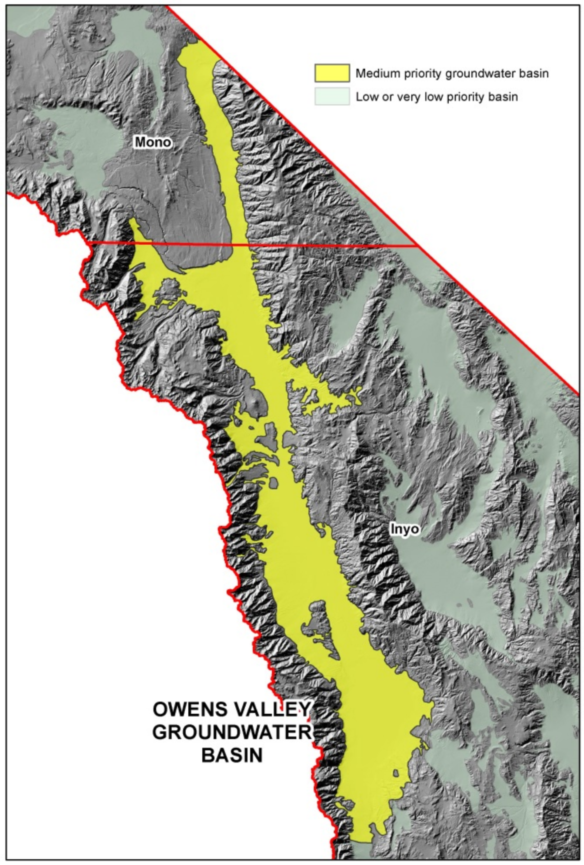
Technical Justification of Proposed Boundary Modification to Owens Valley Groundwater Basin (6-12), Inyo and Mono Counties



Prepared for submittal to the California Department of Water Resources

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Executive Summary

This request for a groundwater basin boundary revision subdivides the Owens Valley Groundwater Basin (6-12) into two subbasins - a Tri Valley Subbasin and an Owens Valley Subbasin. The request is based on the presence of a partial barrier to groundwater flow between Chalfant Valley and Owens Valley that results in groundwater discharge to springs and wetlands at Fish Slough, and relatively little groundwater flow from the Tri Valleys region into Owens Valley. The evidence for the groundwater barrier is geophysical (a gravity anomaly indicative of a bedrock barrier in the alluvial basin fill), geological (a fault system that diverts groundwater from the Hammil Valley area into springs and wetlands at Fish Slough) and hydrological (groundwater discharge at Fish Slough and regional groundwater modeling indicating a relatively small amount groundwater flow from the Tri Valley Subbasin into the Owens Valley Subbasin. This evidence is primarily from various existing studies, principally by the US Geological Survey, and is synthesized and summarized in this report.

The proposed boundary between the Tri Valley Subbasin and the Owens Valley Subbasin aligns with the Inyo/Mono county line because that is the location of the subsurface bedrock groundwater barrier, and dividing the basin along jurisdictional lines facilitates formation of Groundwater Sustainability Agencies. This boundary modification would support sustainable management of the basins by compartmentalizing the basin into more natural water budget units. Recognizing that these subbasins are the natural water budget units, previous studies have generally treated the Tri Valley region and the Owens Valley separately. The proposed boundary change would align the basin boundaries with customary hydrologic practice, which would facilitate preparation of groundwater budgets. The proposed boundary revision would also separate the region under the authority of the Tri Valley Groundwater Management District from the area treated as adjudicated under SGMA (see SGMA section 10720.8(c)). Separating these two jurisdictionally distinct regions would simplify the formation of Groundwater Sustainability Agencies within each subbasin.

Technical Report Supporting the Proposed Boundary Modification

Introduction

The Sustainable Groundwater Management Act (SGMA) established a process for local agencies to request the California Department of Water Resources (DWR) revise the boundaries of existing groundwater basins as defined in Bulletin 118 (California Department of Water Resources, 2003). This boundary revision process is defined in the California Code of Regulations, Title 23 Waters, Division 2 Department of Water Resources, Chapter 1.5 Groundwater Management, Subchapters 1 through 3 Groundwater Basin Boundaries ("Regulations"). Inyo and Mono Counties and the Tri Valley Groundwater Management District are requesting a scientifically-based internal modification to the Owens Valley Groundwater Basin to separate the basin into a Tri Valley Subbasin (TVSB) and an Owens Valley Subbasin (OVSB). According to the Regulations, a local agency may request a scientific internal boundary modification based on the presence of a hydrogeologic barrier. This is such a request.

Requesting Agency Information, Notice and Consolation and Local Agency Input documentation have been submitted to the online Basin Boundary Modification Request System (BBMRS). A Hydrogeologic Conceptual Model to support this scientific modification to the Owens Valley Groundwater Basin has been prepared, "Hydrogeologic Conceptual Model for the Owens Valley Groundwater Basin (6-12), Inyo and Mono Counties" ("Conceptual Model"), and has also been uploaded to the BBMRS, along with previously published supporting studies. This report presents a Description of the Proposed Boundary Modification and the Technical Information for Scientific Modifications.

Description of Proposed Boundary Modification

Inyo County, in cooperation with Mono County and the Tri Valley Groundwater Management District, is requesting a scientific boundary modification to the Owens Valley Groundwater Basin (DWR Bulletin 118 Basin No. 6-12) which would separate the Owens Valley Groundwater Basin into two subbasins: the TVSB from the OVSB (Figure 1). Using the existing lateral and subsurface boundaries of the existing Owens Valley Groundwater Basin, the TVSB and OVSB would be separated along the Public Land Survey System Township 5S and 6S boundary (Inyo/Mono County Line, approximately Latitude 37°27'46"). The proposed name for the new subbasin located north of this new boundary would be the Tri Valley Subbasin and the subbasin located south of the new boundary would be the Owens Valley Subbasin.

The TVSB collectively refers to Benton, Hammill and Chalfant Valleys and the OVSB refers to Round Valley and Owens Valley (Figure 1). The proposed basin subdivision is located in an area where a subsurface bedrock high and faulting interrupt the alluvial basin fill and form an impediment to groundwater flow from the TVSB into the OVSB. In addition, this proposed boundary modification coincides with existing and historic groundwater modelling subdivisions, a topographic high, and also with a jurisdictional division that will be advantageous for formation of groundwater sustainability agencies and developing water budgets to further sustainable groundwater management in the TVSB and OVSB.

General Information

The existing lateral and subsurface boundaries of the Owens Valley Groundwater Basin are defined and mapped in Bulletin 118. The proposed boundary revision will separate the TVSB from the OVSB basin along the Inyo/Mono county line (Township 5S/6S line) and make no other changes or revisions to either the lateral or subsurface boundaries previously assigned to the Owens Valley Groundwater Basin. Figure 1 and accompanying shapefiles uploaded to the BBMRS clearly define the proposed boundary revision. The potentially affected agencies or systems that are within or bordering the existing or proposed basin or subbasin are presented in Inyo County Water Department's (ICWD) Conceptual Model (Inyo County, 2016).

