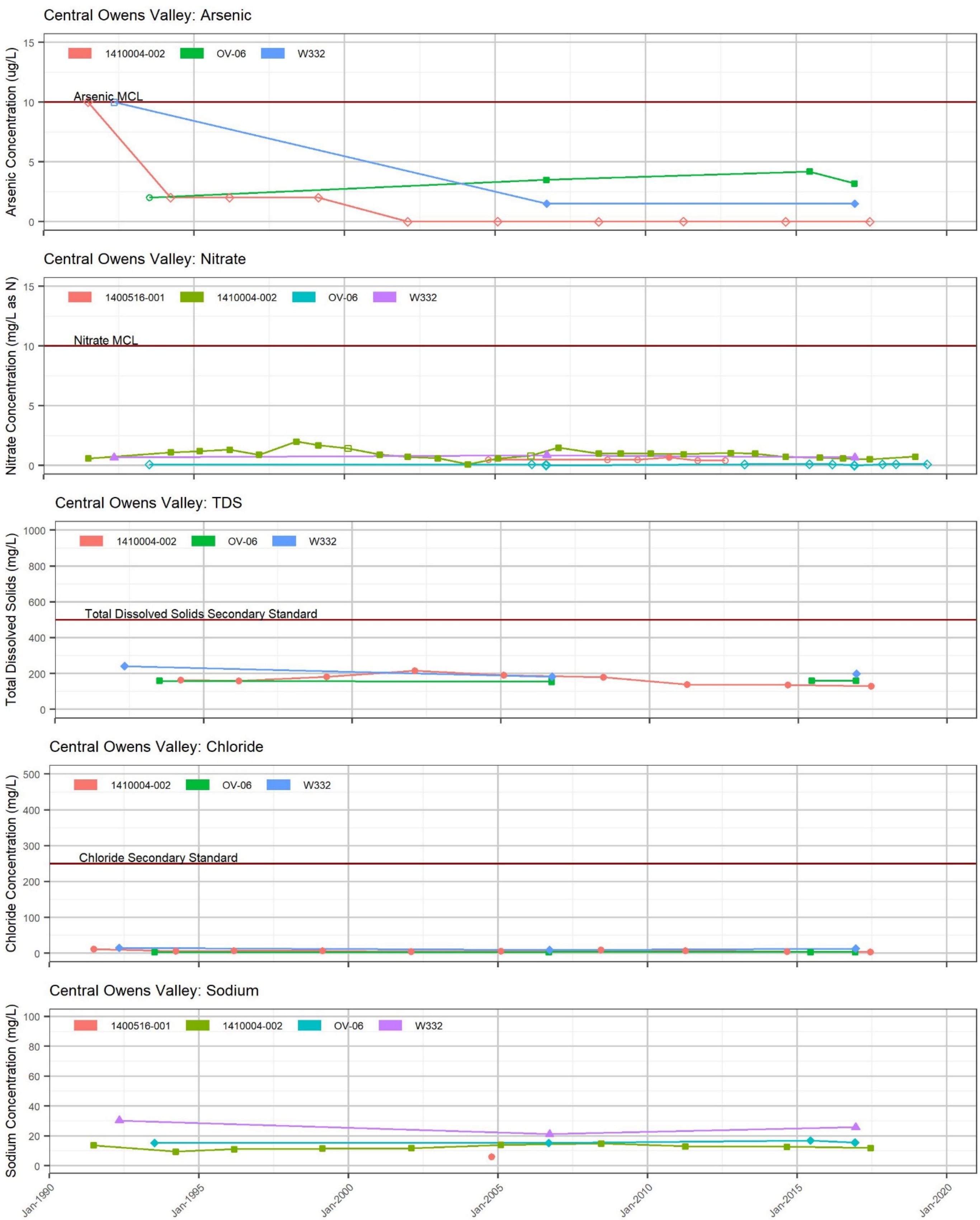
Figure 4-11b

K:\Projects\Water Resource Services\Public\DB18.1418.00 Owens Valley GSP\GSP\Appendices\7- Monitoring Plan and Data Gap Analysis\Figures\Owens_Valley_Northern_WQ_trends.pdf



Notes:
1. Non-detects plotted as open symbols at the reporting limit

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Valley Management Area
Water Quality Trends

Figure 4-11c

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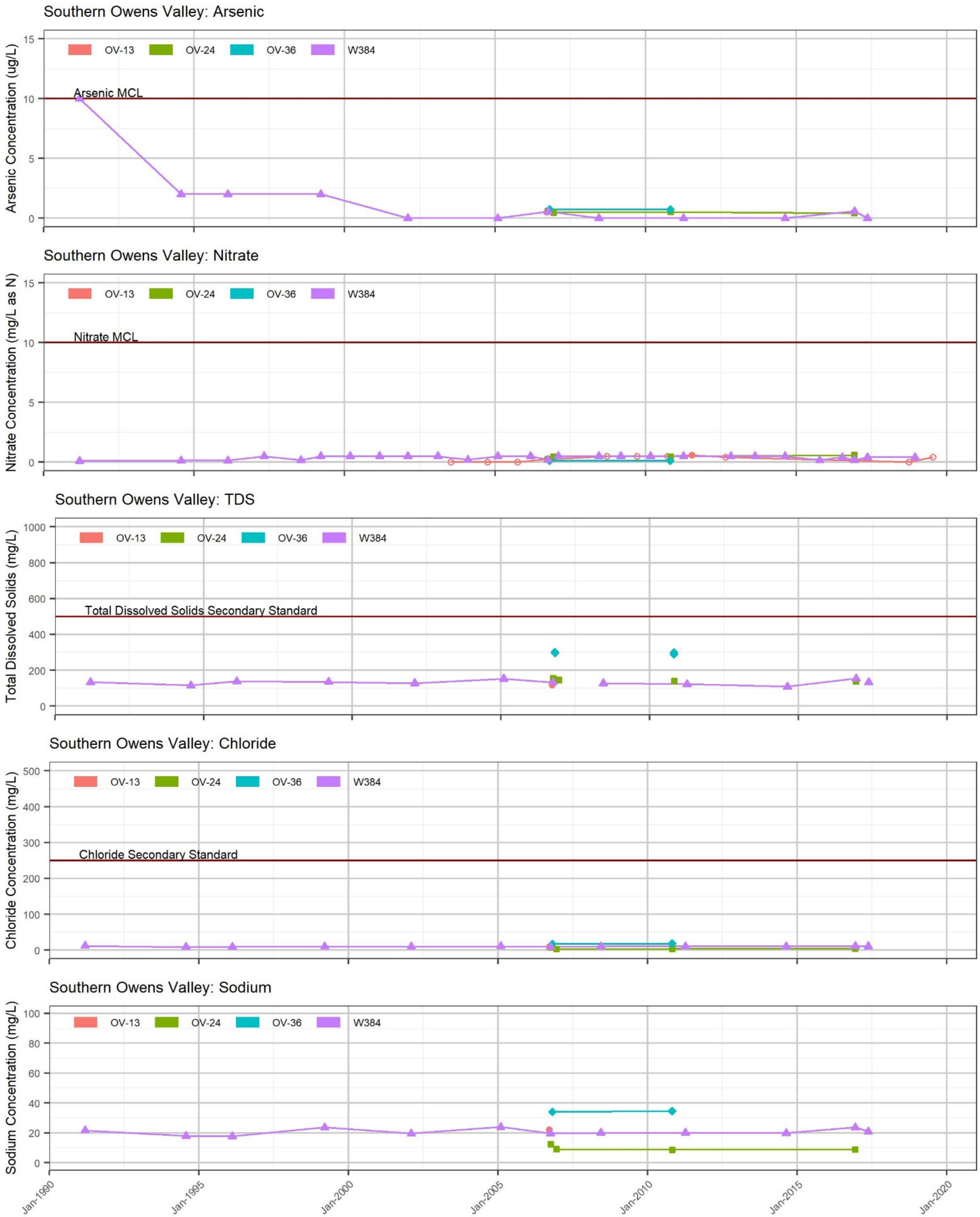

