LOS OSOS VALLEY GROUNDWATER BASIN
FRINGE AREAS CHARACTERIZATION

Prepared for

SAN LUIS OBISPO COUNTY
FLOOD CONTROL AND
WATER CONSERVATION DISTRICT

May 22, 2018

CLEATH-HARRIS GEOLOGISTS
71 Zaca Lane, Suite 140
San Luis Obispo, California 93401

(805) 543-1413

TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

EXECUTIVE SUMMARY

Introduction

This study documents the basin characterization work performed by Cleath-Harris Geologists, Inc., on behalf of the San Luis Obispo County Flood Control and Water Conservation District for the Los Osos Valley Groundwater Basin (Los Osos Basin) Fringe Area characterization and basin boundary modification.

The Sustainable Groundwater Management Act (SGMA) took effect on January 1, 2015, and requires that certain actions be taken in groundwater basins designated as either high or medium priority by the California Department of Water Resources (DWR), including Los Osos Basin. DWR identified the Los Osos Basin as a high priority basin subject to critical conditions of overdraft due to seawater intrusion and nitrate impairment (DWR, 2014, 2016). SGMA does not apply to the Los Osos Basin area that is at issue in *Los Osos Community Services District v. Southern California Water Company* [Golden State Water Company], et al.[1] (Adjudicated Plan Area), for which a Stipulated Judgment was approved in San Luis Obispo Superior Court on October 14, 2015. The boundaries of the Adjudicated Plan Area do not coincide with the Basin boundaries as documented in DWR's Interim Update to Bulletin 118 (2016). The groundwater basin areas between the Bulletin 118 Basin boundaries (Basin 3-8) and the Adjudicated Plan Area boundary are referred to as "Fringe Areas" (Figure 1). In order to comply with SGMA, the County of San Luis Obispo (County) formed the Groundwater Sustainability Agency (GSA) over these Fringe Areas on April 4, 2017.

The results of this basin characterization study are intended to produce a basis of knowledge for use in boundary modification requests and potential future use in development of a Groundwater Sustainability Plan (GSP). Decades of technical studies on the basin have focused primarily on aquifers within the Adjudicated Plan Area. This technical memorandum supplements prior work, which together provide a comprehensive hydrogeologic characterization and conceptual model of the Fringe Areas.

Basin Area

The Los Osos Basin is located on the Pacific coast of San Luis Obispo County, south and southeast of the Morro Bay estuary. The basin is bounded on the north by Park Ridge, on the south by the Irish Hills, and extends from Morro Bay on the west to the drainage divide separating the Los Osos Basin from the San Luis Obispo Valley Groundwater Basin on the east. There are two

[1] Pursuant to Water Code 10720.8(d), SGMA does not apply to the adjudicated areas of the Los Osos Valley Groundwater Basin.

main fringe areas outside of the adjudicated plan area, the Eastern Valley fringe area and the Montaña de Oro fringe area. Two minor fringe areas are also present near the confluence of Los Osos Creek and Morro Bay estuary.

The basin's Bulletin 118 boundary encompasses an area of 6,990 acres (10.9 square miles). Within this area, the Eastern Valley fringe area covers 1,760 acres (2.8 square miles), the Montaña de Oro fringe area covers 643 acres (1.0 square mile), and the minor fringe areas cover less than 5 acres.

Eastern Valley Fringe Area

The Eastern Valley fringe area contains an alluvial aquifer formed by the stream channel and floodplain deposits of Warden Creek. The alluvial deposits are typically close to 60 feet thick where tapped by wells, and overlie serpentinite and Franciscan Assemblage greywacke, mélange, and metavolcanic bedrock. The upper 20 to 30 feet of alluvium is mostly clay, while the lower portion includes mostly sand and gravel, frequently described as fractured red rock or red rock gravel. There is also a bedrock aquifer, consisting mostly of fractured Franciscan Assemblage metavolcanics, that is the principal source of water to wells on the south side of Los Osos Valley Road. Active irrigation and private domestic wells within the Eastern Valley fringe area typically tap the sands and gravels in the alluvium and also extend into bedrock.

Groundwater in the alluvial aquifer generally moves west, toward Warden Lake. Recharge occurs from a variety of sources: direct percolation of precipitation; return flow from irrigation and septic system discharges; stream seepage from unnamed tributaries; and subsurface inflow from bedrock. Warden Lake is a wetland, beneath which the hydraulic gradient appears to be flat through the confluence of the Warden Creek alluvial channel with the Los Osos Creek Valley. There is an estimated 5,200 acre-feet of groundwater storage in the Eastern Valley fringe area. A preliminary water balance was performed for the fringe area, as summarized in Table ES-1.

Table ES-1
Water Balance Summary
Eastern Valley Fringe Area Alluvial Aquifer

INFLOW ITEMS	AFY
Percolation of precipitation	390
Return flow	95
Stream seepage	210
Subsurface	55
TOTAL INFLOW	750
OUTFLOW ITEMS	AFY
Wells	470
Wetland ET	155
Subsurface	<1
Base flow	125
TOTAL OUTFLOW	750

Water quality in the upper Eastern Valley alluvial aquifer is similar to water quality in the bedrock aquifer, with the exception of nitrates, which are greater in the alluvial aquifer. The general mineral character of groundwater is magnesium bicarbonate. Water quality in the lower Eastern Valley fringe area shows a pronounced sodium chloride influence, with lower nitrate concentrations than the upper Eastern Valley.

Field investigation in the Eastern Valley was performed from August through October 2017. Water levels were measured at 26 wells, and groundwater samples were collected from 18 wells. Historical pumping tests were analyzed for six irrigation wells in the alluvial aquifer, and two wells in bedrock aquifers adjacent to the fringe area. One additional constant discharge test was performed during the field investigation near the fringe area west boundary.

<u>Montaña de Oro Fringe Area</u>

The Montaña de Oro fringe area, which is entirely within Montaña de Oro State Park, has a narrow strip of saturated dune sand aquifer along the beach, between the Adjudicated Plan Area boundary and the reef north of Hazard Canyon. Coastal erosion processes and uplift in the Montaña de Oro area have resulted in a series of emergent marine terraces which begin at the modern wave-cut platform and progress through a stepped sequence along the rising coastline. Dune sands and other Quaternary sediments that overlie marine terraces inland of the beach are interpreted to be mostly dry, with locally perched water lenses on top of bedrock and seasonal saturation adjacent to drainages.

There are no groundwater wells tapping basin sediments in the Montaña de Oro fringe area. The only two wells within the fringe area boundary produce water from shale bedrock. The terrace deposits overlying bedrock near these wells are dry.

Subsurface lithologic data indicates a major fault offset is present near the boundary between the Montaña de Oro fringe area and the Adjudicated Plan Area that acts as a subsurface barrier to groundwater flow. The offset is caused by movement along the Los Osos Fault. Uplift of the Irish Hills and tectonic subsidence of the Los Osos Valley juxtaposes the principal aquifers within the Adjudicated Plan Area against soft shale and siltstone bedrock in the Montaña de Oro fringe area. The fault boundary not only creates a subsurface restriction to flow, but also truncates all Quaternary basin sediments north of the fault, except the dune sands and other marine terrace deposits, which are uplifted and mostly unsaturated in the fringe area.

Minor Fringe Areas

There are two minor fringe areas near the confluence of Los Osos Creek and Morro Bay estuary, where the Bulletin 118 boundary includes portions of the stream channel alluvium. Flow between the stream channel alluvium and basin aquifers is interpreted to be hydraulically restricted by bedrock and the regional clay aquitard. The stream channel in the vicinity of the minor fringe areas is also under estuarine influence and subject to seawater intrusion.

1.0 INTRODUCTION

This study documents the basin characterization work performed by Cleath-Harris Geologists, Inc. (CHG), on behalf of the San Luis Obispo County Flood Control and Water Conservation District for the Los Osos Valley Groundwater Basin (Los Osos Basin) Fringe Area characterization and basin boundary modification.

The Sustainable Groundwater Management Act (SGMA) took effect on January 1, 2015, and requires that certain actions be taken in groundwater basins designated as either high or medium priority by the California Department of Water Resources (DWR), including Los Osos Basin. DWR identified the Los Osos Basin as a high priority basin subject to critical conditions of overdraft due to seawater intrusion and nitrate impairment (DWR, 2014, 2016). SGMA does not apply to the Los Osos Basin area that is at issue in *Los Osos Community Services District v. Southern California Water Company* [Golden State Water Company], et al.[1] (Adjudicated Plan Area), for which a Stipulated Judgment was approved in San Luis Obispo Superior Court on October 14, 2015. The boundaries of the Adjudicated Plan Area do not coincide with the Basin boundaries as documented in DWR's Interim Update to Bulletin 118 (2016). The groundwater

1 Pursuant to Water Code 10720.8(d), SGMA does not apply to the adjudicated areas of the Los Osos Valley Groundwater Basin.

basin areas between the Bulletin 118 Basin boundaries (Basin 3-8) and the Adjudicated Plan Area boundary are referred to as “Fringe Areas” (Figure 1). In order to comply with SGMA, the County of San Luis Obispo (County) formed the Groundwater Sustainability Agency (GSA) over these Fringe Areas on April 4, 2017.

The results of this basin characterization study are intended to produce a basis of knowledge for use in boundary modification requests and potential future use in development of a Groundwater Sustainability Plan (GSP). Decades of technical studies on the basin have focused primarily on aquifers within the Adjudicated Plan Area. This technical memorandum supplements prior work, which together provide a comprehensive hydrogeologic characterization and conceptual model of the Fringe Areas.

The work tasks performed for this memorandum include data compilation and review, preparing the hydrogeologic conceptual model, defining potential recharge areas, and field investigation for well testing, water level monitoring, and water quality sampling. Other data include geologic cross-sections, pumping test results, base of permeable sediments and groundwater elevation contour maps, groundwater storage calculations, and an analysis of data gaps.

The Los Osos Basin is located on the coast of San Luis Obispo County, south and southeast of the Morro Bay estuary. The basin is bounded on the north by Park Ridge, on the south by the Irish Hills, and extends from Morro Bay on the west to the drainage divide separating the Los Osos Valley Groundwater Basin from the San Luis Obispo Valley Groundwater Basin on the east. There are two main fringe areas outside of the Adjudicated Plan Area, the Eastern Valley fringe area and the Montaña de Oro fringe area. Two minor fringe areas are also present near the confluence of Los Osos Creek and Morro Bay estuary.

The Los Osos Basin's Bulletin 118 boundary encompasses an area of 6,990 acres (10.9 square miles). Within this area, the Eastern Valley fringe area covers 1,760 acres (2.8 square miles), the Montaña de Oro fringe area covers 643 acres (1.0 square mile), and the minor fringe areas cover less than 5 acres. The remaining 4,582 acres (7.2 square miles) are within the Adjudicated Plan Area (Figure 1).

2.0 DATA COMPILATION AND REVIEW

Data compilation consisted of locating and organizing existing geologic and hydrologic information related to the fringe areas. The data was then reviewed to identify significant gaps with respect to the development of a hydrogeologic conceptual model, basin boundary modification request, or a potential future groundwater model.

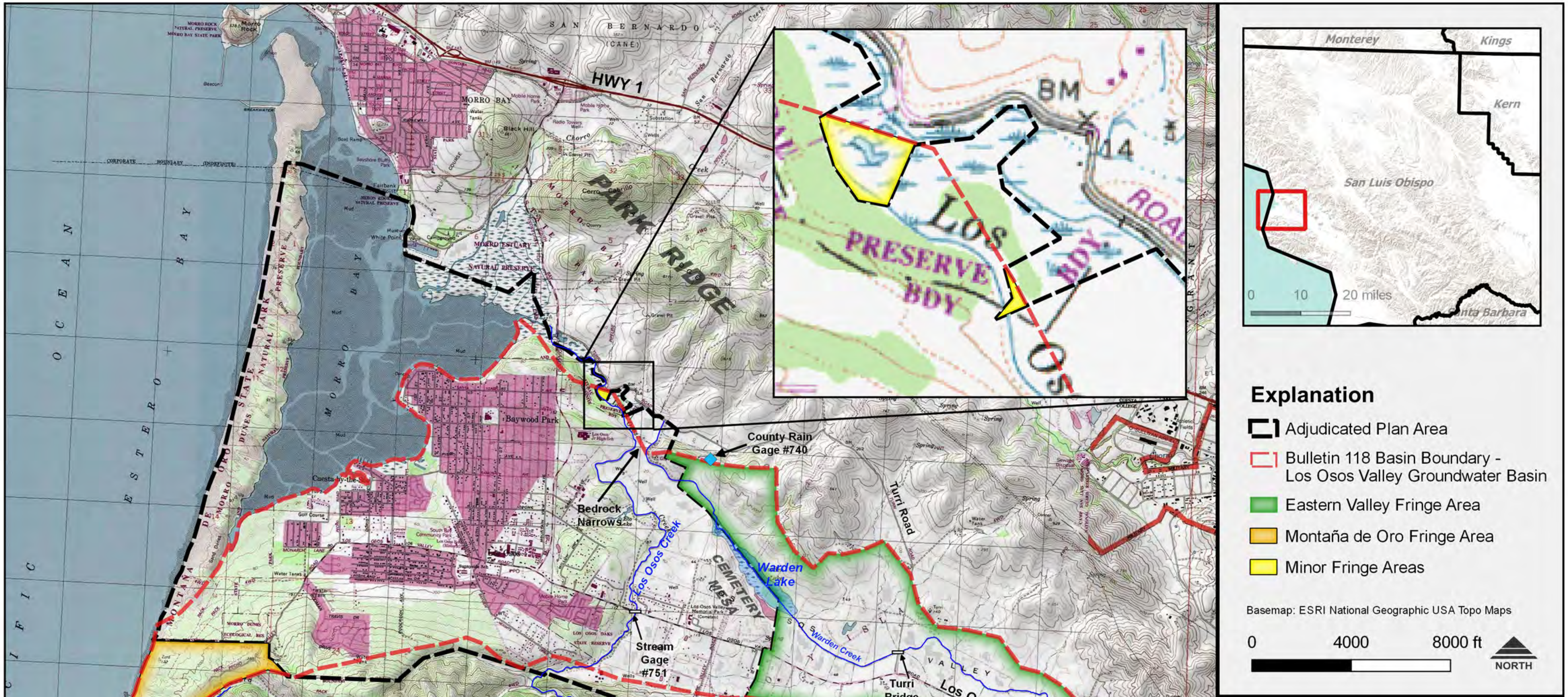


Figure 1 - Fringe Area Overview

Los Osos Valley Groundwater Basin Fringe Areas Characterization

County of San Luis Obispo

Cleath-Harris Geologists

2.1 Data Compilation

Sources of information searched to compile the datasets included the following:

(1) Hydrogeologic and geologic studies and maps
(2) Well construction and testing reports
(3) Groundwater monitoring reports
(4) Water quality reports
(5) County streamflow gages
(6) County precipitation stations
(7) Agricultural Land and Water Use Estimates
(8) California Irrigation Management Information System (CIMIS) weather stations
(9) County water level monitoring program
(10) DWR Well Completion Report Database
(11) Land use data
(12) County Agricultural Commissioner's office datasets
(13) Agricultural applied irrigation estimates
(14) Geotracker Groundwater Ambient Monitoring and Assessment (GAMA) Program Groundwater Information System
(15) United States Environmental Protection Agency (USEPA) Storage and Retrieval (STORET) and Water Quality Exchange (WQX) Databases
(16) Central Coast Regional Water Quality Control Board (CCRWQCB) Irrigated Lands Regulatory Program (ILRP)
(17) Digital soils maps/Agricultural Groundwater Banking Index
(18) Light Detection and Ranging (LiDar) topographic data

A digital compilation of the pertinent information obtained from the above sources is available. An inventory of the electronic information database is included in Appendix A. Summaries of the most useful datasets reviewed are discussed below.

Previous Reports and Studies

Most of the existing published reports that included fringe areas as part of the groundwater basin are from the 1970's. Morro Group (1987) and the United States Geological Survey (USGS; Yates and Wiese, 1988) did not consider the fringe areas as part of the basin, and subsequent basin studies and management plans focused on what became the Adjudicated Plan Area. For historical information on fringe area hydrogeology, the most pertinent reports are:

- 1972 DWR Bulletin No. 63-6, Sea Water intrusion: Morro Bay Area, San Luis Obispo County
    1. Geologic cross-section - extends into lower Eastern Valley fringe area.
    2. Test hole - e-log and lithology for deep test hole near Montaña de Oro fringe area boundary.

3. Water quality - two locations in Eastern Valley fringe area.
4. Water level contour map (Spring 1970) - includes lower Eastern Valley fringe area.

- 1973 DWR Southern District Report, Los Osos-Baywood Ground Water Protection Study
  1. Geologic cross-section from Bulletin No. 63-6 above
  2. Water level contour map (May and June 1973) - no fringe area coverage but shows water levels wells near Montaña de Oro fringe area boundary relative to the Los Osos Fault.
  3. Land use map (1973) - includes Eastern Valley fringe area
  4. Surface water balance - includes Eastern Valley fringe area

- 1974 Brown & Caldwell, Preliminary Groundwater Basin Management Study, San Luis Obispo County Service Area No. 9
  1. Geologic cross-sections - extends into lower Eastern Valley fringe area and also near Montaña de Oro finge area boundary where uplift occurs across Los Osos fault.
  2. Water level contour map (Spring 1974 - extends into lower Eastern Valley fringe area).

The above reports include a few cross-sections, water levels, and water quality data for the lower Eastern Valley fringe area, and some information near the Montaña de Oro fringe area boundary (Figure 1). Most of the subsequent reports, as previously mentioned, are focused on the Adjudicated Plan Area but may contain peripheral information relative to the exclusion of the fringe areas from the basin. A few reports focus on specific properties in the lower Eastern Valley fringe area, including reports for the inactive Los Osos Landfill property and studies for the Los Osos wastewater project. The pertinent reports and studies are included in the fringe area database. An inventory of the database is presented in Appendix A.

DWR Well Completion Report (Well Log) Database

Well completion reports (well logs) for the fringe areas were requested from the DWR. Approximately 70 Well Completion Reports were reviewed for wells located in the Eastern Valley fringe area and vicinity, of which close to 50 well logs are within the fringe area and were used to refine geologic cross-sections and the base of permeable sediments. Static water levels are sometimes reported on well logs. Two well logs were available for the Montaña de Oro fringe.

Geotracker GAMA Groundwater Information System / ILRP

Several online resources were investigated for water level and quality data relevant to the Eastern Valley fringe area. Groundwater water quality data was available from the Central

Coast Regional Water Quality Control Board's (RWQCB) Irrigated Lands Regulatory Program (ILRP) layer on the Geotracker Groundwater Ambient Monitoring and Assessment program (GAMA) interactive map (website link in Appendix A).

Most of the groundwater quality data available from the ILRP during the records search was for the Eastern Valley from 2013 to 2016, and covered general mineral water quality parameters such as total dissolved solids (TDS) nitrates, chloride, and sulfate. Not all wells listed the same suite of constituents. No water level information was found in the ILRP.

Land Use Maps

The DWR has conducted land use/crop surveys in San Luis Obispo County since the 1950's. Historical lands use maps were prepared in 1959, 1968, 1977, and 1985. Beginning in 1996, results of land use/crop surveys are available in digital database format (shapefiles) with searchable attributes. The 1996 digital compilation for San Luis Obispo County was based on aerial photography taken between December 1992 and April 1995, with field verification in September and October of 1995; March and April of 1996; and August and September of 1996. The most recent land use/crop survey is from 2014. Land use information can be useful for developing applied irrigation water estimates.

Other Datasets

Many other types of data were compiled and reviewed for this report. Several of the datasets, such as Agricultural Land and Water Use Estimates, California Irrigation Management Information System (CIMIS) stations, soils maps/Groundwater Recharge Banking Index, and Light Detection and Ranging (LiDar) are shown as a web link on the data inventory (Appendix A), rather than downloading and archiving extracted data. These datasets can be accessed on an as-needed basis.

2.2 Data Gap Identification

Information compiled for fringe area characterization has been reviewed for identifying significant data gaps related to the development of a hydrogeologic conceptual model and boundary modification efforts, as well as potential future groundwater flow modeling. Significant data gaps in the Los Osos fringe areas are to be expected, as they encompass areas that have been excluded from basin studies for decades.

Almost the entire Montaña de Oro fringe area has a data gap, while considerable information for the Eastern Valley is available. With respect to filling data gaps, the Montaña de Oro fringe area is also a more difficult challenge, as there is limited accessibility both physically (sand dunes) and with respect to permitting through California State Parks and Recreation (State Parks) and the California Coastal Commission. Data gaps and recommendations are presented in Appendix A and summarized below:

- *Water levels* - There are currently no formal water level monitoring programs in the fringe areas. Groundwater level monitoring is recommended to characterize seasonal and long-term water level trends. The Eastern Valley fringe area would benefit from at least 3-4 water level monitoring locations. The Montaña de Oro fringe area could also benefit from a few monitoring wells, although basin sediments are likely unsaturated over much of the area.
- *Water Quality* - Additional water quality sampling in the Montaña de Oro fringe area would be needed to characterize the dune sand aquifer.
- *Well head elevations* - The well head elevations used for this report are based on LiDar topographic datasets and physical measurements of casing (reference point) stick-up above ground surface, which is sufficient accuracy for the hydrogeologic conceptual model. Wellhead elevation surveys would be recommended for wells included in any fringe area water level monitoring program.
- *Streamflow* – Collecting seasonal streamflow data in the Eastern Valley fringe area would be recommended for use in water budgets and groundwater flow model development. There are currently no stream gages in the fringe areas, although computer modeling of surface flows for Warden Creek has been performed (Tetra Tech, 1998).
- *Subsurface definition* - Only two boring logs are available in the Montaña de Oro fringe area, and the interpretation of depth to bedrock is based primarily on the surface mapping of marine terraces. The subsurface geometry of the dune sand aquifer in the Montaña de Oro fringe could be confirmed with test holes (including cone penetration testing) and/or geophysics.
- *Water use* - Groundwater production is typically the largest component of subsurface outflow for developed areas. Agricultural irrigation wells are not metered in the Eastern Valley fringe area, and groundwater production estimates are based primarily on local land use/cropping, evapotranspiration, and precipitation. Improvements to groundwater production estimates would benefit from land use surveys that include cropping information for all growing seasons. The Montaña de Oro fringe area is largely undeveloped (State Park) and groundwater production is not significant.

3.0 HYDROGEOLOGIC CONCEPTUAL MODEL

A conceptual model is a compilation and interpretation of available information on the physical system being modeled. For a groundwater basin, it includes a characterization of basin structure, boundary conditions, aquifer geometry, physical parameters, and components of inflow and outflow.

The Los Osos Basin is a coastal sedimentary basin with direct hydraulic connection to the Pacific Ocean. Principal aquifers include older dune sands, the Paso Robles Formation, the Careaga Formation, and the recent alluvium of Los Osos Creek and Warden Creek. Figure 2 presents the geologic map of the basin. The only basin sediments mapped at ground surface are dune sands and alluvial deposits, although the Paso Robles Formation has been mapped at ground surface in older geologic maps (e.g. Hall, 1979). The Careaga Formation has been inferred beneath the Paso Robles Formation based on lithologic correlation from borehole logs (Yates and Weise, 1988).

The basin aquifers are divided into five zones (Zone A through E) plus an alluvial aquifer. Zones A and B are the perched and transitional (semi-perched) aquifers. Zone C is the upper aquifer, and Zones D and E are referred to collectively as the lower aquifer. There is a regional aquitard (the AT2 Clay layer) that separates the upper and lower aquifers. The relationship between geologic units and aquifers for the Adjudicated Plan Area and fringe areas is shown in Figure 3.

The fringe areas are defined as the areas outside of the Adjudicated Plan Area, but within the DWR Bulletin 118 area. For context in presenting the hydrogeologic conceptual model of the fringe areas, geologic-cross sections from prior work for the Adjudicated Plan Area showing all the aquifer zones have been updated and are included in Appendix B.

3.1 Regional Geologic and Structural Setting of Fringe Areas

Eastern Valley Fringe Area

The Eastern Valley fringe area extends approximately 4.2 miles east to west from the drainage divide with San Luis Obispo Valley Groundwater Basin to the Adjudicated Plan Area and confluence with the Los Osos Creek Valley. Topographic elevations on the Eastern Valley floor range from 25 feet above sea level in the Warden Lake area to 185 feet above sea level at the eastern drainage divide. The fringe area boundary is approximately one mile wide near Turri Road, tapering to less than 0.2 miles wide at both the eastern drainage divide and the western confluence with the Los Osos Creek Valley.

Valley alluvial deposits lie between the Irish Hills on the south and a low ridge on the north. Bedrock underlying and surrounding the valley consists of serpentinite, coast range ophiolite complex, and Franciscan assemblage rocks (Dibblee, Jr., 2006), also characterized as serpentinite and Franciscan complex rocks (Hall and others, 1979; Yates and Wiese, 1988; Lettis and Hall, 1994; PG&E, 2014). Formation of the Los Osos Valley was tectonically influenced by movement along the Los Osos fault, which follows the base of the Irish Hills. The Los Osos fault trends northwest-southeast and includes geomorphic expression consistent with late Quaternary faulting near the westerly limits of the City of San Luis Obispo, approximately 4 miles southeast of Turri Road (Treiman, 1989; PG&E, 2014).