DWR presents a general description of the Owens Valley Groundwater Basin (Basin No. 6-12) as follows: "*This groundwater basin underlies the Benton, Hammil, and Chalfant Valleys in Mono County and Round and Owens Valleys in Inyo County. This basin in bounded by nonwater-bearing rocks of the Benton Range on the north, of the Coso Range on the south, of the Sierra Nevada on the west, and of the White and Inyo Mountains on the east. The water-bearing materials of this basin are sediments that fill the valley and reach at least 1,200 feet thick.*"

The aquifer materials of the basin consist of unconsolidated and poorly consolidated alluvial, fluvial, lacustrine sediments, and volcanic rocks that are collectively referred to as valley fill. The lateral boundaries of the basin are the surface contact between the valley fill and the surrounding bedrock. Beneath the valley fill is low-permeability bedrock consisting of pre-Cenozoic granitic and metamorphic rock. Granitic plutons of the Sierra Nevada batholith form the Sierra Nevada range (west of the Owens Valley) and also form large areas of the White and Inyo Mountains (east of the valley) and these correlations imply that the granitic and metamorphic rock is continuous across the Owens Valley beneath the valley floor (Danskin, 1991). Numerous geo-physical studies have been performed in the basin that indicate the impermeable basement rock consists of fault bounded blocks at varying depths. This basement rock is not a single down-dropped block, but a series of basins separated by relatively shallow bedrock divides, including a notable divide south of the town of Big Pine at the Poverty Hills, and a divide between Owens Valley and Chalfant Valley. These basins include the deep Owens Lake and Bishop basins, and the more shallow Lone Pine and Hammil basins. The Conceptual

Model describes in greater detail the lateral and subsurface boundaries of the Owens Valley Groundwater Basin and the valley fill.

Technical Information for Scientific Modifications

The scientific basis of this boundary revision request is that the bedrock high located between Chalfant Valley and Laws is a significant impediment to groundwater flowing south from the TVSB to the OVSB, deflecting a significant amount of groundwater to Fish Slough Valley where groundwater discharges in springs and wetlands, and that groundwater flow from Chalfant Valley into Owens Valley is a minor part of the overall groundwater budget of the Owens Valley Groundwater Basin. The technical information presented below will provide detailed evidence that basement structure, faulting, topography, hydrography, water budgets, and modeled groundwater flows form the technical basis for separating the TVSB and the OVSB. Aquifer testing, water quality, and jurisdictional information will also be provided.

Summaries of numerous technical studies relating to the Owens and Tri-Valleys areas are presented in the Owens Valley Hydrogeologic Conceptual Model (Conceptual Model) submitted to the BBMRS. Key reference material for these summaries are listed as follows and have been uploaded to the BBMRS: Pakiser, L.C., M.F Kane, and W.H. Jackson, 1964, *Structural Geology and Volcanism of Owens Valley Region, California – A Geophysical Study, USGS Professional Paper 438*; Bateman, P.C., 1965, *Geology and Tungsten Mineralization of the Bishop District, California, USGS Professional Paper 470*; Hollett, K.J., W.R. Danskin, W.F. McCaffery, and C.L. Walti, 1991, *Geology and Water Resources of Owens Valley, California, USGS Water Supply Paper 2370-B*; Danskin, W.R., 1998, *Evaluation of the Hydrologic System and Selected Water-Management Alternatives in the Owens Valley, California, USGS Water Supply Paper 2370-H*; Jayko, A.S. and J. Fatooh, 2010, *Fish Slough, a geologic and hydrologic summary, Inyo and Mono Counties, California, Prepared for the BKM Bishop Field Office, USGS Administrative Report*.

Geologic, geophysical, and hydro-geologic maps and cross sections that present data on the physical properties of the aquifers and subbasins have also been uploaded to the BBMRS and include: Pakiser 1964, Plate 1 Sheets 1, 2, 3; Bateman 1965, Plates 3 & 5; Hollett, 1991, Figure 10.

Overview

The proposed TVSB would consist of the Benton, Hammil and Chalfant Valleys, and the OVSB would consist of Owens Valley and Round Valley. The general topography of these valleys slopes from north to south, with prominent alluvial fans spreading from the mountain fronts toward the valley-axis. The Benton and Hammil Valleys constitute about 75% of the Tri Valley acreage. At the southern end of the Chalfant Valley, the Coldwater Canyon alluvial fan creates a topographic high that separates Chalfant Valley in the north from the Laws area (northeast of

Bishop) in the south. Fish Slough Valley lies to the west of this alluvial fan, separated from the Chalfant Valley and Laws by an up-thrown fault block of Bishop Tuff (Figure 2). Also located between these areas is a prominent gravity anomaly which is been interpreted to represent a subsurface bedrock high which separates the deeper Hammil and Bishop structural basins (Pakiser et al., 1964, Plate 1 Sheets 1,2,3; Bateman, 1965, Plates 3 & 5; Hollett et al., 1991, Figure 10).

A significant amount of groundwater discharges in Fish Slough Valley (west of the subsurface bedrock high) along the Fish Slough fault zone (a series of north-south and northeast-southwest trending faults) as seeps and springs (Figure 3). Fish Slough discharge flows south as surface water to join the Owens River north of Bishop and west of Laws. Jayko and Fatooh (2010) suggested it likely that the Fish Slough fault zone intercepts groundwater flow from the Benton and Hammil basins, deflecting flow to the southwest into Fish Slough while impeding flow to the southeast across the fault zone.

There is no direct surface water connection between the TVSB and the OVSB except for occasional ephemeral flow related to flood runoff from Coldwater and Chidago Canyons. Groundwater elevations from high to low are as follows: Benton Valley, Hammil Valley, Chalfant, and Laws (Figure 5). Groundwater elevation hydrographs from the Chalfant Valley and Laws area show a significant difference in head between Chalfant and Laws (Figure 6, transect A-A'). Hydrographs also reveal varying responses to groundwater extraction and recharge in the Laws area (Figure 4). Groundwater modeling studies have produced varying estimates of groundwater flow between the Chalfant and Laws. The most comprehensive study is that of Danskin (1998), which estimated an annual average underflow from Chalfant Valley to Laws of 1,665 acre-feet/year plus 210 acre-feet/year from beneath the Volcanic Tablelands west of Chalfant Valley. Also modelling efforts have historically separated the TVSB and OVSB.

Geophysical Evidence

There is substantial geophysical evidence that a subsurface bedrock high exists along the proposed boundary modification line in the area between Chalfant Valley and Laws, and that this low-permeability material interrupts groundwater flow from the TVSB, deflecting flow to the southwest. Numerous geophysical methods have been used to define the structural form and depth of the bedrock surface in the Owens Valley (Pakiser et al., 1964; Danskin, 1998; MWH, 2010; MWH, 2011).

The primary geophysical data used to demarcate the bedrock high between Chalfant Valley and Laws structure are gravity measurements. The acceleration due to the earth's gravity varies slightly at different locations due to the varying density of rock at depth. Gravitational acceleration is slightly greater at points overlying high density rock than at points overlying less dense rock. Because alluvial basin fill is less dense than typical bedrock types, variations in gravitational acceleration are widely used to estimate the depth to bedrock in alluvial basins and other features of the basin geometry. Gravity anomaly data is useful in the Owens Valley Groundwater Basin because of the density differences between unconsolidated sediments (2.1 gm/cc) versus granitic (2.65 gm/cc) or metamorphic rock (2.64-3.0 gm/cc).

Gravity data indicate bedrock is relatively shallow between Benton and Hammil valleys and between Laws and Chalfant Valley. Pakiser et al. (pg. 27, 1964) noted the isolated gravity high between Laws and Chalfant and described it as follows: "*A dominant gravity high interrupts the Owens Valley gravity low northeast of Bishop. This gravity high must be the expression of a mass of dense rock within or surrounded by the Cenozoic section* [alluvial sediments]." Pakiser et al.'s Plate 1 has been uploaded to the BBMRS as the qualified map showing the lateral boundaries of the groundwater basin and the location of the gravity anomaly. Bateman (pg. 193, 1965) discusses this gravity anomaly as well: "*A detailed study was made of the conspicuous positive anomaly north of Bishop and east of Fish Slough … the gravity anomaly can be explained by a truncated rectangular pyramid rising above the bedrock floor of the valley.*" Bateman describes the size of this uplift block as "*about 3.5 miles wide and 7 miles long, and strikes in a northerly direction. The top of the mass is a rectangle about 1 mile wide and perhaps 4 miles long, rising to within about 1,000 feet of the surface*."