Notes:

1. Non-detects plotted as open symbols at the reporting limit

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Valley Management Area

Water Quality Trends

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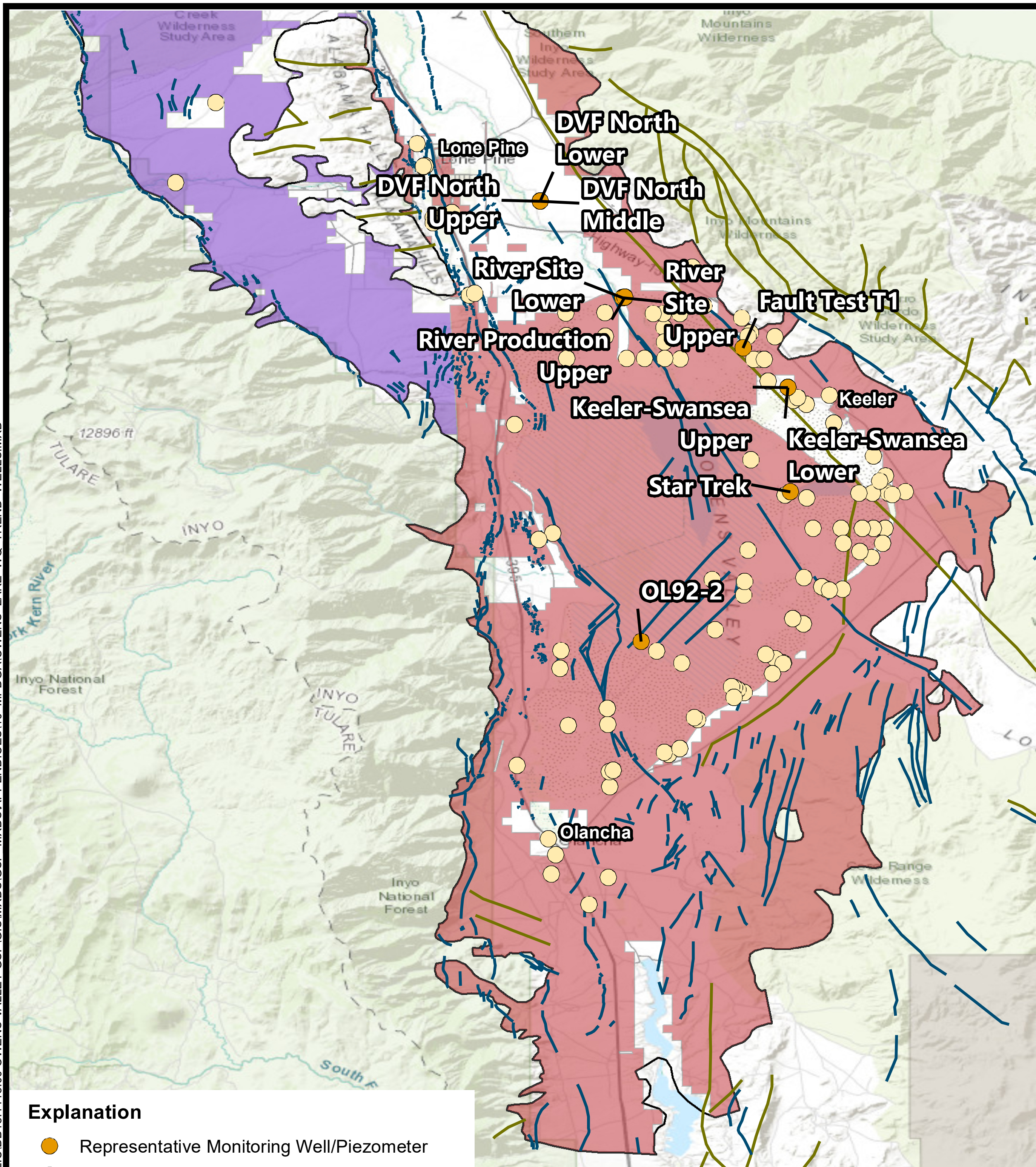
Figure 4-11d

K:\Projects\Water Resource Services\Public\DB18.1418.00 Owens Valley GSP\GSP\Appendices\7- Monitoring Plan and Data Gap Analysis\Figures\Owens_Valley_Southern_WQ_trends.pdf