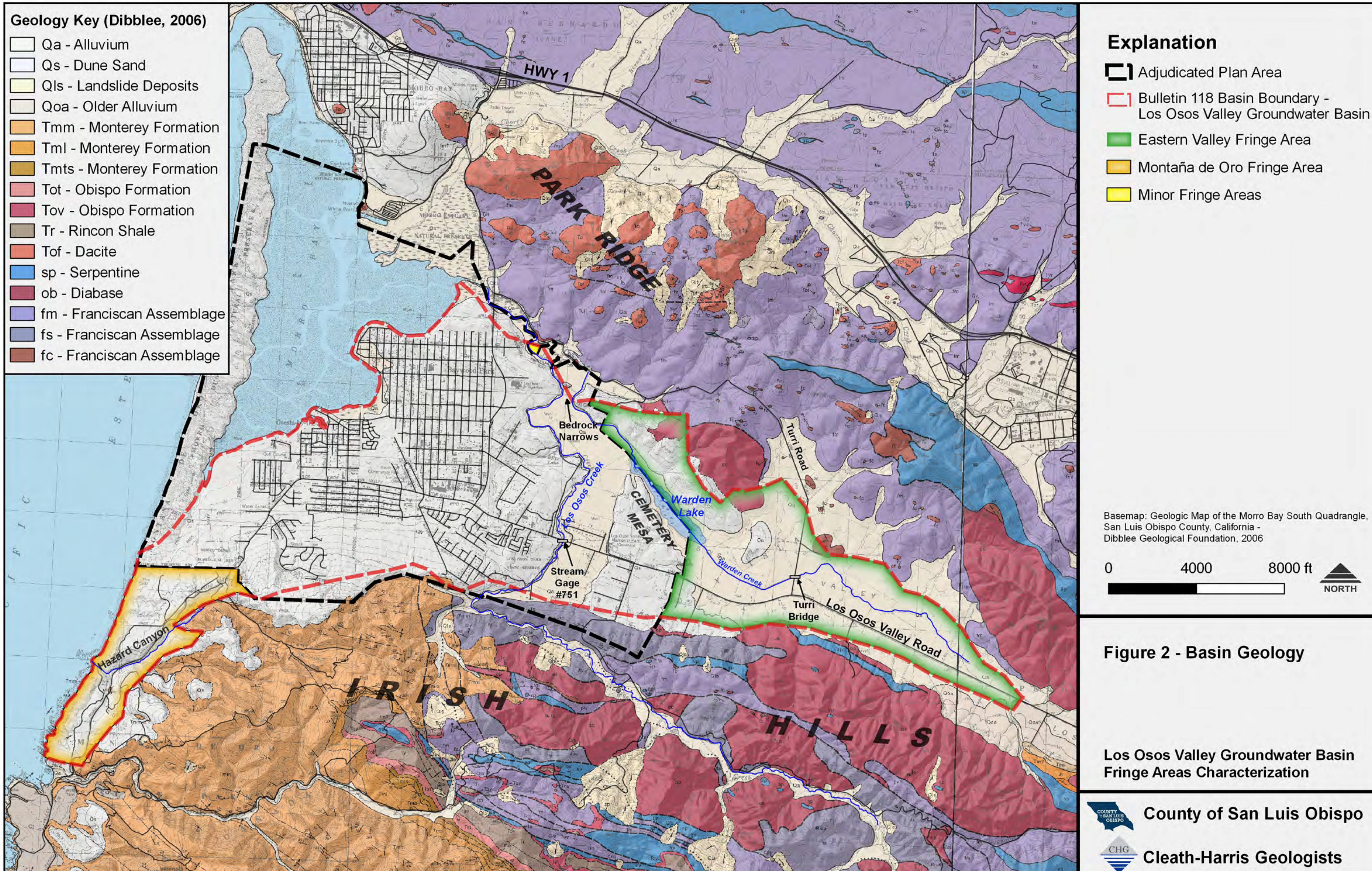


Figure 2 - Basin Geology

Los Osos Valley Groundwater Basin Fringe Areas Characterization

County of San Luis Obispo

Cleath-Harris Geologists

Geologic Unit		Time Scale (MYA)			Adjudicated Plan Area	Eastern Valley Fringe Area	Montaña de Oro Fringe Area	Minor Fringe Areas
Recent Alluvium Dune / Beach Sand	Qa / Qs		Holocene	Quaternary	Alluvial Aquifer	Alluvial Aquifer	Dune Sand Aquifer (mostly unsaturated)	Alluvial Aquifer under (estuarine influence)
Older Alluvium Older Dune Sand	Qoa	0.01	Pleistocene	Quaternary	Aquifer Zones A,B & C			
Paso Robles Formation	Qpr		Pleistocene	Quaternary	Aquifer Zones C,D & E	Minor areas with Zone E present along western boundary		
Careaga Formation	Tca	1.8	Pliocene	Tertiary	Aquifer Zone E			
Pismo Formation (Hall 1979) Monterey Formation (Dibblee 2006)	Tmpm / Tmm	5.3	Miocene	Tertiary			Bedrock Aquifer	
Dacite	Tof	23	Oligocene	Tertiary				
Serpentinite	s	33.9		Cretaceous				
Diabase / Franciscan Assemblage	ob / KJfm	145.5		Jurassic		Bedrock Aquifer		

Figure 3
Stratigraphic Column with Aquifer Correlations

Los Osos Valley Groundwater
Basin Fringe Areas Characterization
San Luis Obispo County
Cleath-Harris Geologists

In the Adjudicated Plan Area, between the Eastern Valley fringe area and the coast, a combination of uplift in the Irish Hills and tectonic subsidence in the Los Osos Valley produced a synclinal structure and associated deep coastal groundwater basin within late Tertiary and Quaternary deposits (C&A, 2005). In the Eastern Valley fringe area, however, the valley floor is underlain by thin Quaternary alluvial deposits, indicating little to no tectonic subsidence north of the Irish Hills (PG&E, 2014).

Montaña de Oro Fringe Area

The Montaña de Oro fringe area extends approximately 2 miles along the coast, from the Adjudicated Plan Area boundary on the north to the bluff overlooking Islay Creek on the south. Topographic elevations from west to east range from sea level to 400 feet above sea level. The fringe area averages close to a half-mile wide.

Bedrock underlying the dune sands is mapped as Tertiary-age Monterey Formation (Dibblee, Jr., 2004), although also assigned to the Miguelito Member of the Pismo Formation by other investigators (Hall and others, 1979; UGSG, 1988; Lettis and Hall, 1994; PG&E, 2014). The Montaña de Oro fringe area lies across (south of) the Los Osos fault zone, compared to the rest of the Los Osos Basin. As a result, the fringe area has been uplifted with the Irish Hills, and there is no deep aquifer or associated tectonic subsidence.

Within the Irish Hills, south of the Los Osos fault, folding and faulting associated with the Edna fault zone has created the Pismo Syncline. Displacement on Edna faults is normal, with the relative up-thrown side to the north, opposite of the reverse-motion Los Osos fault. Geophysical work for the WorldCom Morro Bay fiber optic cable landing identified potential faulting at the coast along the Montaña de Oro with normal motion (Gasch & Associates, 2000). The geophysical data is shown in Appendix C, and indicates shallow bedrock in the vicinity of deep coastal test hole MBO-2, which supports the conclusion that the main Los Osos fault lies north of MBO-2, as interpreted by DWR (1973), Brown & Caldwell (1974) and Cleath & Associates (2005).

Coastal erosion processes and uplift in the Montaña de Oro area have resulted in a series of emergent marine terraces which begin at the modern wave-cut platform and progress through a stepped sequence along the rising coastline. Correlation and age-dating of the emergent marine terraces has led to an estimate of coastal uplift of the Irish Hills at a rate of 0.2 to 0.23 millimeters per year (Hanson et al., 1994; Lettis and Hall, 1994). Deposition on the marine terraces would include near-shore marine sands, slope wash and alluvium, and wind-blown dune sands.

Minor Fringe Areas

There are two minor fringe areas near the confluence of Los Osos Creek and Morro Bay estuary, where the Bulletin 118 boundary was drawn through portions of the stream channel alluvium. Flow between the stream channel alluvium and basin aquifers is interpreted to be hydraulically restricted by bedrock and the regional clay aquitard. The stream channel in the vicinity of the minor fringe areas is also under estuarine influence and subject to seawater intrusion. These minor fringe areas, which combine for less than 5 acres in total area, are located on portions of State Parks and Coastal San Luis Resource Conservation District property (Figure 1).

3.2 Principal Aquifers and Aquitards

Eastern Valley Fringe Area

The Eastern Valley fringe area is a contiguous alluvial aquifer overlying bedrock. The dune sands mapped on the slopes north of Warden Lake are thin (less than 40 feet thick) and unsaturated, except for seasonally perched water on top of shallow bedrock (Figure B2, Appendix B; and C&A, 2008).

There is also a bedrock aquifer, consisting mostly of fractured Franciscan Assemblage metavolcanics, that is the principal source of water to wells on the south side of Los Osos Valley Road. Areas of groundwater production from fractured rock aquifers are not included in the groundwater basins defined by DWR Bulletin 118 (DWR, 2003). The distinction in drillers logs between bedrock, fractured (water-bearing) bedrock, and alluvial gravels derived from weathered bedrock can be uncertain. In the Eastern Valley fringe area, "fractured red rock" and "red rock gravel" logged beneath the valley floor are interpreted as alluvial gravels and therefore basin sediments for this hydrogeologic conceptual model.

Figure 4 presents the surface geology in the Eastern Valley fringe area. Geologic cross-sections are shown in Figures 5, 6, 7, and 8. Figure 5 also covers a portion of the Adjudicated Plan Area, where basin sediments reach a thickness of over 700 feet, compared to less than 100 feet thickness for the fringe area sediments. Figures 6, 7 and 8 detail lithology within the fringe area alluvial aquifer.

The alluvial aquifer formed from stream channel and floodplain deposits of Warden Creek, and overlies serpentinite and Franciscan Assemblage greywacke, mélange, and metavolcanics. The alluvial deposits are typically close to 60 feet thick where tapped by wells (including fractured red rock), based on an analysis of 35 well logs within the fringe area. Average saturated thickness, based on water levels reported on the well logs, is 40 feet. The upper 20 to 30 feet of alluvium is mostly clay, while the lower portion includes mostly sand and gravel, frequently described as fractured red rock or red rock gravel (Figures 6, 7, and 8). Active irrigation and

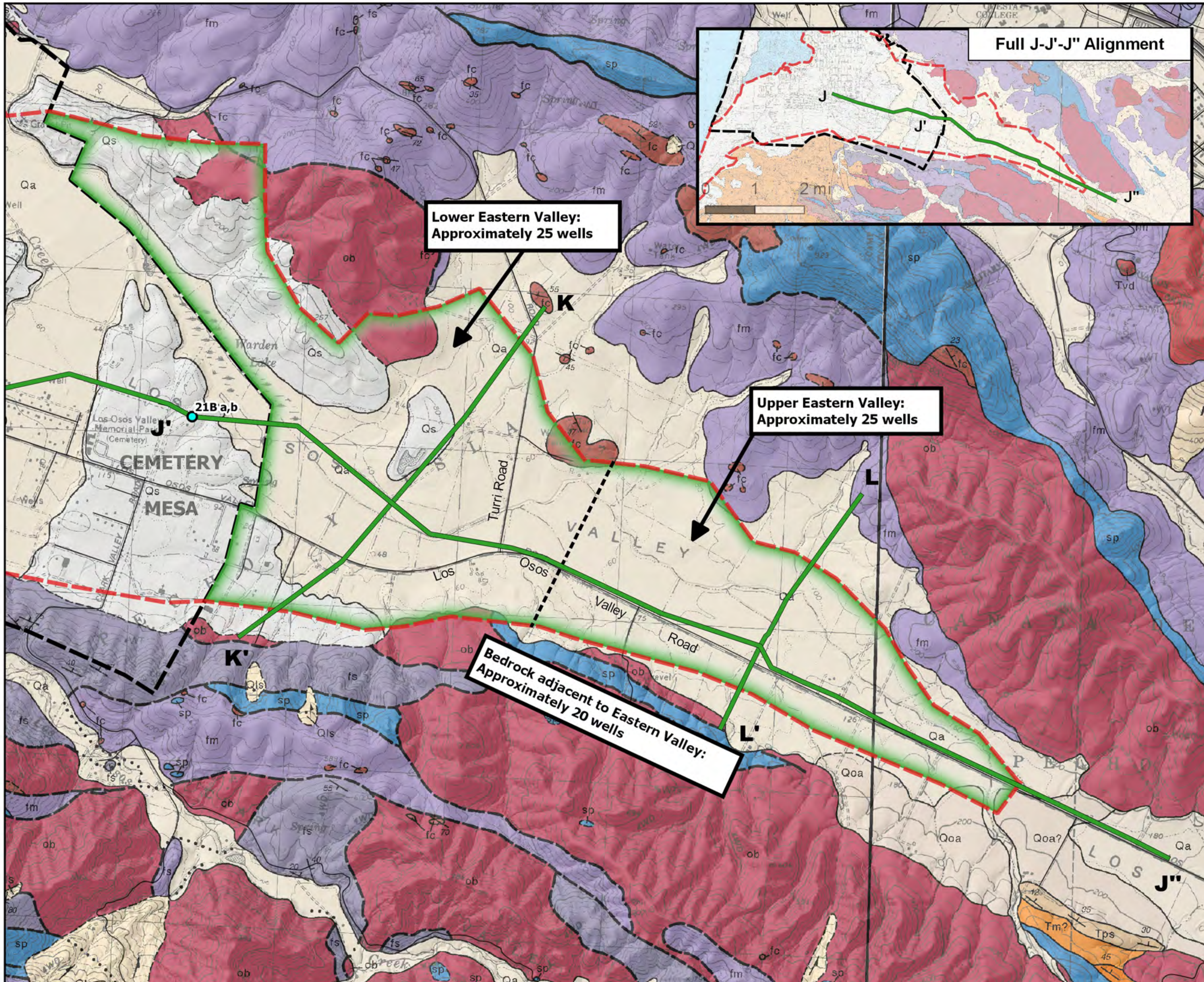
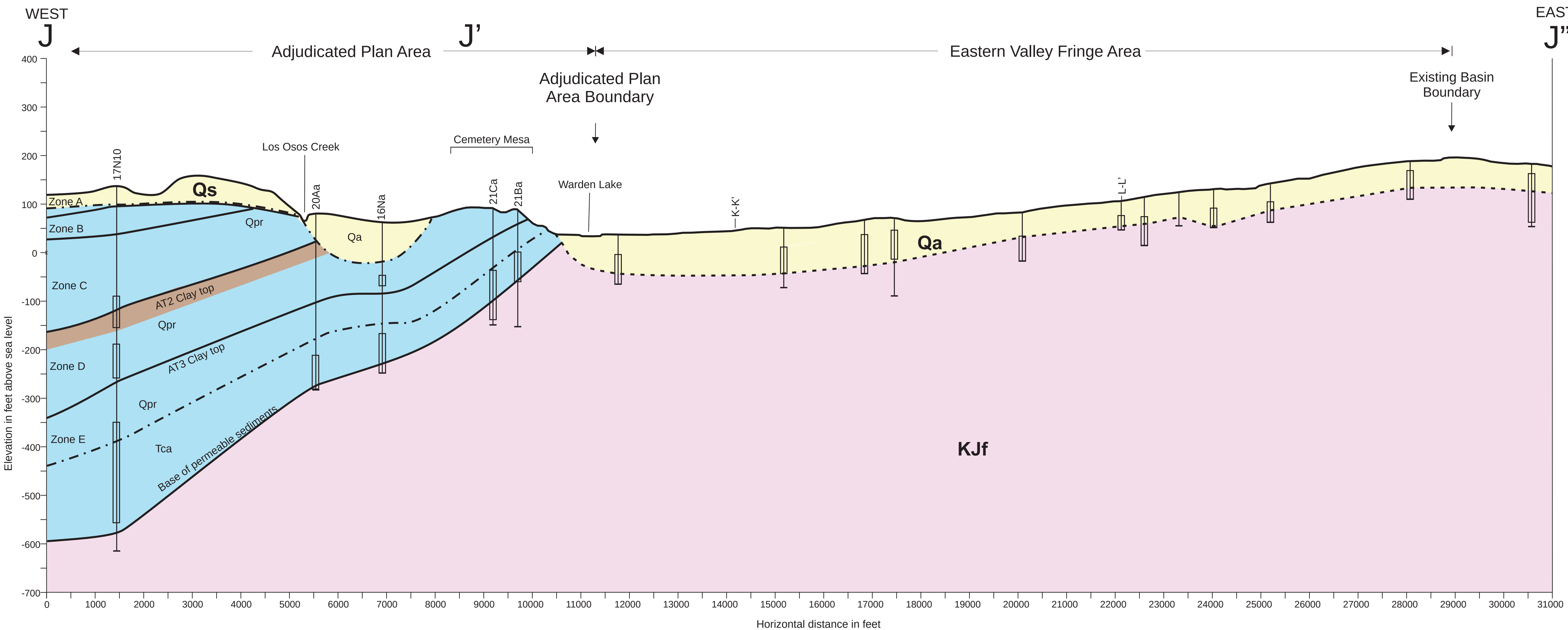