Hollett (pg. B25, 1991) further defines the subsurface structure of the gravity anomaly: "*The northern extension of the valley graben under Chalfant, Hammil and Benton Valleys is partly isolated from the deepest part of the Bishop Basin by a bedrock slump block. A high, isolated gravity anomaly depicted in the contoured gravity northeast of Bishop and west of the White Mountain fault zone defines the extent of the buried slump block of bedrock that partially obstructs the south end of the Chalfant Valley.*" The shallow bedrock is presented in the A' to A" cross section from Hollett's Plate 5 (Hollett's Plate 3 locates this cross section in plan view). Recent and more extensive gravity surveys continue to demark this gravity anomaly and can be viewed on the USGS Mineral Resources On-Line Spatial Data at http://mrdata.gov/general/map.html.

The Pan American Center for Earth and Environmental Studies (PACES) has also compiled recent gravity data from gravimeter stations across the country. Hildenbrand (2002) describes the data gathering efforts. ICWD downloaded USGS terrain-corrected, complete Bouguer anomaly reduced to background density of 267 gravity data sets from the PACES regional geospatial service center's online "Gravity and Magnetic extract utility" at http://research.utep.edu/default.aspx?tabid=37229. A gravity anomaly contour map was created (Figure 3) using the ArcMap Geostatistical Analyst tool's Empirical Bayesian Kriging (EBK) method. EBK uses an iterative process of sub-setting and simulations to determine the underlying semivariogram and to select kriging parameters which minimize errors of prediction.

These more recent data largely agree with and confirm the presence and location of the bedrock block identified by Pakiser et al. (1963). When comparing the recent gravity data with Pakiser's Plate 1 note that Pakiser added a 1,000 milligal offset to his gravity data, and this offset explains the large difference in gravity values between Pakiser and the more recent data.

Since bedrock is less permeable than valley-fill material, the bedrock block impedes groundwater flow from Chalfant Valley to Laws. Hollett et al. (1991) notes the effects this bedrock high has on groundwater (pg. B25): "*The protrusion of the buried slump block at the south end of Chalfant Valley, conjunctive with the overlying fan, probably deflects deep ground water – flowing south along the Chalfant, Hammil, and Benton Valleys to the Bishop Basin – farther west beneath the southeastern part of the Volcanic Tableland near Fish Slough. This is west of where underflow would be expected on the basis of present topography*."

The effect of the bedrock block is evident in regional groundwater modeling efforts. Danskin calibrated a regional groundwater flow model that included underflow from Chalfant Valley and the Fish Slough area into Owens Valley (Danskin, 1998, Table 11). His estimated annual average underflow from Chalfant Valley and the Volcanic Tablelands was 1,665 acre-feet/year and 210 acre-feet/year respectively.

Faulting

The accompanying Conceptual Model describes the regional fault environment of the Owens Valley and the Eastern California Shear Zone/Walker Lane Belt. Of the numerous faults in the Owens Valley, several cross the Volcanic Tablelands, extending into the TVSB and affecting groundwater flow in the TVSB.

The Volcanic Tablelands, consisting of the Bishop Tuff rock unit, forms the southwestern boundary of the TVGB. The Pleistocene Bishop Tuff consists of basal unconsolidated pumice, overlain by a dense heat-welded zone, and a less dense gas welded zone resulting from the violent eruption of the Long Valley Caldera approximately 760,000 years ago. Where Bishop Tuff forms the groundwater basin boundary west of Chalfant and Hammil valleys, it is likely underlain by valley fill. The surface of the Volcanic Tablelands is broken by many faults that are part of the active, regional fault system (Hollett, 1991). Of particular interest to this technical report is the Fish Slough fault zone, located on the eastern edge of the Volcanic Tableland, just west of Chalfant Valley (Figure 3).

Jayko and Fatooh (2010) present evidence that the fault zone in the Volcanic Tablelands that forms the eastern side of Fish Slough Valley may impact subsurface flow of groundwater from Hammil Valley. The Fish Slough fault zone consists of several west-dipping faults linked by step-overs and/or relay ramps, and active warm springs discharge at the southern terminations or near the relay ramp junctions of the fault segments (Jayko, 2010). Jayko noted (pg.3): "*The Fish*

Slough Fault zone … crosses from the Volcanic Tablelands into the southern-most edge of Hammil Valley."

The Department of Fish and Wildlife drilled three shallow subsurface cores in Fish Slough to characterize the subsurface material (Pinter and Keller, 1991). They encountered Bishop Tuff at shallow depths noting "*The three cores successfully obtained penetrated from 2.8 to 4.5 m below the surface, and two of them bottomed in the volcanic material (Pinter and Keller, 1991, pg. III-7). These observations are consistent with the gross stratigraphy from trenching and deeper drilling*" associated with the 1964 DWR Fish Slough Dam feasibility study. Fish Slough cores from the 1964 DWR Fish Slough Dam feasibility study encountered 13-22 foot thick sections of alluvial sediments along the central, north-south axis of the slough and sections of sediments 38-65 feet thick in the immediate vicinity of the Fish Slough fault zone itself (DWR, 1964).

Hollett et al. (1991), Danskin (1998) and others have noted that faults in Owens Valley frequently form barriers to groundwater flow across the fault boundaries due to either lithologic offsets of permeable layers or due to abrupt changes in hydraulic characteristics along the fault (creation of low permeability, fault gouge material in the fault zone). These fault zones, however, may also provide increased hydraulic conductivity parallel to the fault trend, especially in extensional tectonic environments such as the Owens Valley where normal faulting results in open fractures and grabens filled with permeable material. Numerous examples of this groundwater/fault interaction are evident in the springs and seeps that form along mountain front and Owens Valley fault zones (Hollett et al., 1991, pg. 52).

Jayko and Fatooh (2010, pg. 3) observed that the Fish Slough fault zone "*crosses the axial part of the southern Hammil Valley watershed …*" and "*locally diverts (captures) the southern part of the 'Hammil' axial wash… through the east edge of the Tablelands into the Chidago Wash drainage before entering northern Chalfant Valley. The structural capture of the surface stream by the Fish Slough fault zone may also impact subsurface flow of groundwater from Hammil Valley…. As noted in the 1984 BLM Planning document, the* [Fish Slough's] *inferred aquifer boundary may include a different and larger area than the watershed boundary delineated at the surface.*" Jayko and Fatooh (2010, pg. 5) also argued that temperature and isotopic characteristics suggest that the Fish Slough Springs discharge deep groundwater with hydrothermal input and that this indicates "*the fault zone, although discontinuous at the surface, is integrated at depth and reaches a deep-seated aquifer as well as any other shallow aquifers intersected by the fault zone.*"

Topography

A prominent alluvial fan at the mouth of Coldwater Canyon forms a topographic high separating Chalfant Valley from the Owens Valley. There is no direct surface water connection, although an ephemeral wash occasionally flows from southwest Chalfant into Laws. Hollett (1991, pg. B25) argued that this topographic high created by the alluvial fan contributed to groundwater deflection to the west. As delineated in Bulleting 118, the southern boundary of the Owen Valley Groundwater Basin, is in alluvial cover similar to that at the site of the present boundary revision request.