Source: USGS Geologic Hazards Science Center

Notes:
1. Locations sampled for arsenic, chloride, sodium, nitrate, and total dissolved solids (TDS) shown
2. Wells with observations after January 1, 2000 shown
3. Wells with fewer than three observations omitted

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Lake Water Quality
Representative Monitoring Wells

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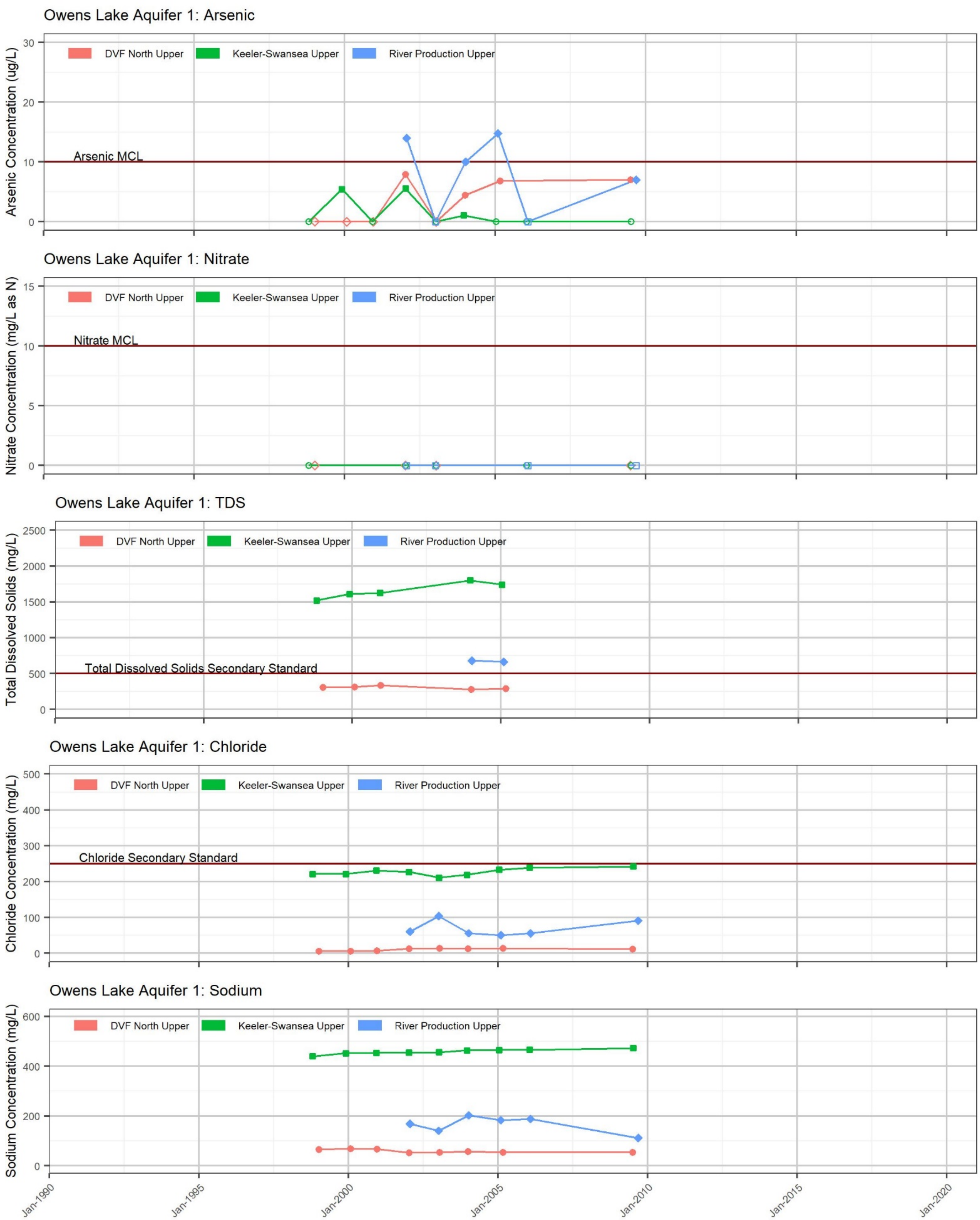
Figure 4-12

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP MXDS\APPENDICES\10 MPDGA\OWENS LAKE WQ TREND WELLS.MXD



Notes:

1. Non-detects plotted as open symbols at the reporting limit

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Lake Management Area
Water Quality Trends