Figure 4 - Surface Geology - Eastern Valley Fringe Area

Los Osos Valley Groundwater Basin Fringe Areas Characterization

County of San Luis Obispo

Cleath-Harris Geologists



Explanation

Aquifer Zones:
Zone A - Perched Aquifer
Zone B - Transitional Aquifer
Zone C - Upper Aquifer
Zone D - Lower Aquifer (shallow)
Zone E - Lower Aquifer (deep)

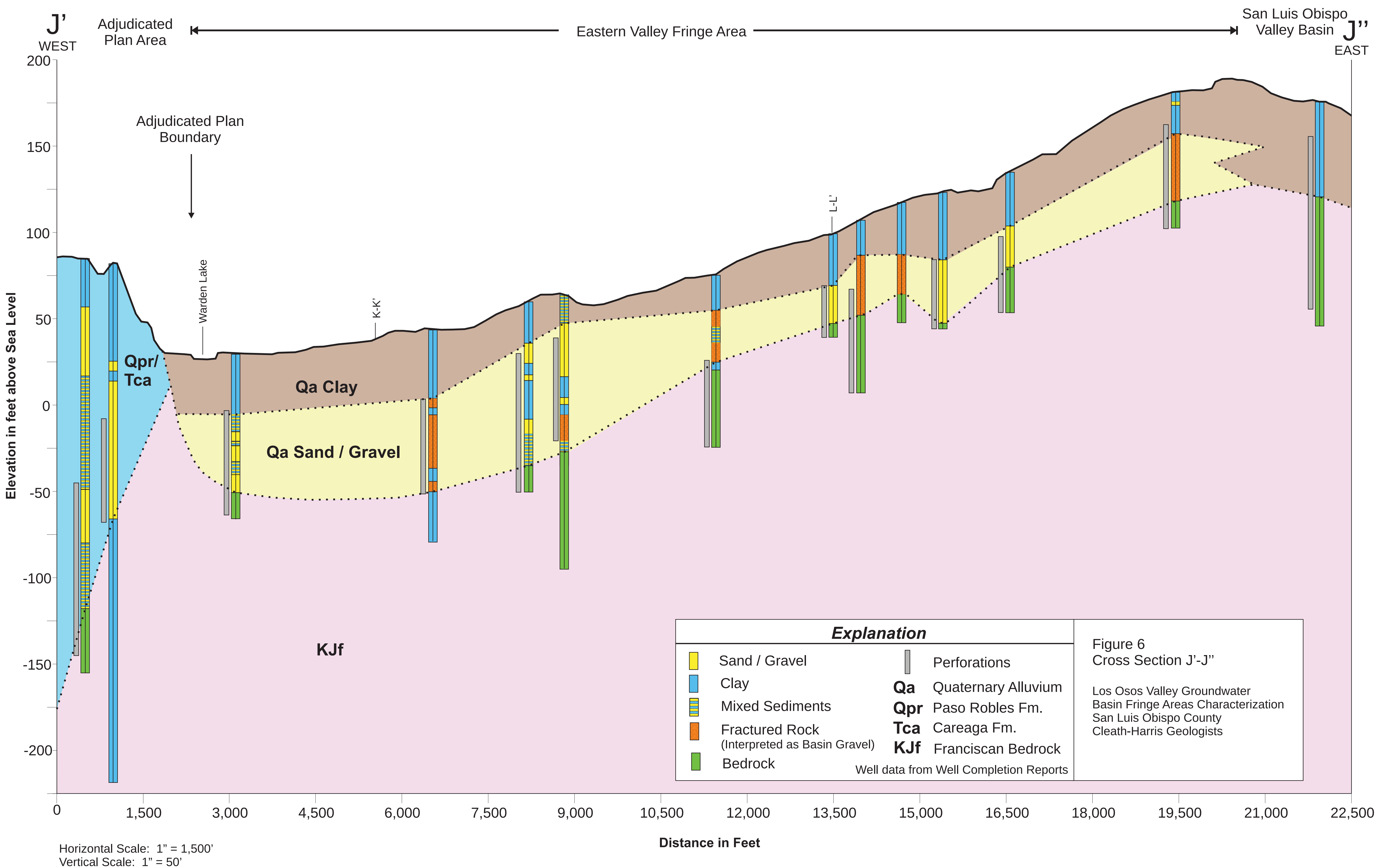
Well data point
17N10 Well ID
←Perforations

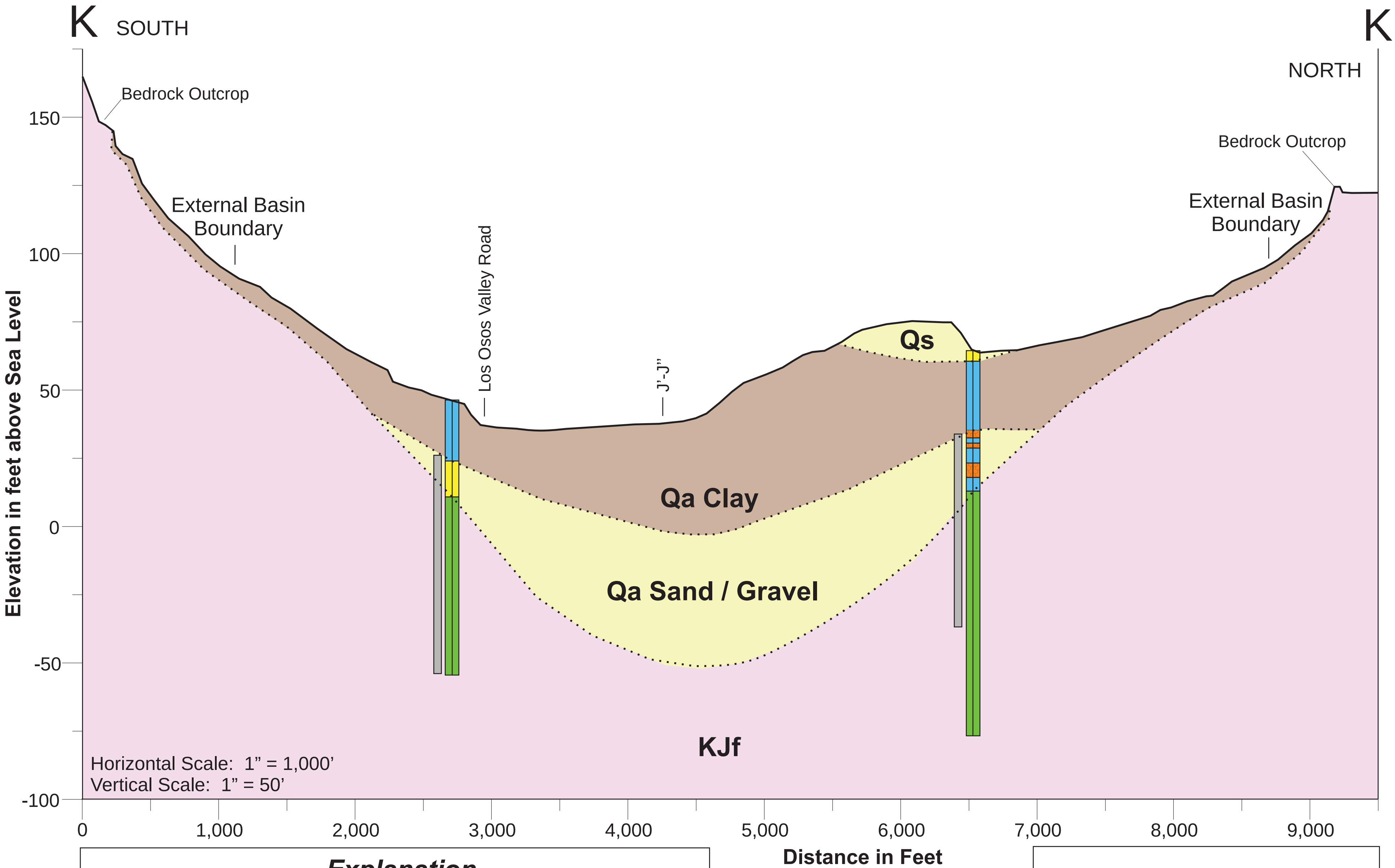
Formations:
Qa - alluvium
Qs - dune sand
Qpr - Paso Robles Formation
Tca - Careaga Formation
KJf - Franciscan Assemblage

Note: Well data from Well Completion Reports

Figure 5
Cross Section J-J'-J''

Los Osos Valley Groundwater
Basin Fringe Areas Characterization
San Luis Obispo County
Cleath-Harris Geologists


J'
WEST
Adjudicated Plan Area
Eastern Valley Fringe Area
San Luis Obispo Valley Basin
J''
EAST
Adjudicated Plan Boundary
Warden Lake
K-K'
L-L'
Qpr/ Tca
Qa Clay
Qa Sand / Gravel
KJf
Elevation in feet above Sea Level
200
150
100
50
0
-50
-100
-150
-200
0
1,500
3,000
4,500
6,000
7,500
9,000
10,500
12,000
13,500
15,000
16,500
18,000
19,500
21,000
22,500
Distance in Feet
Horizontal Scale: 1" = 1,500'
Vertical Scale: 1" = 50'
Explanation
Sand / Gravel
Clay
Mixed Sediments
Fractured Rock
(Interpreted as Basin Gravel)
Bedrock
Perforations
Qa Quaternary Alluvium
Qpr Paso Robles Fm.
Tca Careaga Fm.
KJf Franciscan Bedrock
Well data from Well Completion Reports
Figure 6
Cross Section J'-J''
Los Osos Valley Groundwater
Basin Fringe Areas Characterization
San Luis Obispo County
Cleath-Harris Geologists