Hydrographs, Groundwater Elevations and Aquifer Stress

Groundwater elevation (GWE) data has been collected from monitoring wells in Owen Valley Groundwater Basin for a period of almost 100 years. The primary source of this data comes from Los Angeles Department of Water and Power (LADWP)-owned wells located from Chalfant Valley and Owens Valley. Groundwater elevation data from Benton and Chalfant Valleys is more limited. Based on data from MHA (2001), LADWP, and TVGMD's CASGEM monitoring wells for a period from 1990 to date, GWEs in Benton Valley have ranged from 5250 and 5350 feet (Figure 5). Based on data from 1970 to date, GWEs in Chalfant Valley have ranged from 4230 and 4190 feet. Based on data from 1966 to 2005, GWEs in Hammil Valley have ranged from 4530 and 4430 feet. GWE trends in Benton, Hammil and Chalfant Valleys have been generally downward. Groundwater elevations in the TVSB, Fish Slough Valley and OVSB can be compared to assess groundwater head differences and potential flow barriers. Hydrographs generated from monitoring well data can also be used to compare the trends in groundwater levels and also responses to various aquifer stress such as drought or increased extraction.

LADWP's Laws Wellfield is located northeast of Bishop and approximately three miles south of the proposed boundary modification (Figure 2). Several significant hydrologic events have occurred in this wellfield related to periods of extraction or directed surface water recharge from LADWP-operated canals. By comparing hydrographs from monitoring wells which depict the large variations (tens of feet) in groundwater level in the Laws wellfield (OVSB), to hydrographs from monitoring wells in Chalfant Valley (TVSB) with smaller variations in groundwater level, determinations as to the potential hydraulic connectivity of the TVSB and the northern OVSB can be made. Difference in groundwater elevations can also be compared from data from Chalfant and Laws.

A map of groundwater level monitoring wells with partial and/or continuous data reads since 1970 are presented in Figure 2. Wells V283 and V261 are located approximately 3 and 6 miles north of the bedrock/topographic high between TVSB and OVSB; wells V291, V265, and V252 are located in the vicinity of the high with V265 located along the proposed boundary line; well V271 is located approximately 2 miles south of the high; and well T397 is located approximately 5 miles northwest of the subsurface high north of the Fish Slough wetland and west of the prominent Bishop Tuff horst. Two primary observations can be made from the hydrographs of these wells (Figure 4).

1. A significant change in hydraulic head exists between the Chalfant and Laws area wells in the vicinity of the gravity anomaly and Coldwater Canyon alluvial fan (Figure 6). Note that the data from Figure 6 are from January 1972, a period when data from several additional monitoring wells existed in the vicinity of the subsurface high. The data displayed in Figure 6 is consistent with the longer period of record from the monitoring wells with more data (Figure 4). In northern and central Chalfant, a gentle hydraulic head gradient sloped south to the TVSB boundary, as evidenced by the groundwater elevations of V283, V261 and V291 (a hydraulic head gradient of approximately 7 feet/mile). However, a difference of more than 50 feet of water table elevation occurs along a 1.5 mile axis south of V291 to V265 (a gradient of 39 feet per mile in Jan. 1972) at the proposed TVGB boundary. The water table begins to dip less steeply from V265 to V271 (northern Laws) losing another 50 feet in head over 2.5 miles (hydraulic gradient of approximately 13 feet per mile). This difference in groundwater head, when combined with both the geophysical and structural evidence presented in previous sections and with the small amount of modeled groundwater flow between Chalfant and Laws described in the following section, is best explained by a barrier to southward flow between the Chalfant area north of the proposed TVSB boundary and the Laws area south of the boundary.

2. Significant changes in GWE caused by pumping, and artificial recharge are evident in the high amplitude variations in the Laws area wells but are not reflected in Chalfant or Fish Slough Valley wells (Figure 4). Changes of 30 to 40 feet over a few months are evident in the Laws area wells south of bedrock/topographic high as reflected in hydrographs from V252 and V271. The large negative change in water level reflects the significant drought and associated groundwater pumping by LADWP from 1988-90. Peaks from the above average precipitation periods of the early 1980s, the late 1990s and 2005-06, when water was diverted from the Owens River north into the Laws field, are also evident in corresponding positive GWE swings. The close association between groundwater levels in Laws, LADWP groundwater pumping in Laws, and recharge from the McNally Canals has been documented by the Inyo County Water Department (Harrington, 2001). The Chalfant and Fish Slough Valley wells (V261, V283 and T397) show no evidence of such large changes in groundwater levels, but instead exhibit a gradual decline with apparent muted responses to similar periods of drought and above average precipitation. Also, well V283, located in northern Chalfant Valley near Chidago Canyon, shows almost twice the decline of V261 located in central Chalfant Valley. If groundwater extractions from Laws were the primary driving factor in the Chalfant Valley water levels, one would expect wells in the south (V261) to show greater declines than farther north (V283). Also if Chalfant Valley wells were in strong hydraulic communication with Laws, one

would expect to see similar large swings in groundwater levels, but instead Chalfant wells show a steadier decline.

Water Budgets and Modeling

Water budgets and groundwater modelling efforts for the Tri-Valley area and the Owens Valley areas have customarily been prepared separately for the two regions. The groundwater budget for the TVSB can be conceptualized as recharge from precipitation and some irrigation return flow versus outflows from agricultural and domestic extractions, spring discharge, evapotranspiration (ET) mainly by phreatophytes, and subsurface outflow to the Owens Valley. MHA (2001) developed a water budget for the Tri Valley area and calibrated a steady-state groundwater model to refine its initial estimates. The groundwater budget for the OVSB can be created by considering recharge from precipitation, surface water inflow from the Owens River, and subsurface inflow from the TVSB and Volcanic Tableland versus outflow from agricultural and domestic extractions, LADWP groundwater export, ET, and subsurface outflows to the Owens Lake. Danskin (1998) developed an Owens Valley water budget and also used a calibrated steady-state model to refine his estimates. The principal link between the TVSB and OVSB groundwater budgets is subsurface outflow from TVSB from Chalfant as inflow to OVSB at Laws. Groundwater discharge from TVSB at Fish Slough enters the Owens Valley as surface water and discharges into the Owens River. Similar to Danskin (1998) and MHA (2001), the ICWD Conceptual Model presented separate water budgets for both TVSB and OVSB. The combination of existing, independent water budgets for the TVSB and OVSB along with the minor amount of subsurface flow discussed below provides additional justification for the proposed boundary revision.

A detailed discussion of the OVSB and TVSB groundwater budgets is presented in ICWD's Conceptual Model, Danskin's 1998 Hydrologic System evaluation, MWH's study of Owens Lake (2011), and MHA's (2001) hydrologic study of the Tri Valley region. Danskin (Table 10) estimated the amount of Owens Valley average inflows to be 196,000 acre feet per year (AFY) and estimated the outflows to be 189,000 AFY for the time period of 1970-1984. For the TVSB, MHA estimated average inflows to be 27,653 AFY and outflows to be 27,621 for the calibrated, steady-state groundwater model, though these figures appear to be modeled based on erroneously low discharge at Fish Slough and erroneously high LADWP pumping at Laws.