Figure 4-13a

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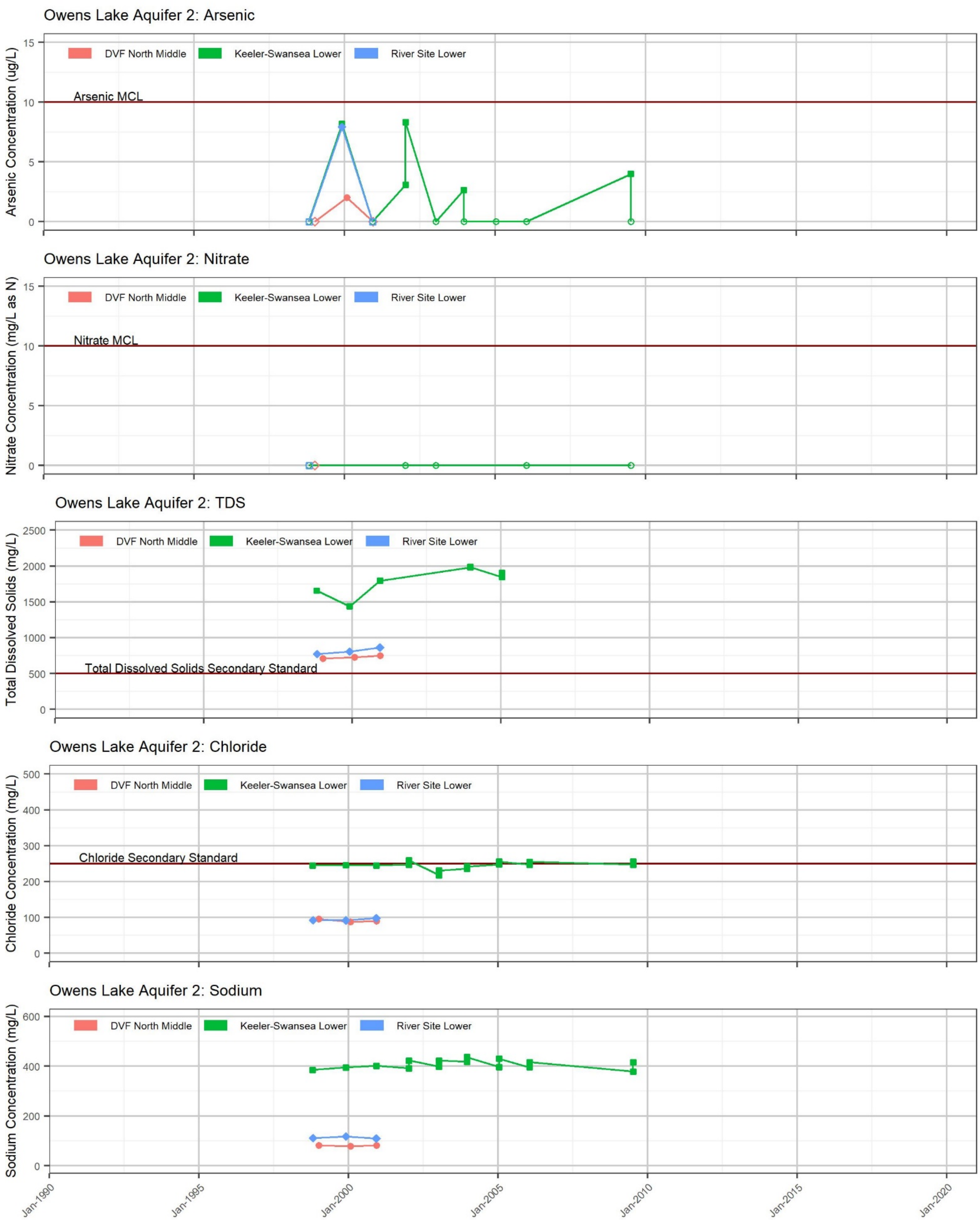

Notes:

1. Non-detects plotted as open symbols at the reference limit

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Lake Management Area

Water Quality Trends

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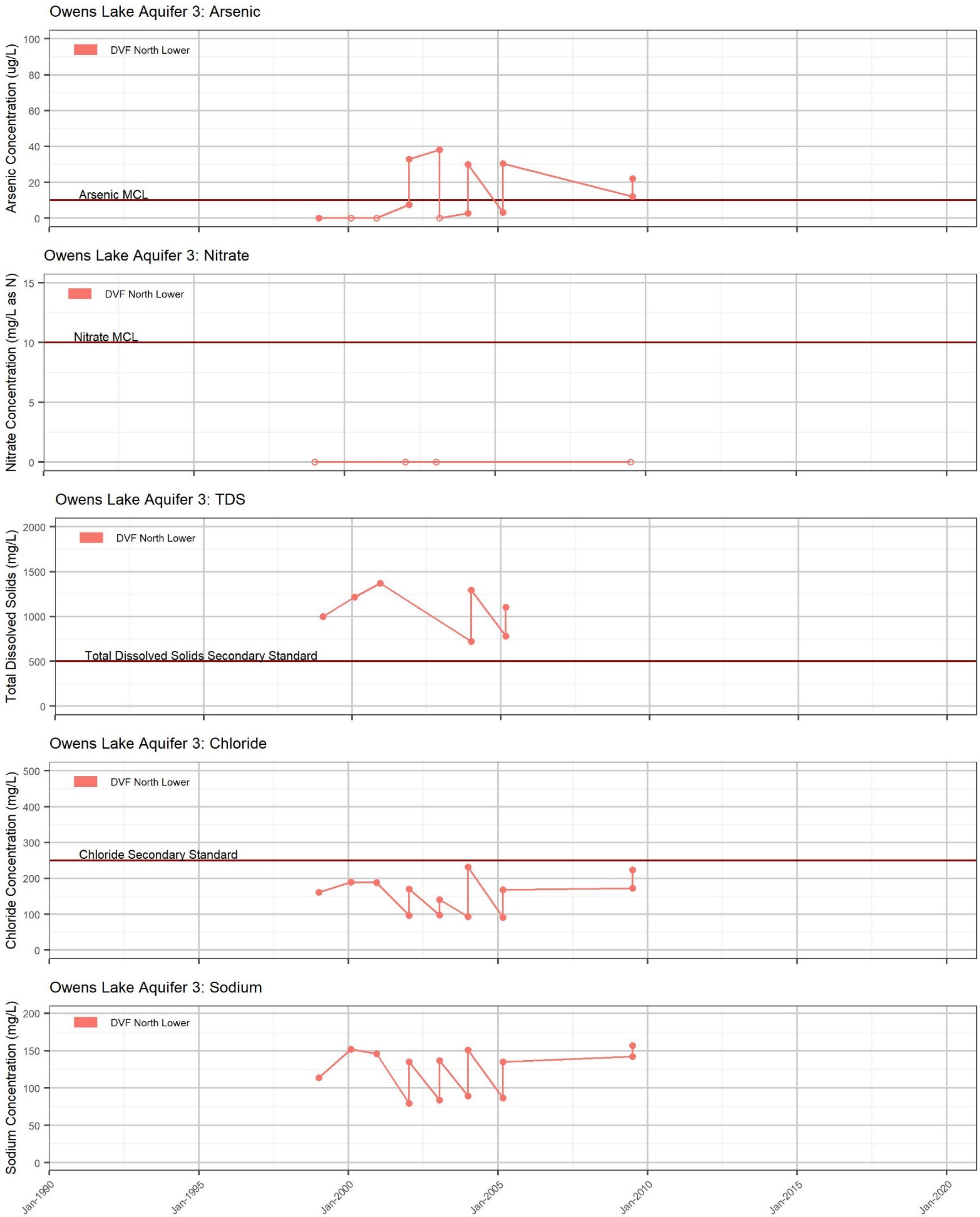
Figure 4-13b



Notes:

1. Non-detects plotted as open symbols at the reporting limit

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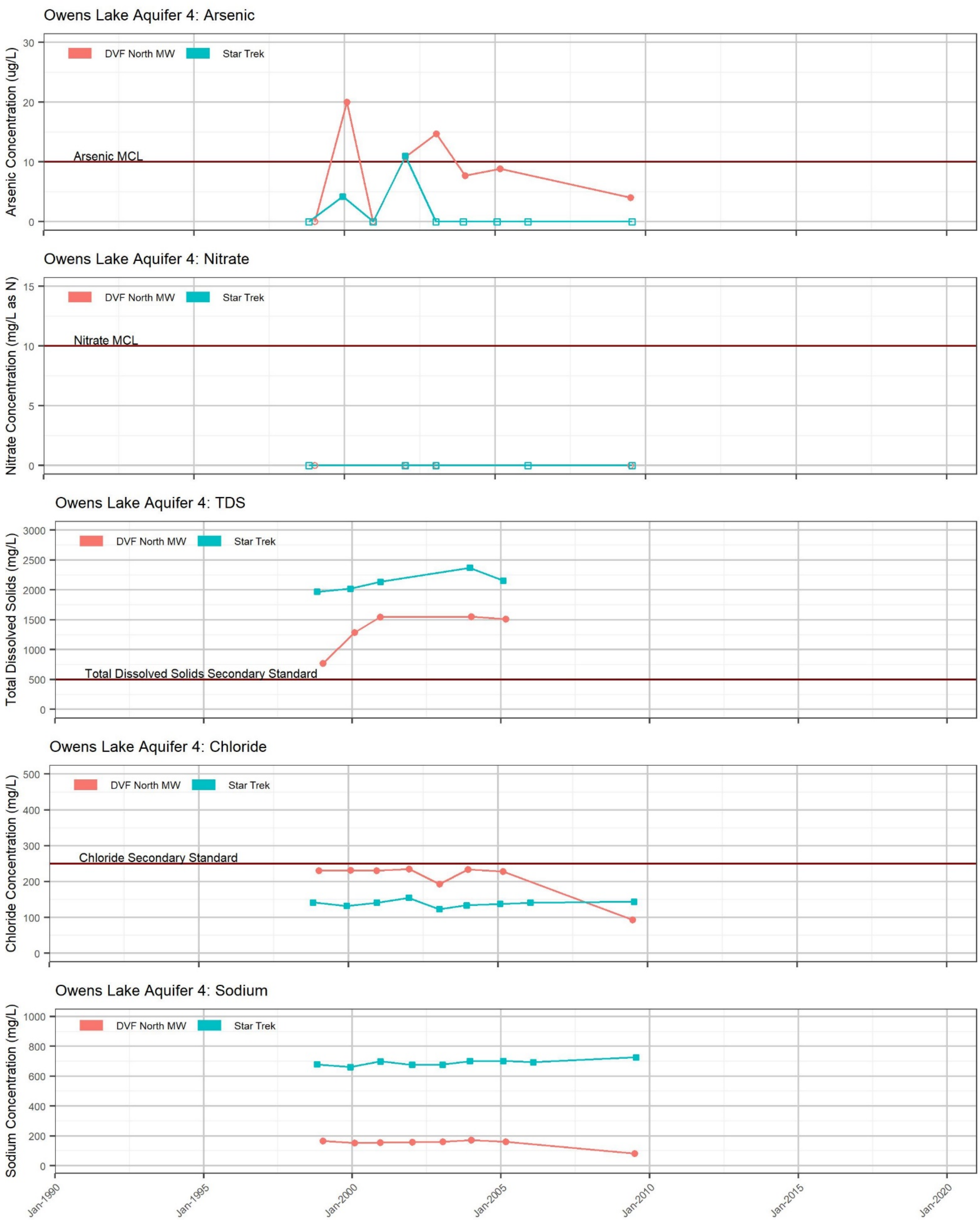
MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Lake Management Area
Water Quality Trends

Figure 4-13c



Notes:

1. Non-detects plotted as open symbols at the reporting limit

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Lake Management Area

Water Quality Trends

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Figure 4-13d

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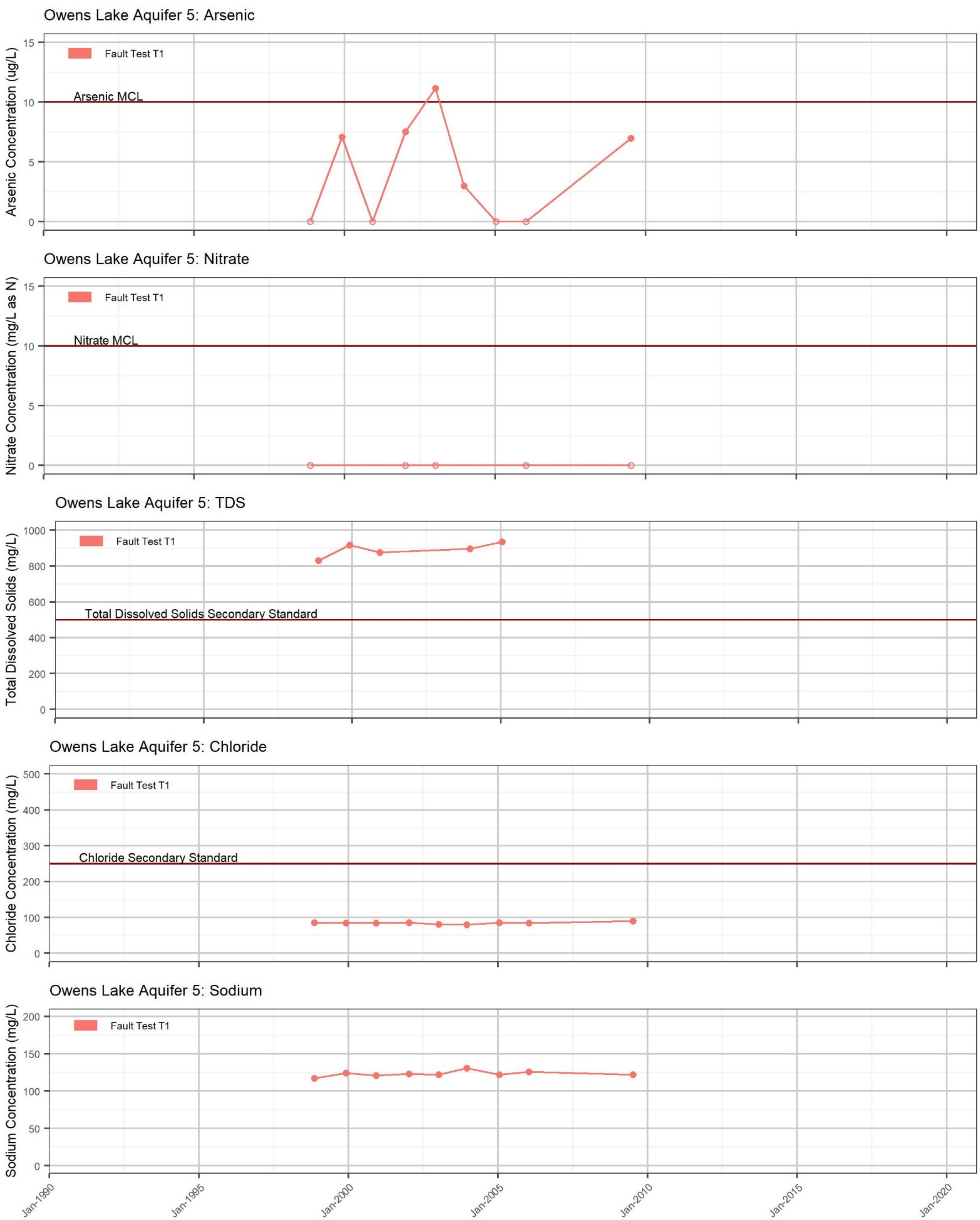