Explanation

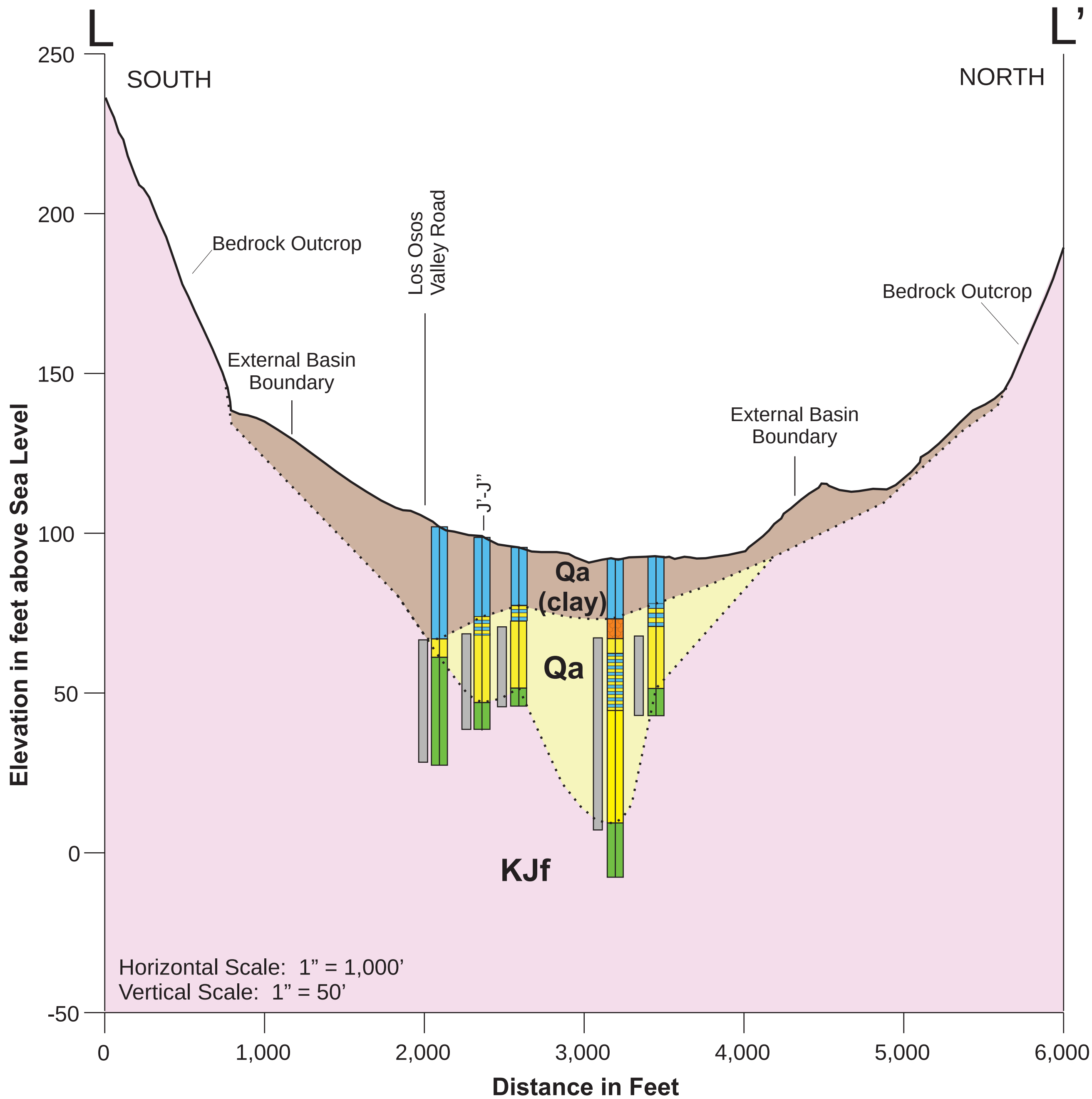
- Sand / Gravel
- Clay
- Mixed Sediments
- Fractured Rock (Interpreted as Basin Gravel)
- Bedrock
- Perforations

Qa Quaternary Alluvium
Qs Dune Sand
KJf Franciscan Bedrock

Well data from Well Completion Reports

Figure 7
Cross Section K-K'

Los Osos Valley Groundwater
Basin Fringe Areas Characterization
San Luis Obispo County
Cleath-Harris Geologists



Explanation

- Sand / Gravel
- Clay
- Mixed Sediments
- Fractured Rock (Interpreted as Basin Gravel)
- Bedrock
- Perforations

Qa Quaternary Alluvium

KJf Franciscan Bedrock

Well data from Well Completion Reports

Figure 8
Cross Section L-L'

Los Osos Valley Groundwater
Basin Fringe Areas Characterization
San Luis Obispo County
Cleath-Harris Geologists

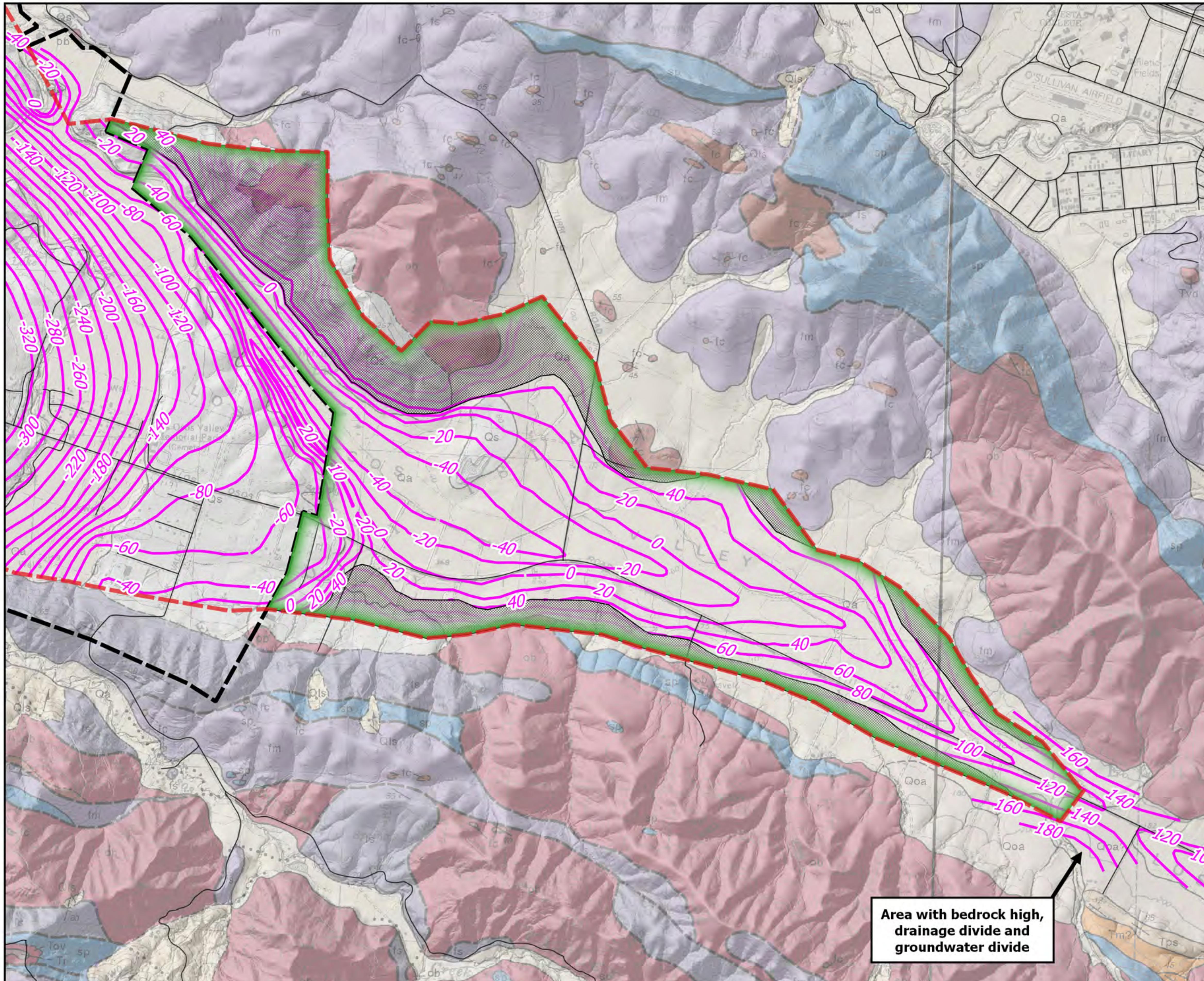
private domestic wells typically tap the sands and gravels in the alluvium and also extend into bedrock.

Figure 9 presents the base of permeable sediments for the area, and Figure 10 shows Summer 2017 groundwater elevation contours. The base of the alluvial deposits is interpreted to extend close to 50 feet below sea level near Warden Lake, although some of the deepest alluvial channel deposits in the lower Eastern Valley fringe area may be in-situ fractured rock, rather than Holocene-age alluvial deposits.

Groundwater in the alluvial aquifer of the Eastern Valley fringe area generally moves west, toward Warden Lake, at an average hydraulic gradient of 0.01 ft/ft, based on Summer 2017 measurements. There is also a component of subsurface flow moving north-northeast from the Cemetery Mesa toward Warden Lake (Figure 10).

Recharge occurs from a variety of sources: direct percolation of precipitation; return flow from irrigation and septic system discharges; stream seepage from unnamed tributaries; and subsurface inflow from bedrock and the Cemetery Mesa (Adjudicated Plan Area). Warden Lake is a wetland, beneath which the hydraulic gradient appears to be flat through the confluence of the Warden Creek alluvial channel with the Los Osos Creek valley. This flat hydraulic gradient is likely controlled by the invert elevation of Warden Creek downstream of Warden Lake; groundwater moving into the wetland area that is not evapotranspired becomes baseflow in Warden Creek. Historical water level trends are not documented in the Eastern Valley.

Existing data were analyzed for pumping tests at six irrigation wells in the alluvial aquifer, and two wells in bedrock aquifers adjacent to the fringe area. One additional constant discharge test was performed during the field investigation in 2017 at well 21Ba on the Cemetery Mesa (Figure 5) to characterize the lower aquifer in the Adjudicated Plan Area near the fringe area west boundary. Aquifer test results are summarized below in Table 1.



Explanation

- Adjudicated Plan Area
- Bulletin 118 Basin Boundary- Los Osos Valley Groundwater Basin
- Eastern Valley Fringe Area
- Unsaturated Areas within Bulletin 118 Boundary
- Contours - Base of Permeable Sediments [ft above MSL]

Eastern Valley fringe area contours are based on lithologic data from 40 wells within the fringe area and 29 wells adjacent to the fringe area.

Geology Key on Figure 2

Basemap: Geologic Map of the Morro Bay South Quadrangle, San Luis Obispo County, California - Dibblee Geological Foundation, 2006

0 2000 4000 ft

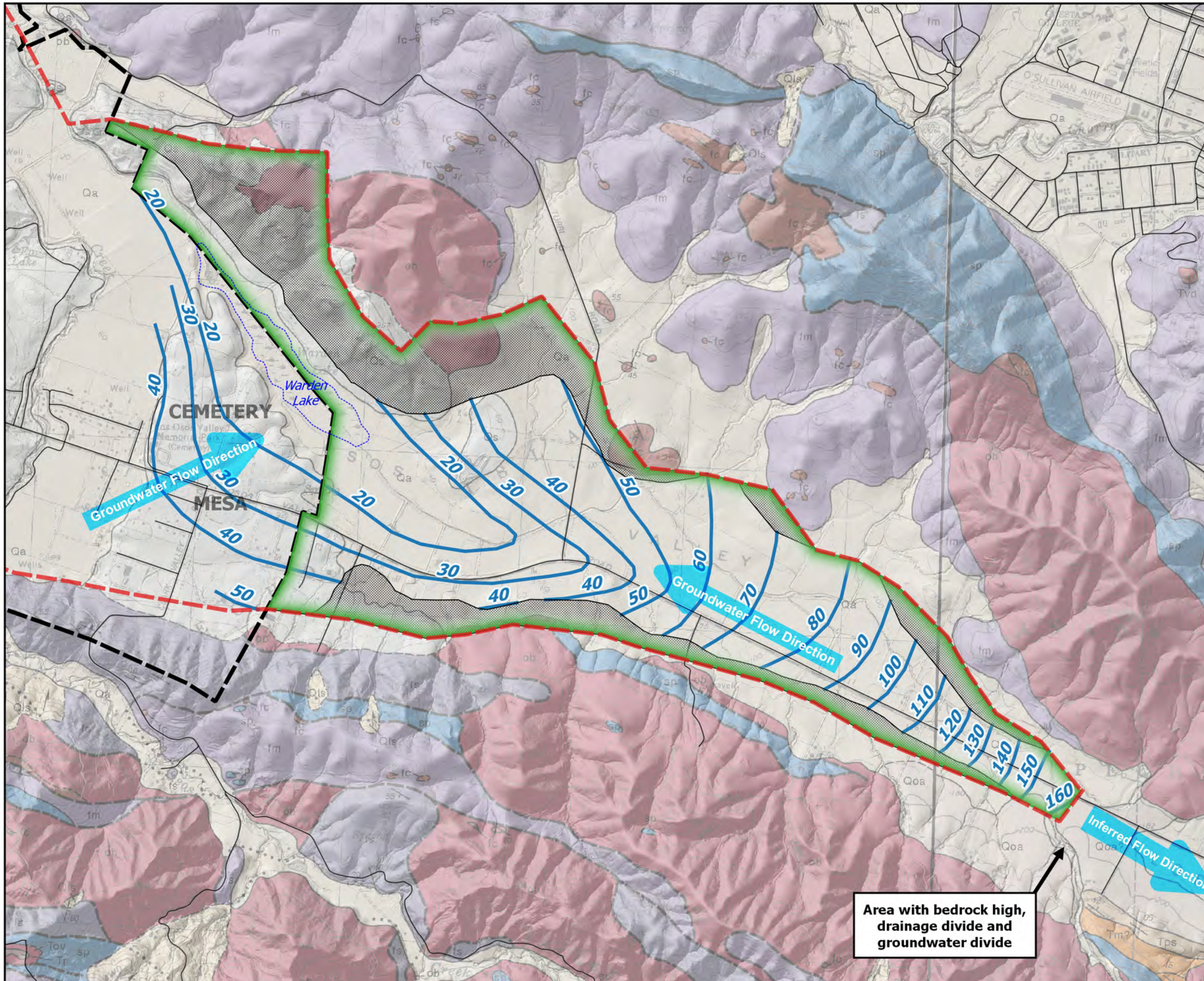
NORTH

Figure 9 - Base of Permeable Sediments - Eastern Valley Fringe Area

Los Osos Valley Groundwater Basin Fringe Areas Characterization

County of San Luis Obispo

Cleath-Harris Geologists



Explanation

Adjudicated Plan Area

Bulletin 118 Basin Boundary-
Los Osos Valley Groundwater Basin

Eastern Valley Fringe Area

Unsaturated Areas
within Bulletin 118 Boundary

Contours -
Groundwater Elevation
[ft above MSL]

Contours are based on 12 water levels inside the fringe area and 14 water levels adjacent to the fringe area.