Danskin, in his 1998 Owens Valley basin-wide modelling study, estimated 1,665 AFY of outflow from Chalfant to Laws plus 210 AFY from the Volcanic Tableland. MHA (2001) estimated this outflow to be 14,481 AFY; however, the overestimate of pumping at Laws and the underestimate of discharge at Fish Slough would greatly reduce MHA's estimated flow between Chalfant and Laws. Table 5 of the Conceptual Model reconciles the steady-state water budgets of the Tri-Valley, Owens Valley, and Owens Lake regions, presenting average values for the water management practices of the past several decades. Based on this reconciliation, total groundwater outflow from the TVSB to OVSB was estimated to be approximately 1,900 AFY. During the period, groundwater discharge at Fish Slough averaged 4,400 AFY with a significant component of that discharge coming from TVSB groundwater flow. As noted in the section describing faulting, Jayko (2010) observed a warm temperature component in spring discharge at Fish Slough. If surface or near surface runoff from the Volcanic Tablelands to the north and west of Fish Springs were the dominant component of Fish Slough groundwater discharge, one would not anticipate significant warming. Jayko (2010) also described the groundwater outflow at Fish Slough as "substantial" and "declining" ranging from 6,000-8,000 AFY between 1935 and 1980. More recently, discharge has been in the 3,000-4,000 AFY range (See Conceptual Model, Figure 8). The amount of discharge and warmth suggest that a significant source of Fish Slough discharge is from a hydrothermal system sourcing a larger subsurface aquifer. Combining these observations with the groundwater outflow component of the TVSB, a substantial amount of outflow from the TVSB must supply Fish Slough, leaving a smaller residual amount of groundwater flow from Chalfant to Laws. Therefore, Danskin's (1998) estimate of flow between Chalfant Valley and Laws of 1,665 AFY is the more probable amount. This amount of subsurface flow is estimated to be less than one-percent of the OVSB water budget's total inflow component.

Water Quality and Characteristics

Groundwater in both the TVSB and OVSB is primarily from recent mountain precipitation infiltrating the valley fill and is, in general, of high quality. The classification of OVSB (excluding Owens Lake area) water is calcium bicarbonate water with total dissolved solids ranging from 100-325 ppm, slightly alkaline pH ranging from 7.2 to 7.7, and alkalinity as $CaCO_3$ ranging from 75-175 ppm (Hollett, 1991, table 5). Some naturally occurring arsenic is present in the OVSB as are minor amounts of man-made contamination in urban areas related to leaky underground storage tanks and landfills.

In a recent USGS study, volatile organic compounds and pesticides were detected in samples from less than one-third of sampled wells in OVSB; all detections were below health-based thresholds, and most were less than one-one hundredth of threshold values. All detections of perchlorate and nutrients in samples from OVSB were below health-based thresholds (Densmore et al., 2009).

For the purpose of differentiating groundwater basins, the water quality data is inconclusive. Additionally, isotope data collected by the BLM and summarized by Jayko and Fatooh (2010) is inconclusive in identifying a unique source of water for Fish Slough.

Jurisdictional and Sustainability Considerations

The evidence presented in this technical report provides the basis for a scientific boundary modification to the Owens Valley Groundwater Basin boundary, establishing the TVSB and OVSB. The effects of a subsurface bedrock high, faulting and topography combine to create a significant impediment to groundwater flow from the Tri-Valley region southward toward the Bishop area and Owens Valley. This proposed scientific boundary could be drawn anywhere in the vicinity of the peak of the gravity anomaly that identifies the location of the bedrock block. We have deliberately selected the Inyo and Mono County boundary line which coincidentally crosses the peak of the gravity anomaly. We feel that the combined relationship between groundwater flow and jurisdiction expediency will provide greater opportunity for sustainable groundwater management in both basins.

The two primary jurisdictional representatives for the TVSB would be Mono County and the Tri-Valley Groundwater Management District (TVGMD). The TVGMD is a Special Act district established by the California Legislature in 1989 in response to specific concerns related to potential groundwater exportation and overdraft. As a Special Act District, the TVGMD is deemed the exclusive local agency for the purposes of complying with SGMA (CWC 10723(c)(1)(H)). The primary sustainable groundwater management challenge would be balancing recharge against Tri-Valley usage and Fish Slough habitat requirements. TVSB uses consist primarily of private entities extracting groundwater for agricultural and domestic purposes. There is currently no groundwater export from the TVSB.

In contrast, the OVSB's groundwater management is dominated by the interaction between two public agencies, LADWP and Inyo County. LADWP is the primary threat to sustainable groundwater management in the Owens Valley, diverting surface water and pumping groundwater for export from the OVSB via the LA aqueduct system and for use on LADWP-owned land in Owens Valley. LADWP does not pump groundwater from the TVSB. A series of legal documents, most notably the 1991 Inyo/Los Angeles Long Term Water Agreement and associated 1991 Final Environmental Impact Report, govern LADWP groundwater extraction. Although this agreement does not formally adjudicate groundwater rights, it is a court-enforceable settlement to litigation over Los Angeles's water management and Inyo County's regulatory powers. The Inyo/Los Angeles Water Agreement imposes a number of monitoring, management, and mitigation requirements on Los Angeles, including limitations on pumping, standards for siting new wells, maintenance of baseline conditions, and annual reporting of hydrologic and water-use data. For the purposes of SGMA, the OVSB is considered adjudicated within the portion of the basin managed pursuant to the Inyo/Los Angeles Long Term Water Agreement (CWC 10720.8(c)). By separating the TVGB from the OVSB, the complex interaction between Inyo County and LADWP will be removed as an obstacle for the TVSB management.

Summary

This technical report presents information to support a subdivision of the Owens Valley Groundwater Basin into a subbasin comprising Benton, Hammil, and Chalfant Valleys (the Tri Valley Groundwater Subbasin), and a subbasin comprising the Owens Valley and Round Valley (the Owens Valley Subbasin). This request for a scientific basin boundary revision is supported by the following:

1. Geophysical evidence – a gravity anomaly – indicates the presence of a bedrock barrier between Chalfant Valley and Laws (Pakiser et al., 1964; Bateman, 1965) that impedes groundwater and deflects most groundwater flow west along faults where it discharges at Fish Slough (Hollett et al., 1991; Jayko and Fatooh, 2010).

2. The USGS developed a regional groundwater flow model for Owens Valley (Danskin, 1998). Calibration of this model estimated groundwater flow from Chalfant Valley to the northeastern Owens Valley to be 1,665 AFY, which an additional 210 AFY of underflow from the Volcanic Tablelands. These results are consistent with the presence of a subsurface feature that impedes groundwater flow from Chalfant Valley to Laws, resulting in groundwater discharging at Fish Slough.

3. Hydrographs from the Laws area in northeastern Owens Valley, Fish Slough, and Chalfant Valley indicate a contrast between groundwater level patterns over time in Laws versus Chalfant Valley and Fish Slough. This reflects different groundwater stressors in the Tri Valley Subbasin versus the Owens Valley, consistent with the presence of a groundwater flow barrier between the Tri Valley region and Owens Valley.

4. Previous studies of the Tri Valley area and the Owens Valley have treated the water budgets for the two areas separately (e.g., Danskin, 1998; MHA, 2001). This request for a basin subdivision between the two subbasins is consistent with the customary prior hydrogeologic practice of treating the basins as separate water budget units.

5. Geochemical and isotopic studies have been inconclusive as to the source and flow path of groundwater discharging at the Fish Slough springs and wetlands. Discharge of warm water in springs at the ends of faults is evidence that groundwater flows from Hammil Valley along the Fish Slough Fault to Fish Slough (Jayko and Fatooh, 2010).

6. This request for a subdivision of the Owens Valley Groundwater Basin to a Tri Valley Subbasin and an Owens Valley Subbasin has jurisdictional merits. In the Tri Valley

Subbasin, SGMA identifies the Tri Valley Groundwater Management Agency as the exclusive local agency with first rights to become the Groundwater Sustainability Agency for that portion of the basin. In the Owens Valley Subbasin, SGMA treats the portions of the subbasin that are managed pursuant to the Inyo County/City of Los Angeles Long Term Water Agreement as adjudicated.

References

Bateman, P.C., 1965, Geology and Tungsten Mineralization of the Bishop District, California, USGS Professional Paper 470.

California Department of Water Resources, 2003, California's Groundwater – Bulletin 118 – Update 2003.