Notes:

1. Non-detects plotted as open symbols at the reporting limit

MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Lake Management Area
Water Quality Trends

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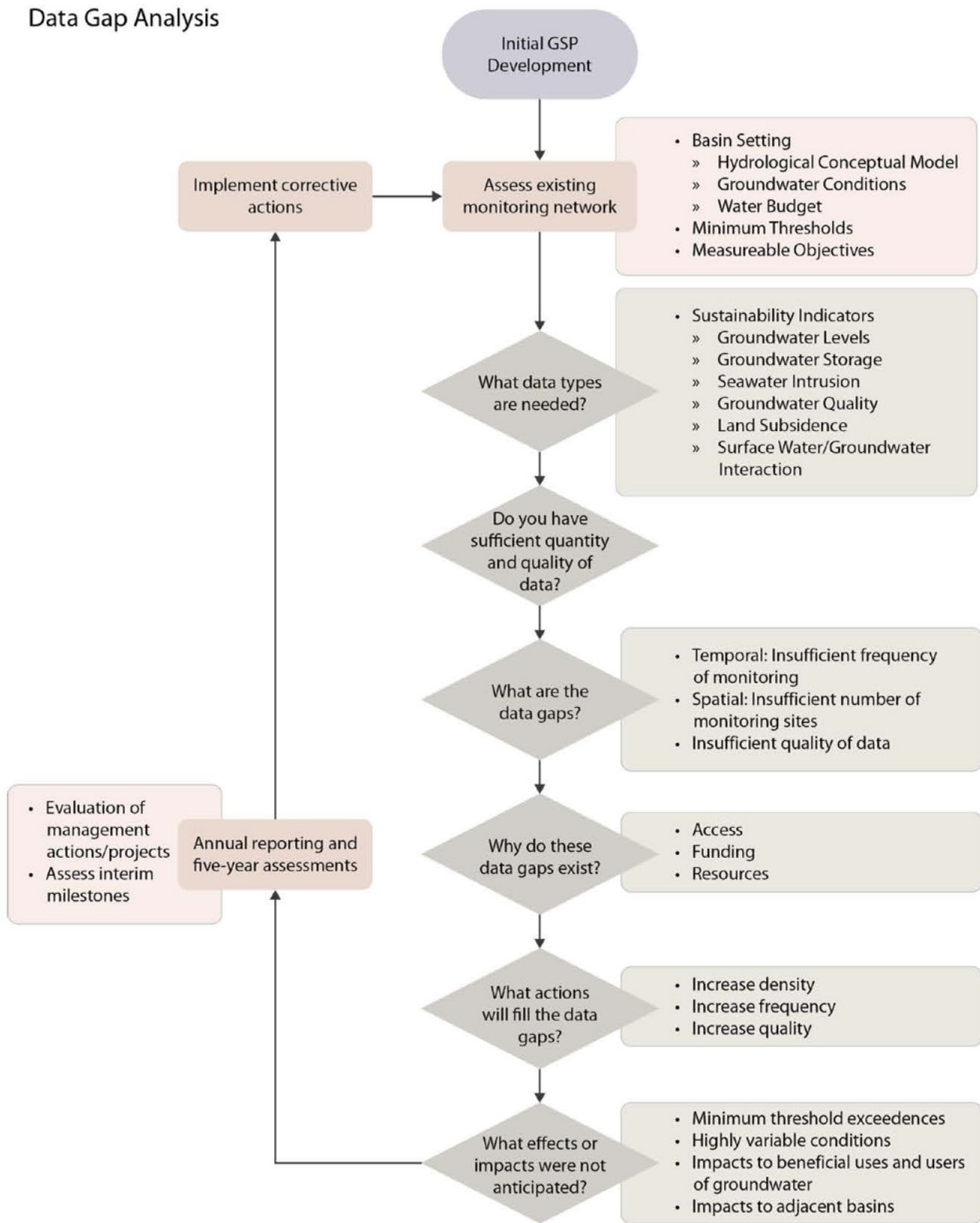
Figure 4-13e



Notes:

1. Figure 4 from DWR BMP#2: Monitoring Networks and Identification of Data Gaps

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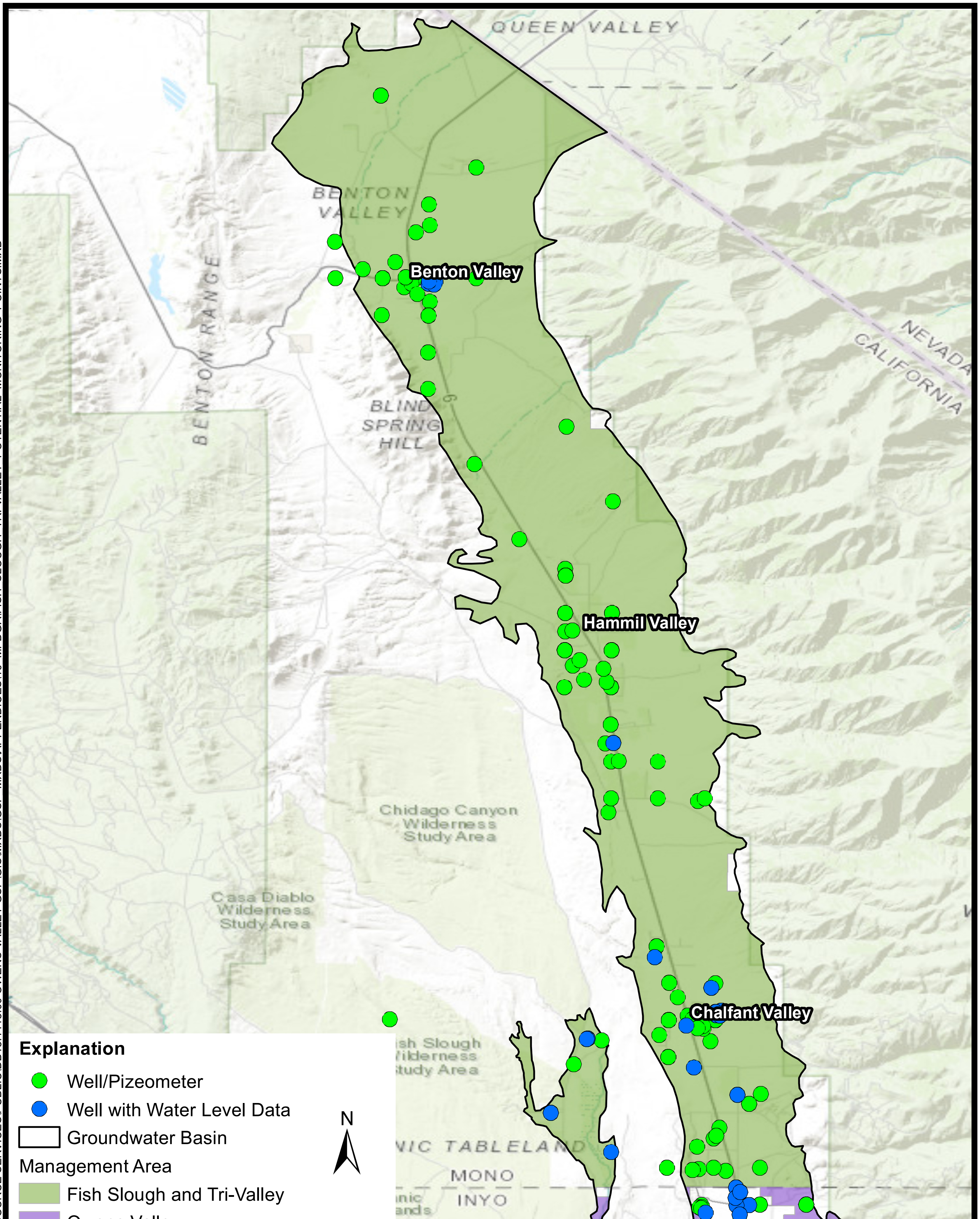
MONITORING PLAN AND DATA GAPS ANALYSIS
Data Gaps Analysis Flow Chart

Figure 5-1



0 2 4 Miles

MONITORING PLAN AND DATA GAPS ANALYSIS

Fish Slough and Tri-Valley
Potential Monitoring Points

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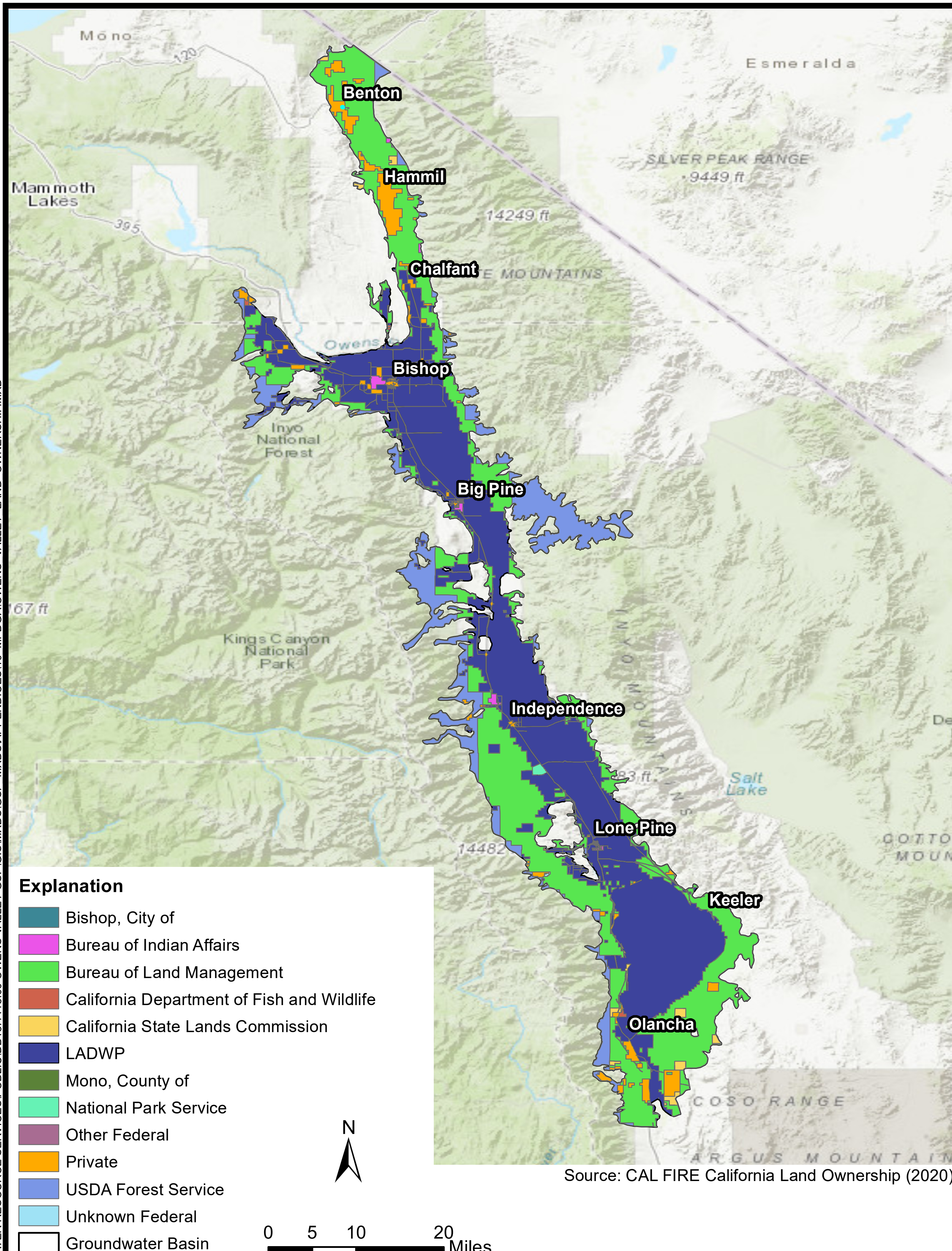
Figure 6-1