Geology Key on Figure 2

Basemap: Geologic Map of the Morro Bay South Quadrangle, San Luis Obispo County, California - Dibblee Geological Foundation, 2006

0 2000 4000 ft

NORTH

Figure 10 - Summer 2017 Groundwater Elevation Contours Eastern Valley Fringe Area

Los Osos Valley Groundwater Basin Fringe Areas Characterization

County of San Luis Obispo

Cleath-Harris Geologists

Table 1
Aquifer Tests
Eastern Valley Fringe Area and Vicinity

Aquifer Zone	Flow (gpm)	Duration	T (gpd/ft)	Thickness (ft)	K (gpd/ft^2)	K (ft/day)
Lower Valley[1] Alluvial Aquifer	110	4 hours	2,760	70	39	5.2
	117	4 hours	2,070	70	30	4.0
Upper Valley[2] Alluvial Aquifer	49	4 hours	2,640	27	98	13.1
	50	4 hours	2,170	27	80	10.7
	42	4 hours	2,300	28	82	11
	25	4 hours	1,320	31	43	5.7
Adjudicated Plan Area (Zone E) at Boundary	12	8 hours	530	60	9	1.2
Bedrock Aquifer[3] OUT OF BASIN	300	12 hours	3,900	100	39	5.2
	150	12 hours	2,920	320	9.1	1.2

T = transmissivity; K = hydraulic conductivity; gpm = gallons per minute; gdp = gallons per day; ft = foot
[1]Lower Valley-from Turri Road area west to Adjudicated Plan Area boundary (Figure 4)
[2]Upper Valley-from Turri Road area east to drainage divide with San Luis Obispo Creek watershed (Figure 4)
[3]Bedrock aquifer parameters are not directly comparable to basin parameters due to variable fracture and reservoir geometry.

The hydraulic conductivity of the Eastern Valley fringe area alluvial aquifer ranges from 4 to 13 feet per day (ft/day), averaging 8.3 ft/day for the six tests listed in Table 1. By comparison, the hydraulic conductivity of the upper and lower aquifers in the Adjudicated Plan Area ranges from 1 to 32 ft/day, averaging 14.3 ft/day for 16 tests (15 test listed in C&A, 2005 along with the Zone E test in Table 1). Bedrock aquifer hydraulic conductivity is estimated at 1.2 to 5.2 ft/day, although these values are based on transmissivities for relatively thick intervals which likely contain both less permeable and more permeable zones. Bedrock aquifer parameters are also typically anisotropic due to reservoir geometry and fracture patterns.

Specific yield estimates for San Luis Obispo County alluvial deposits range from 3 percent in clay to 25 percent in sand. The specific yield for the fractured red rock and red rock gravels is estimated at 14 percent, based on classifying the material as similar to tight gravel or cemented gravel (Johnson, 1967).

Montaña de Oro Fringe area

Figure 11 shows the surface geology in the fringe area. Geologic cross-sections are shown in Figures 12, 13, 14, and 15. Figure 12 begins at deep monitoring well 13M1 in the Adjudicated Plan Area, where basin sediments reach a saturated thickness of over 700 feet, compared to less than an estimated 30 feet saturated thickness for Montaña de Oro fringe area sediments at the coast. Figures 13, 14 and 15 detail the sequence of marine terraces underlying the dune sands throughout the fringe area.

The Montaña de Oro fringe area has a narrow strip of saturated dune/beach sand along the coast between the Los Osos fault and the reef north of Hazard Canyon (Figure 13). The dune sands consists of white to reddish brown, mostly fine to medium grained, quartz sand. Dune sands that overlie marine terraces inland of the beach are interpreted to be mostly dry, with locally perched water lenses on top of bedrock and seasonal saturation adjacent to drainages.

There are no groundwater wells tapping basin sediments in the Montaña de Oro fringe area. The only two wells within the fringe area boundary produce water from shale bedrock (Figure 15). The terrace deposits overlying bedrock near these wells are dry.

Aquifer parameters for the dune sand aquifer in Montaña de Oro, where saturated along the coast, would likely be similar to the older dune sand (perched) aquifer in the Los Osos Adjudicated Plan Area. The average hydraulic conductivity of older dune sands is estimated to range from 70 to 230 gallons per day per square foot (gpd/ft^2), or 9.4 to 30.7 ft/day, based on the first and third quartile of 50 laboratory and fields tests from various locations across the Basin (Cleath & Associates, 2005). The specific yield for dune sands is estimated between 20 and 25 percent (Johnson, 1967).

Minor Fringe Areas

Figure 16 Shows the surface geology of the minor fringe areas near the confluence of Los Osos Creek and Morro Bay estuary. The geologic map by Hall and others (1979) is included on this figure due the increased detail showing bedrock cropping out at the bedrock narrows. The regional clay aquitard (mapped as Paso Robles Formation) is also present at the narrows and along the edge of the dune sand sheet (Hall and others, 1979; Cleath & Associates, 2005). Geologic cross-sections and Q-Q' (Figure 17) and northwest portion of I-I' (Figure 18) show the subsurface relationship between bedrock, basin sediments, and the stream channel alluvial deposits.

Downstream of the bedrock narrows, the stream channel alluvium is incised into bedrock. Flow between the stream channel alluvium and basin aquifers is interpreted to be hydraulically restricted by bedrock and the regional clay aquitard. Figure 17 shows the subsurface directly

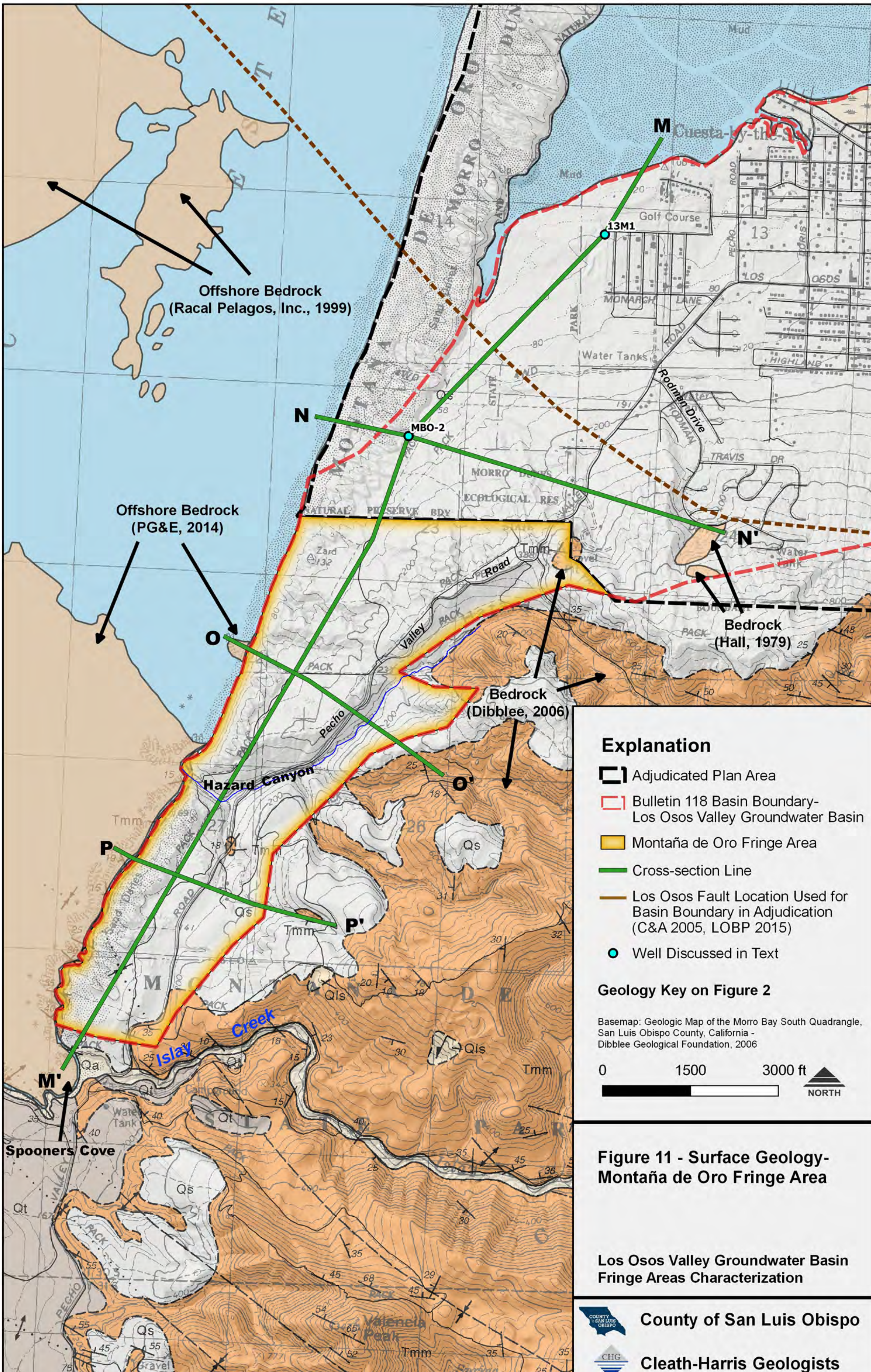
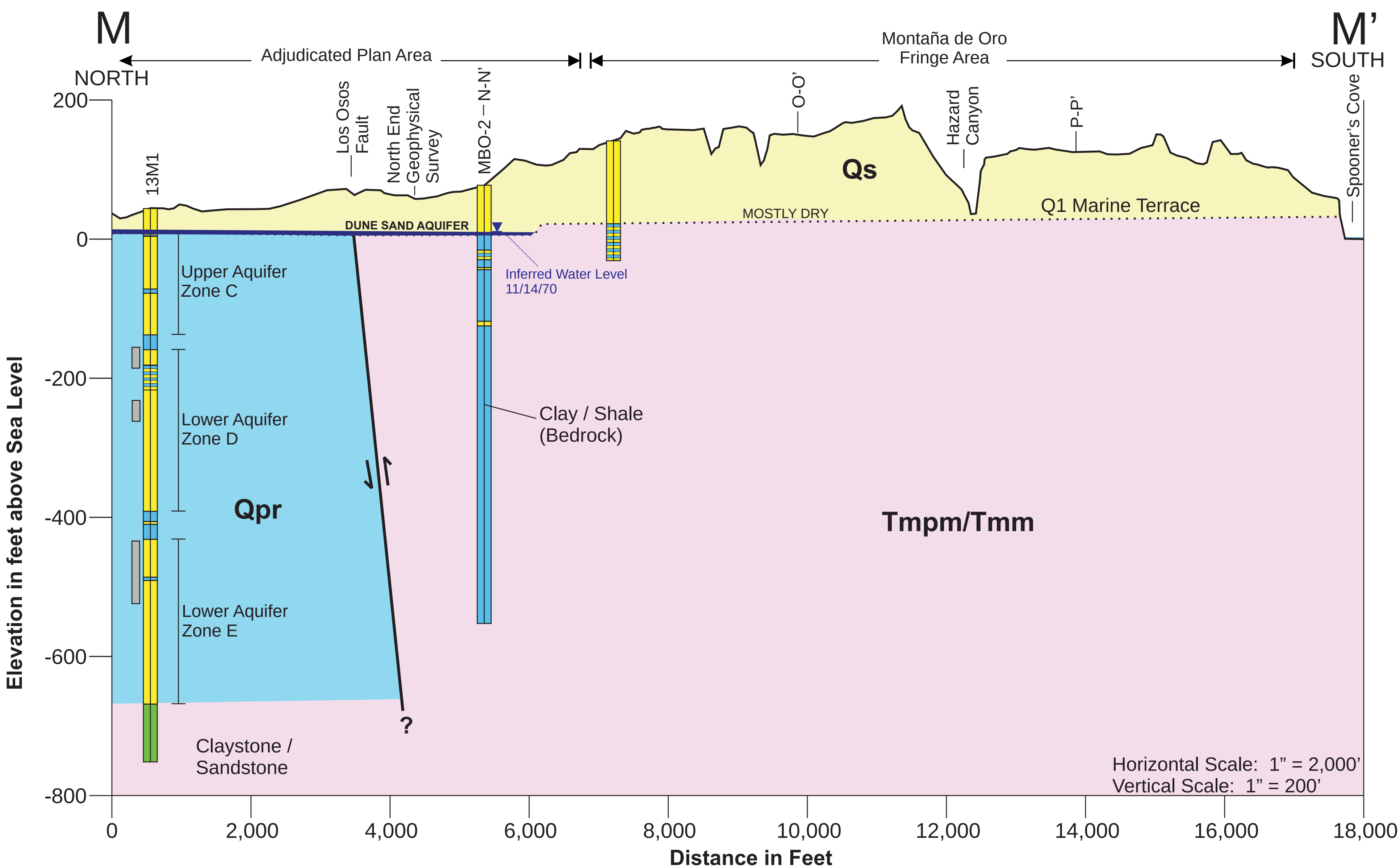