California Department of Water Resources, 1964, Fish Slough Dam and Reservoir Feasibility Investigation – Bulletin 126.

Danskin, W.R., 1998, Evaluation of the Hydrologic System and Selected Water-Management Alternatives in the Owens Valley, California, USGS Water Supply Paper 2370-H. http://ca.water.usgs.gov/archive/reports/wsp2370/

Densmore, J.N., M.S. Fram, and K. Belitz, 2009, Ground-Water Quality Data in the Owens And Indian Wells Valleys Study Unit, 2006: Results from the California GAMA Program, Data Series 427.

Harrington, R., 2001, Development of Multiple Linear Regression Models for Prediction of Water Table Fluctuations, Inyo County Water Department Report.

Hildenbrand et al., 2002, USGS Open File Report 02-463 "Rationale and Operational Plan to Upgrade the U.S. Gravity Database."

Hollett, K.J., W.R. Danskin, W.F. McCaffery, and C.L. Walti, 1991, Geology and Water Resources of Owens Valley, California, USGS Water Supply Paper 2370-B. http://pubs.er.usgs.gov/publication/wsp2370B

Inyo County Water Department, 2016, Hydrogeologic Conceptual Model for the Owens Valley Groundwater Basin (6-12), Inyo and Mono Counties, Report prepared for submittal to the Department of Water Resources.

Jayko, A.S. and J. Fatooh, 2010, Fish Slough, a geologic and hydrologic summary, Inyo and Mono Counties, California, Prepared for the BKM Bishop Field Office, USGS Administrative Report.

Los Angeles, City of, Department of Water and Power, and County of Inyo, Agreement Between the County of Inyo and the City of Los Angeles and its Department of Water and Power on a Long Term Groundwater Management Plan for Owens Valley and Inyo County, Stipulation and Order for Judgement, Inyo County Superior Court, Case no. 12908, 1991.

Jayko, A.S. and J. Fatooh, 2010, Fish Slough, a geologic and hydrologic summary, Inyo and Mono Counties, California, Prepared for the BKM Bishop Field Office, USGS Administrative Report.

Los Angeles, City of, and Inyo County, 1991, Water From the Owens Valley to Supply the Second Los Angeles Aqueduct – 1970 to 1990 – 1990 Onward, Pursuant to a Long Term Groundwater Management Plan, Volume I, Final Environmental Impact Report.

MHA Environmental Consulting Inc., TEAM Engineering and Management Inc., M. Bagley, EMRICO, D. Sada, and Sage and Associates, 2001, Task 1 Report – Preliminary Data Collection and Hydrologic Models, Prepared for the US Filter Tri Valley Groundwater Surplus Program, Mono County, California.

MWH, 2011, Owens Lake Groundwater Evaluation Project, Appendix C – Preliminary Conceptual Model, prepared for the Los Angeles Department of Water and Power.

MWH, 2011a, Owens Lake Groundwater Evaluation Project – Appendix R – Evaluation of Geophysical Data, Phase II, prepared for the Los Angeles Department of Water and Power.

Pakiser, L.C., M.F Kane, and W.H. Jackson, 1964, Structural Geology and Volcanism of Owens Valley Region, California – A Geophysical Study, USGS Professional Paper 438.

Pinter, N. and E.A. Keller, 1991, Geological Setting, in “Biotic Inventory and Ecosystem Characterization for Fish Slough, Inyo and Mono Counties, California, Univ. of Calif, Santa Barbara, Report Prepared for Calif. Dept. of Fish and Game, W.R Ferren and F.W. Davis, editors.