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP_MXDS\APPENDICES\10_MPDGA\FISH_SLOUGH_TRI-VALLEY_POTENTIAL_MONITORING_POINTS.MXD



Source: CAL FIRE California Land Ownership (2020)

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP MXDS\APPENDICES\10 MPDGA\OWENS VALLEY LAND OWNERSHIP.MXD

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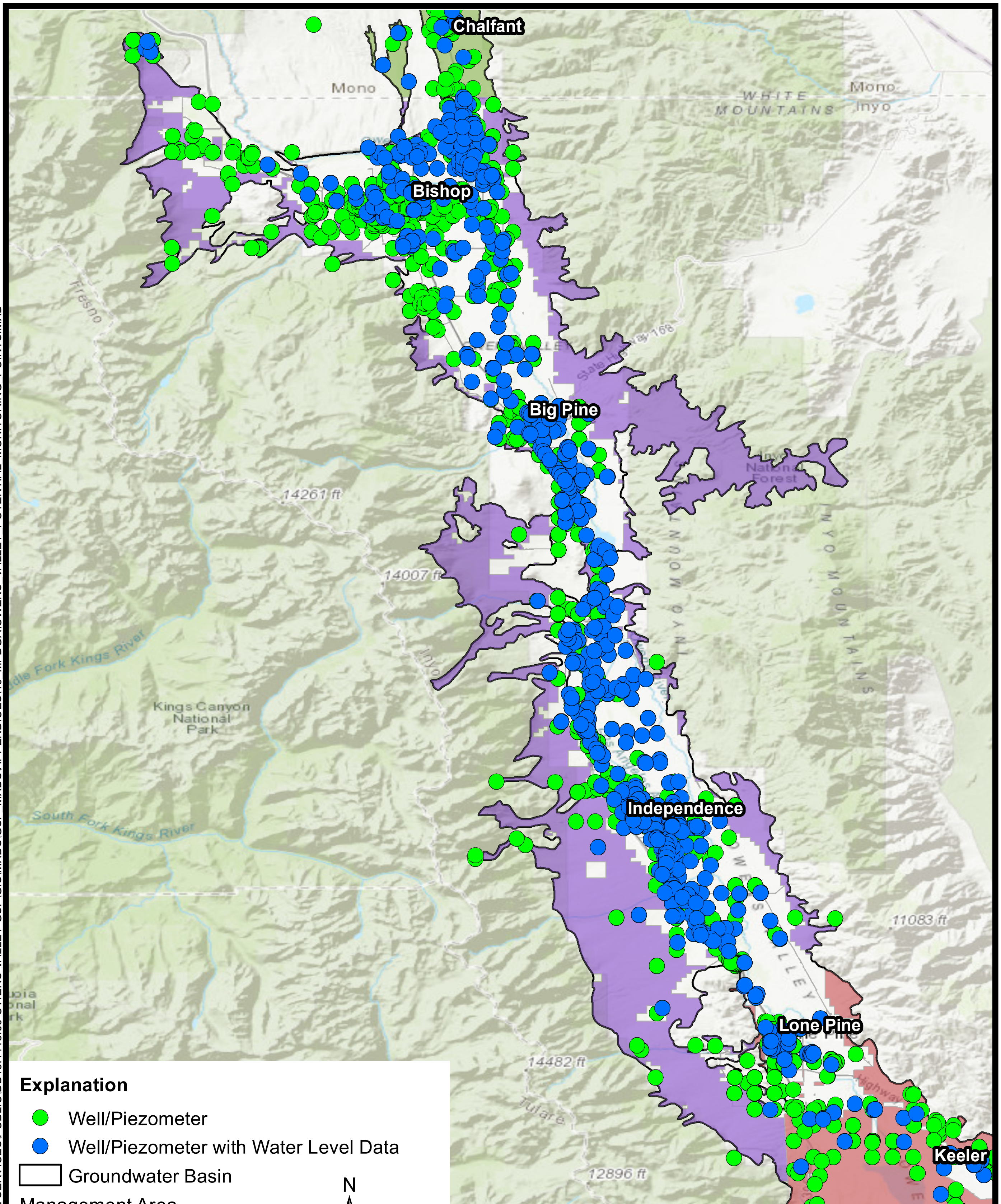
MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Valley Land Ownership

Figure 6-2



MONITORING PLAN AND DATA GAPS ANALYSIS

Owens Valley Management Area
Potential Monitoring Points

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Figure 6-3

K:\PROJECTS\WATER RESOURCE SERVICES\PUBLIC\DB18.1418.00 OWENS VALLEY GSP\GIS\MXDS\GSP_MXDS\APPENDICES\10_MPDGA\OWENS_VALLEY_POTENTIAL_MONITORING_POINTS.MXD