Figure 11 - Surface Geology-
Montaña de Oro Fringe Area

Los Osos Valley Groundwater Basin
Fringe Areas Characterization

County of San Luis Obispo

Cleath-Harris Geologists

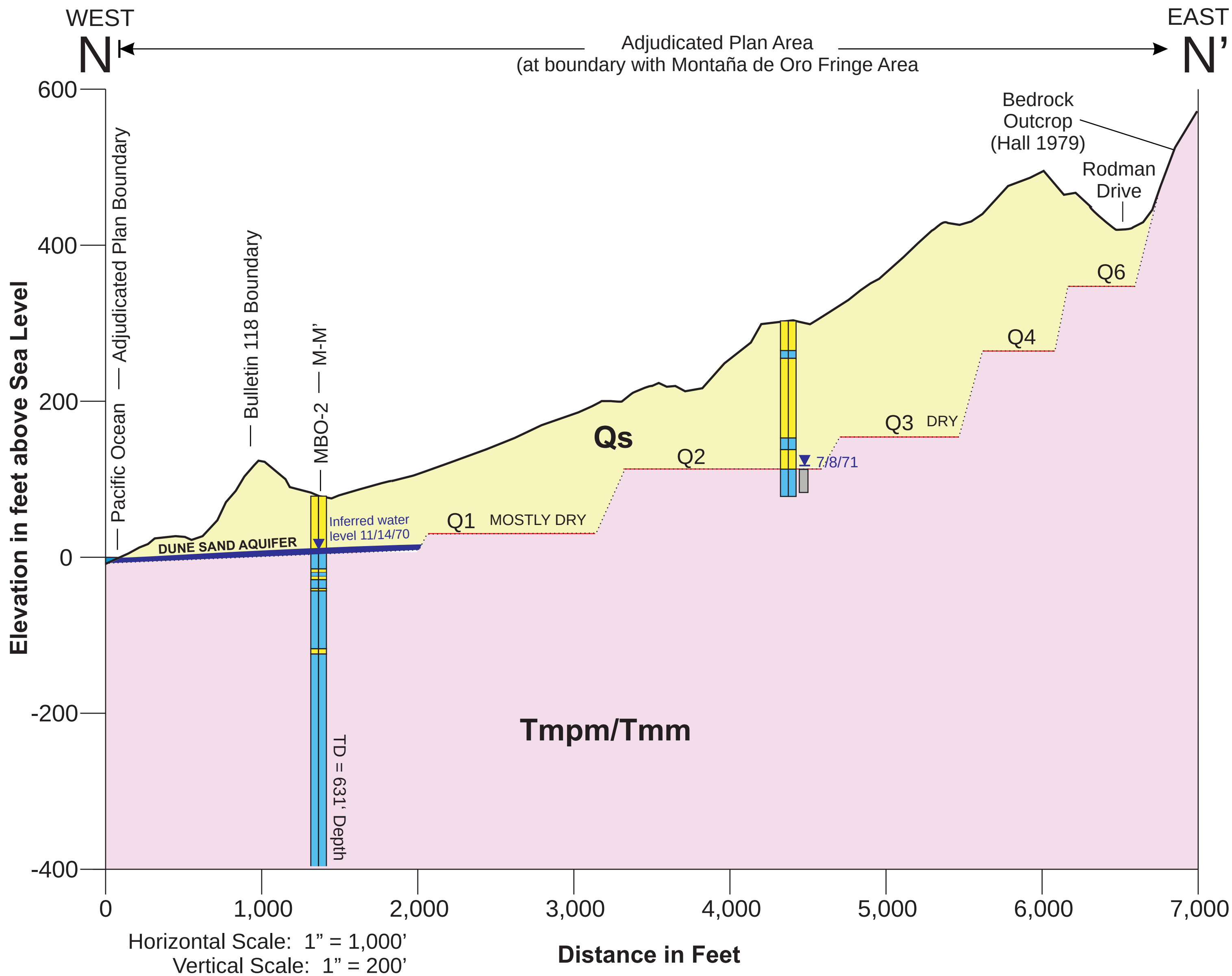


Explanation

Sand / Gravel	**Qs**	Dune Sands	**Tmpm**	Pismo Formation
Clay / Shale	**Qpr**	Paso Robles Formation	**Tmm**	Monterey Formation
Mixed Sediments				Dune Sand Aquifer
Bedrock		Perforations		Well data from Well Completion Reports

Figure 12
Cross Section M-M’

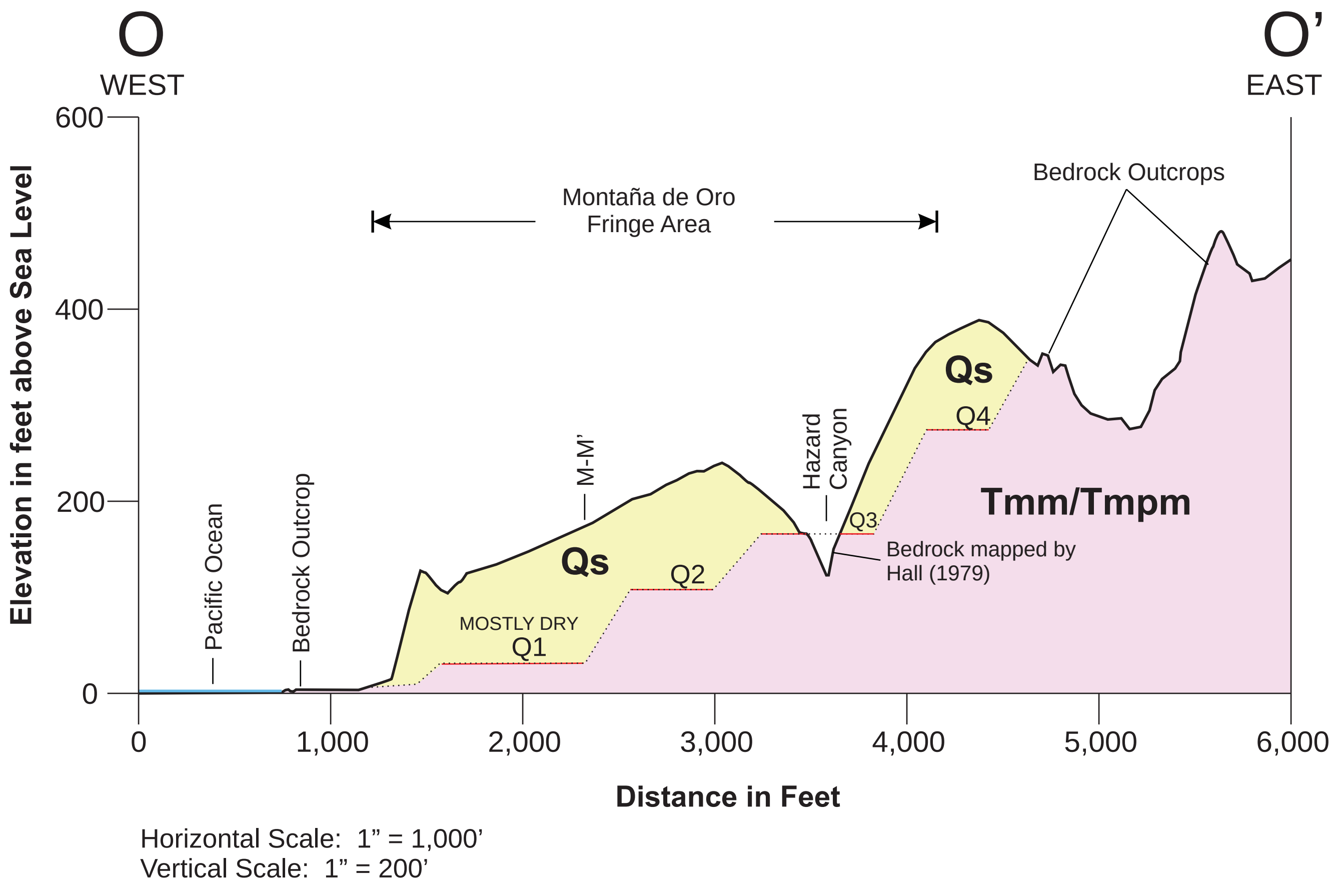
Los Osos Valley Groundwater
Basin Fringe Areas Characterization
San Luis Obispo County
Cleath-Harris Geologists



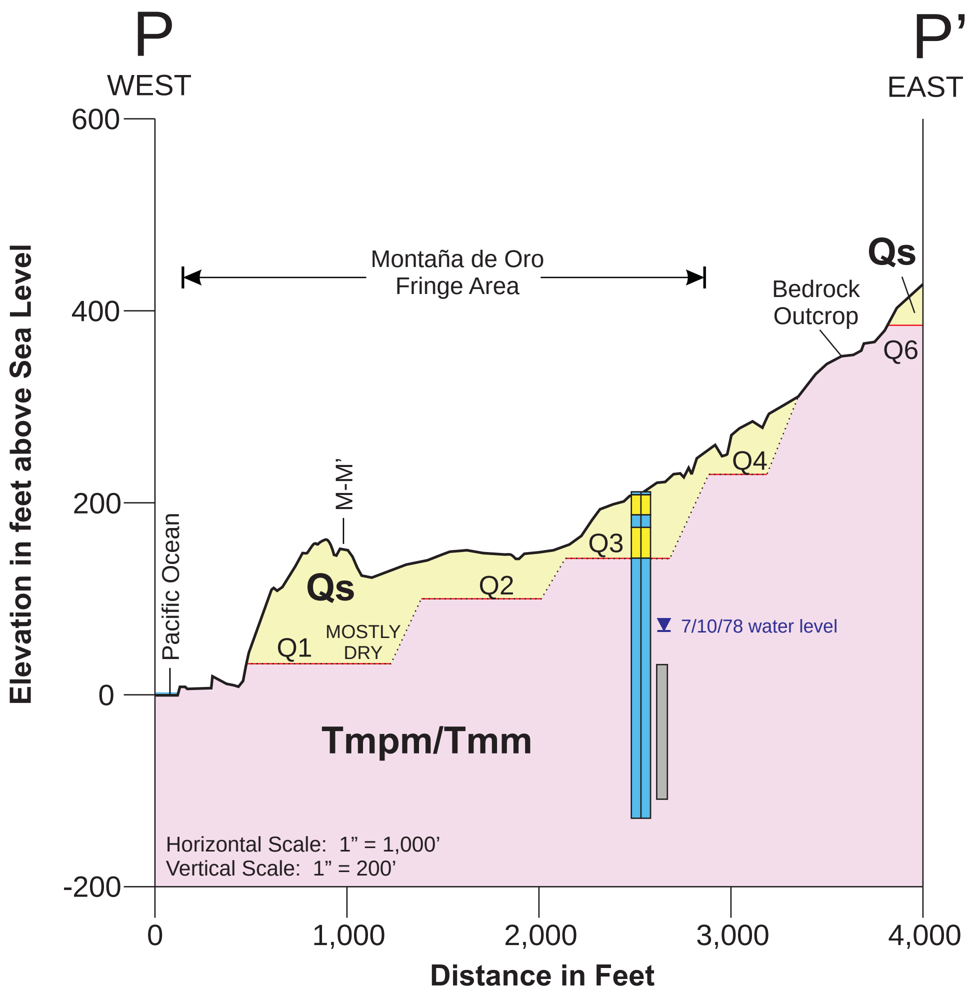
Explanation			
(yellow)	Sand / Gravel	**Tmpm**	Pismo Formation
(blue)	Clay / Shale	**Tmm**	Monterey Formation
(dark blue line)	Dune Sand Aquifer	(grey)	Perforations Well data from Well Completion Reports
Q1	Wave-Cut Terraces		
Qs	Dune Sands		

Figure 13
Cross Section N-N'

Los Osos Valley Groundwater
Basin Fringe Areas Characterization
San Luis Obispo County
Cleath-Harris Geologists



Explanation	
Qs Dune Sands **Tmpm** Pismo Formation **Tmm** Monterey Shale Q1 Wave-Cut Terraces	Figure 14 Cross Section O-O' Los Osos Valley Groundwater Basin Fringe Areas Characterization San Luis Obispo County Cleath-Harris Geologists