Figures

Figure 1. Proposed Owens Valley Groundwater Basin Boundary Modification Overview

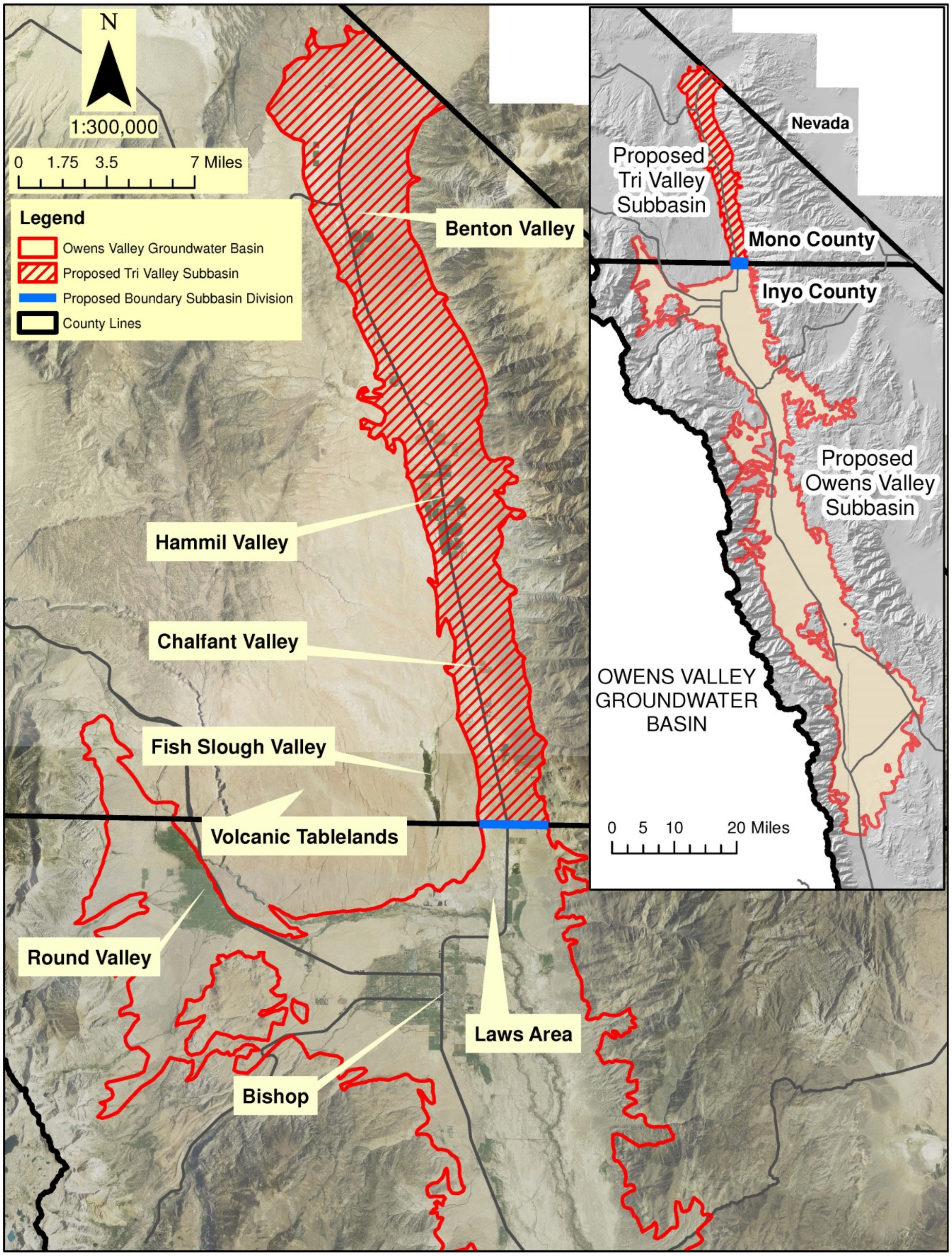

Figure 2. Chalfant, Laws and Fish Slough Area

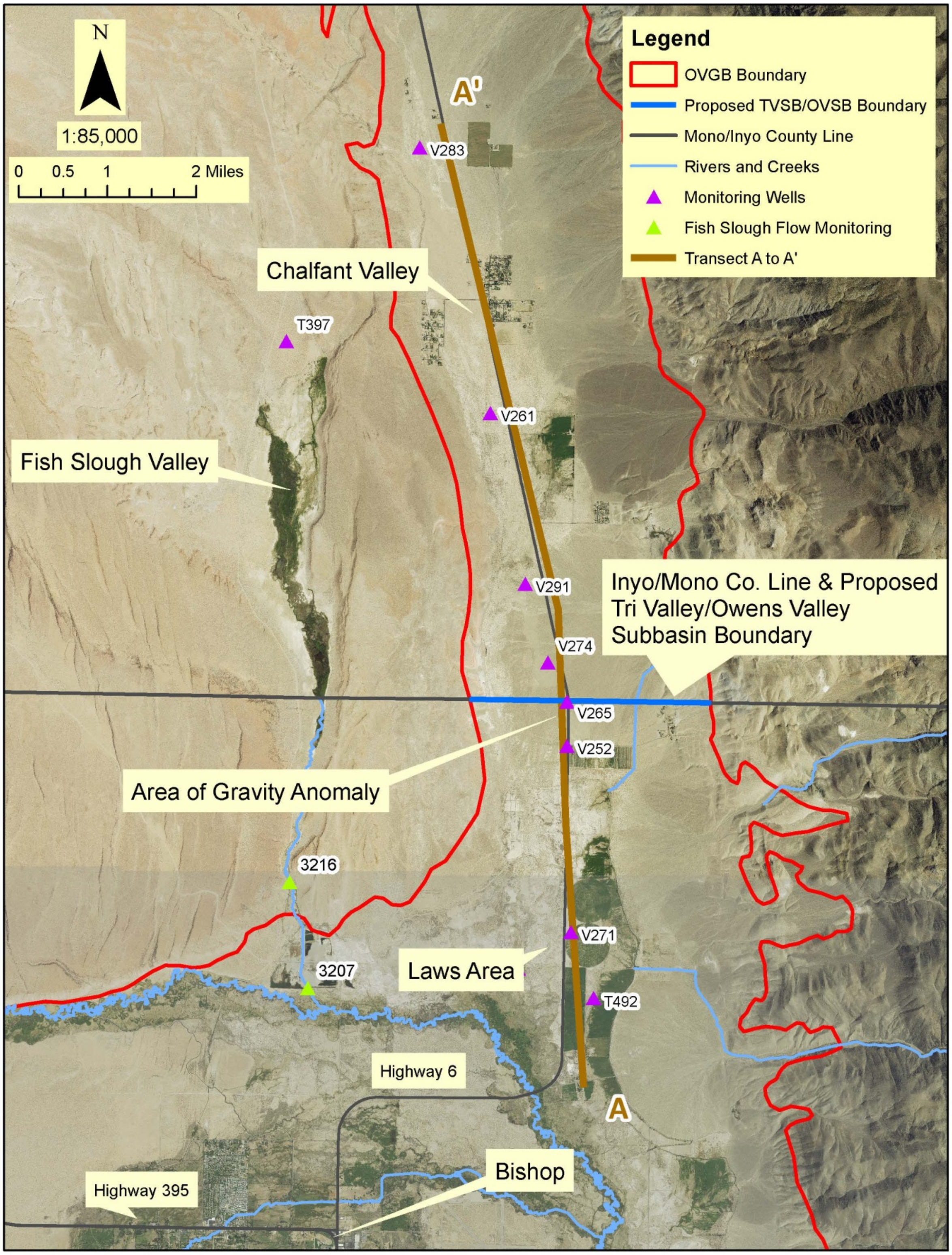

Figure 3. Complete Bouguer Gravity Contours

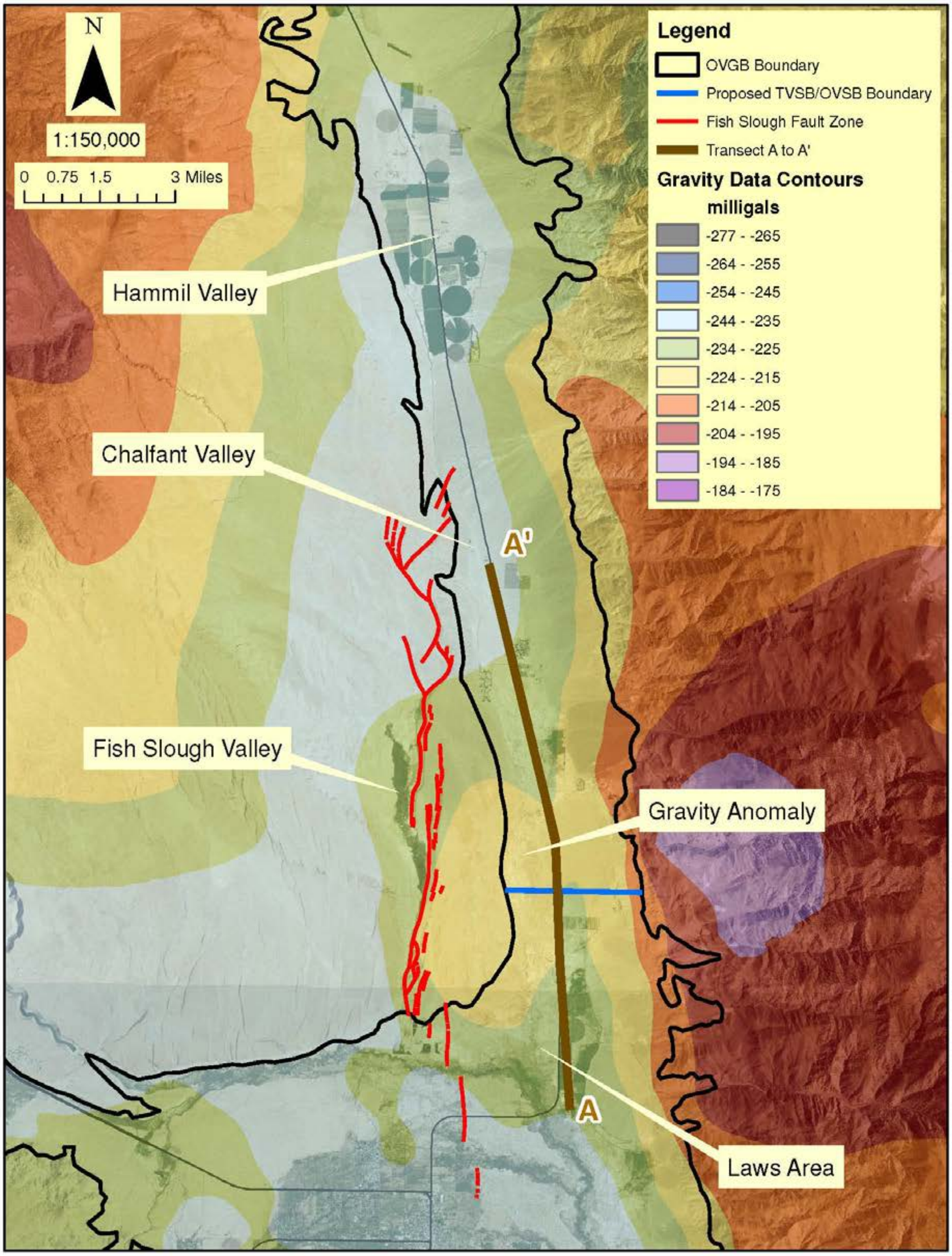

Figure 4. Groundwater Elevations in Chalfant, Fish Slough and Laws

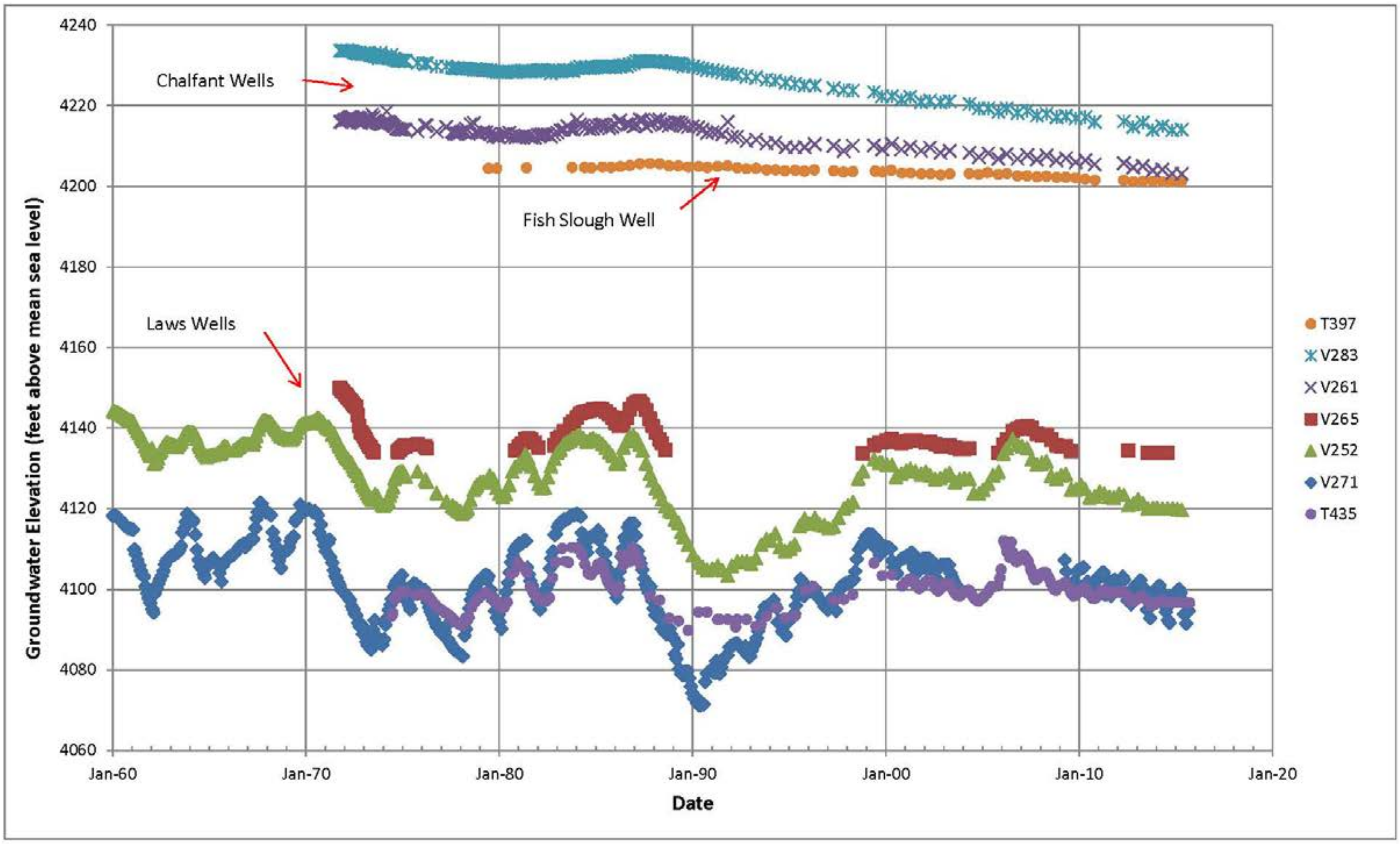

Figure 5. Groundwater Elevations Tri-Valley and Laws

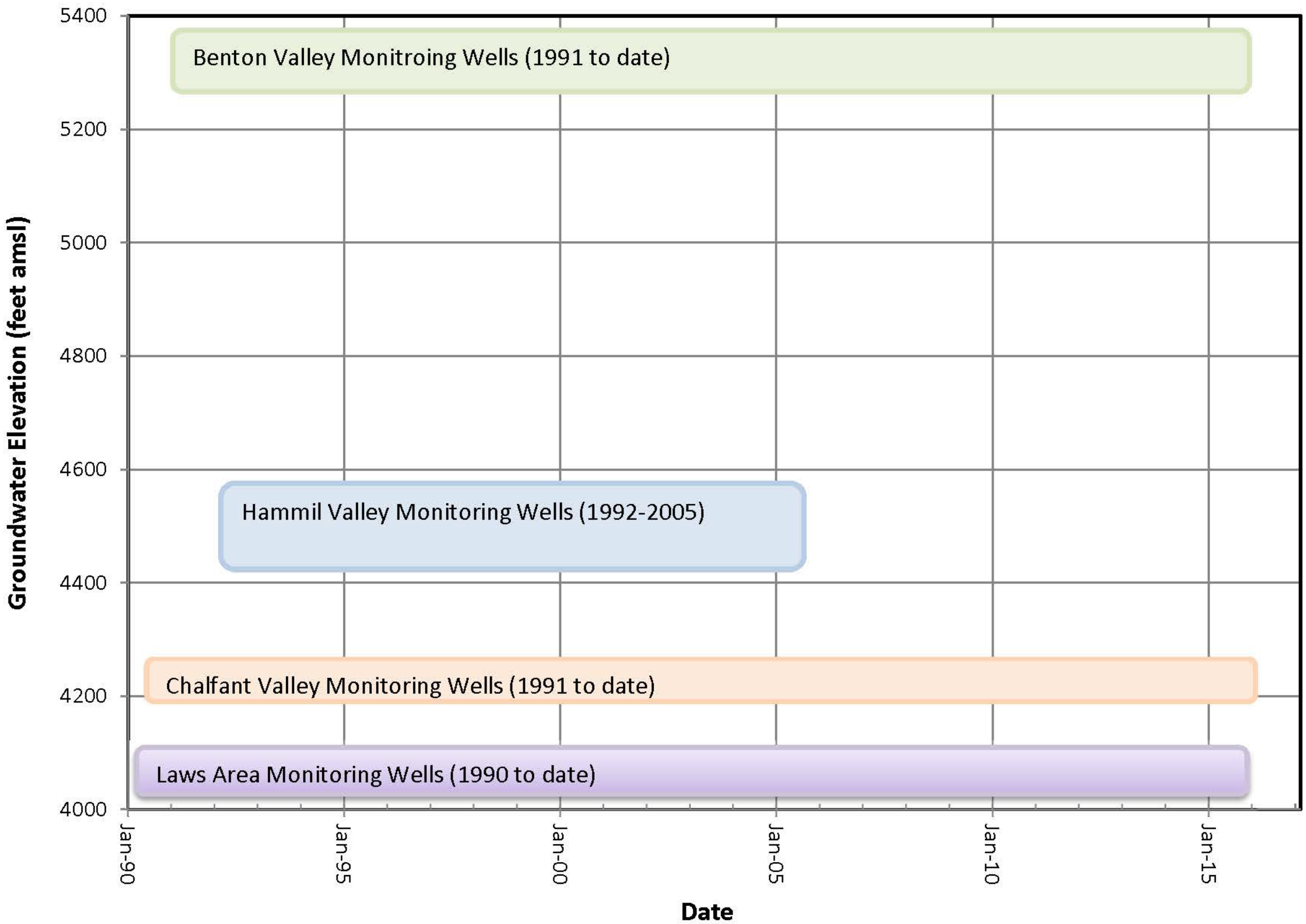

Figure 6. Groundwater Elevation, Surface Elevation, and Gravity Cross Section A to A’