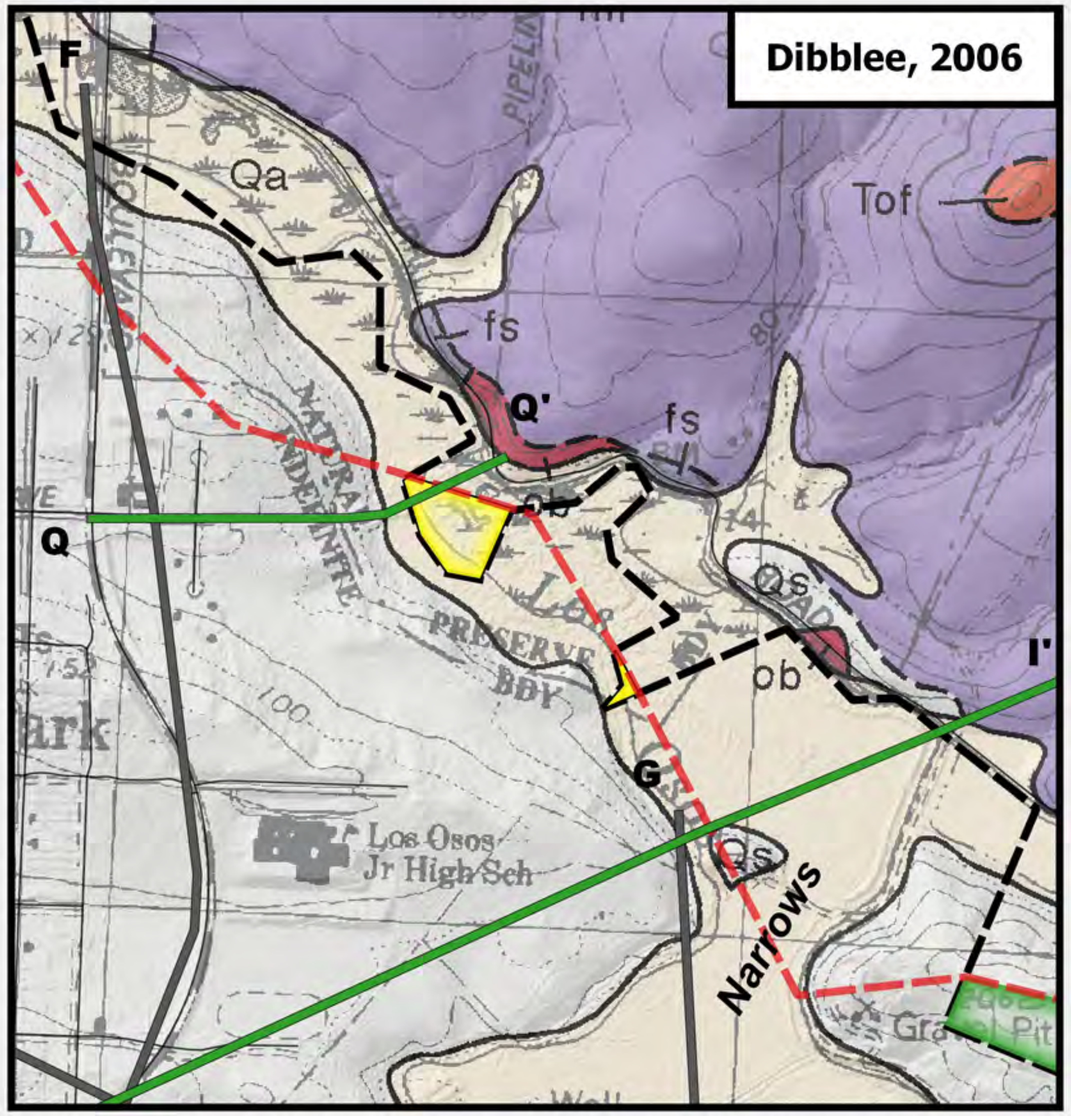


Explanation	
Sand / Gravel	
Clay / Shale	
Perforations	
Qs	Dune Sands
Tmpm	Pismo Formation
Tmm	Monterey Shale
Q1	Wave-Cut Terraces

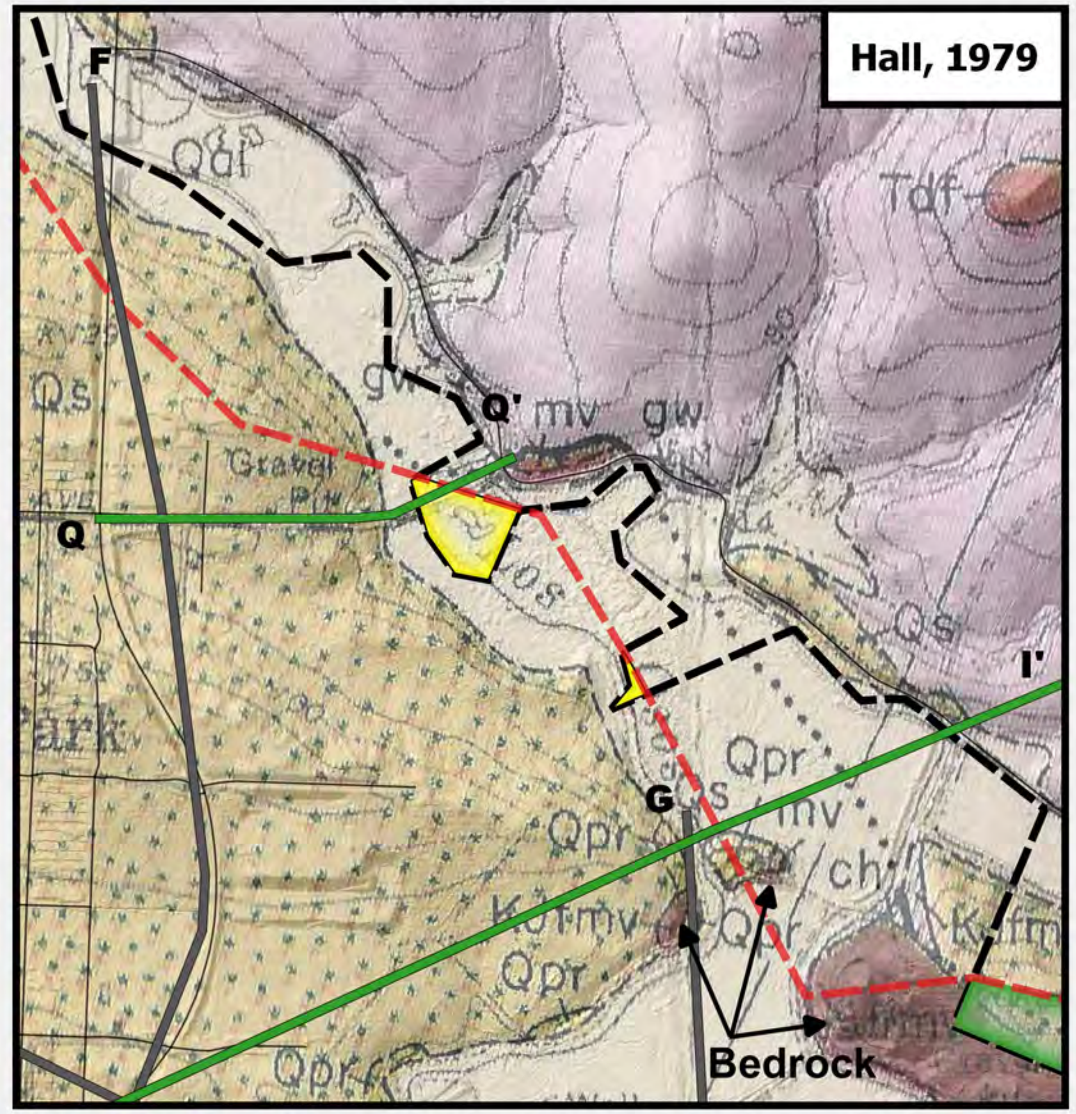
Well data from
Well Completion Reports

Figure 15
Cross Section P-P’

Los Osos Valley Groundwater
Basin Fringe Areas Characterization
San Luis Obispo County
Cleath-Harris Geologists



Basemap: Geologic Map of the Morro Bay South Quadrangle, San Luis Obispo County, California - Dibblee Geological Foundation, 2006



Basemap: C.A. Hall, Jr., et al, Geologic Map of the San Luis Obispo-San Simeon Region, California - U.S. Geological Survey, 1979.

Explanation

- Adjudicated Plan Area
- Bulletin 118 Basin Boundary- Los Osos Valley Groundwater Basin
- Eastern Valley Fringe Area
- Minor Fringe Areas
- Cross-section Line for Minor Fringe Areas
- Other Cross-section Line

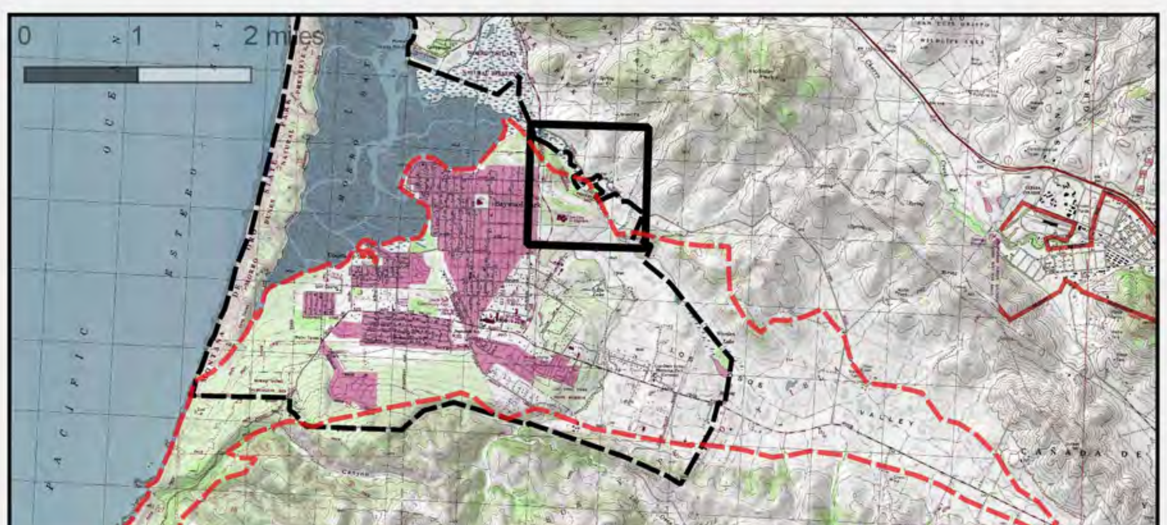
The Hall (1979) geologic map includes bedrock (as KJfmv) and the regional aquitard (as Qpr) at the narrows. These features are not shown by Dibblee (2006), but are important for characterizing minor fringe area geology.

0 1000 2000 ft

NORTH

Geology Key (Dibblee, 2006)

- Qa - Alluvium
- Qs - Dune Sand
- Tof - Dacite
- ob - Diabase
- fm - Franciscan Assemblage
- fs - Franciscan Assemblage



Geology Key (Hall, 1979)

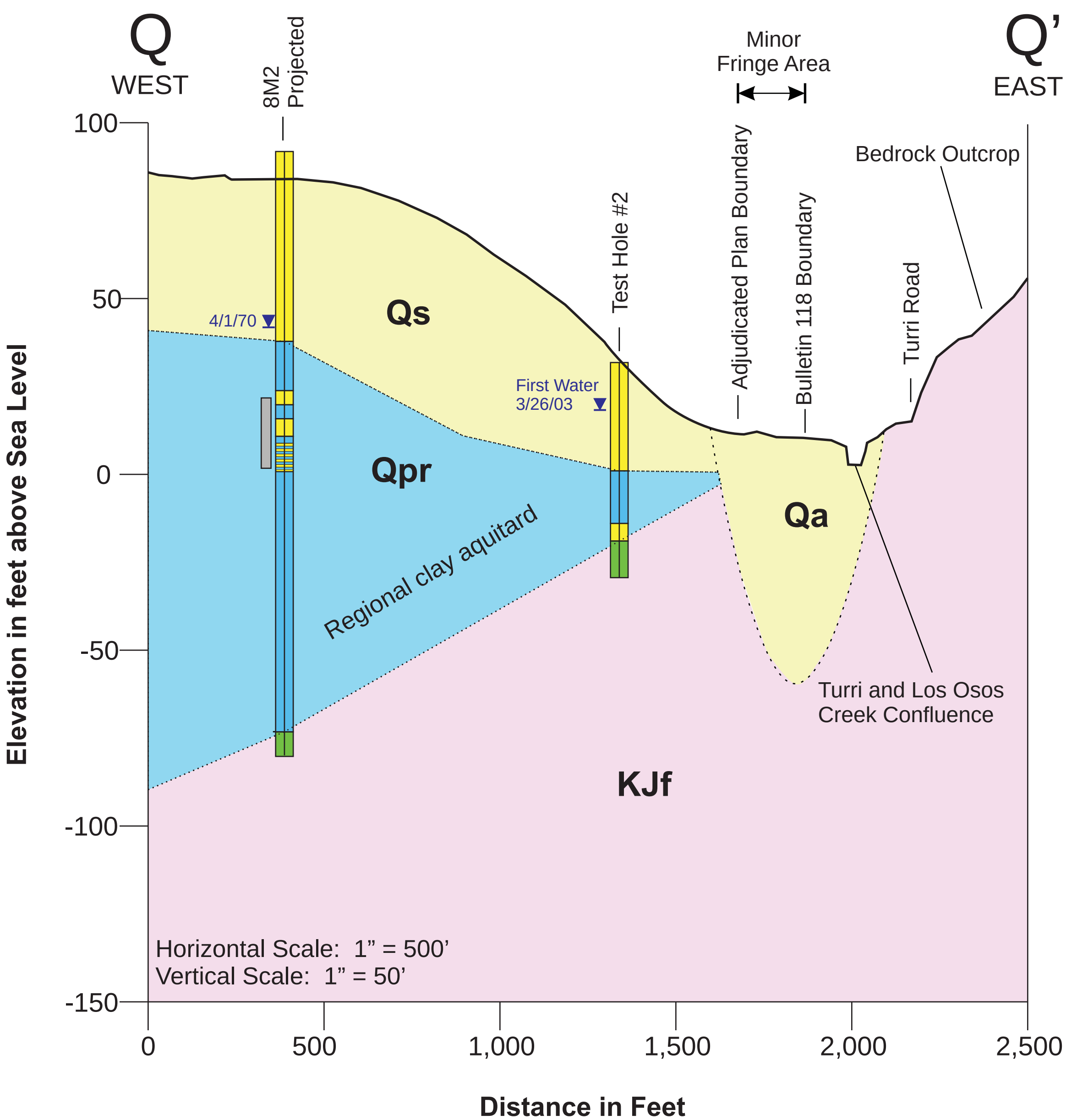
- Qal - Alluvium
- Qs - Dune Sand
- Qpr - Paso Robles Formation
- Tdf - Dacite
- KJfm - Franciscan Assemblage
- KJfmv - Franciscan Assemblage

Figure 16 - Surface Geology - Minor Fringe Areas

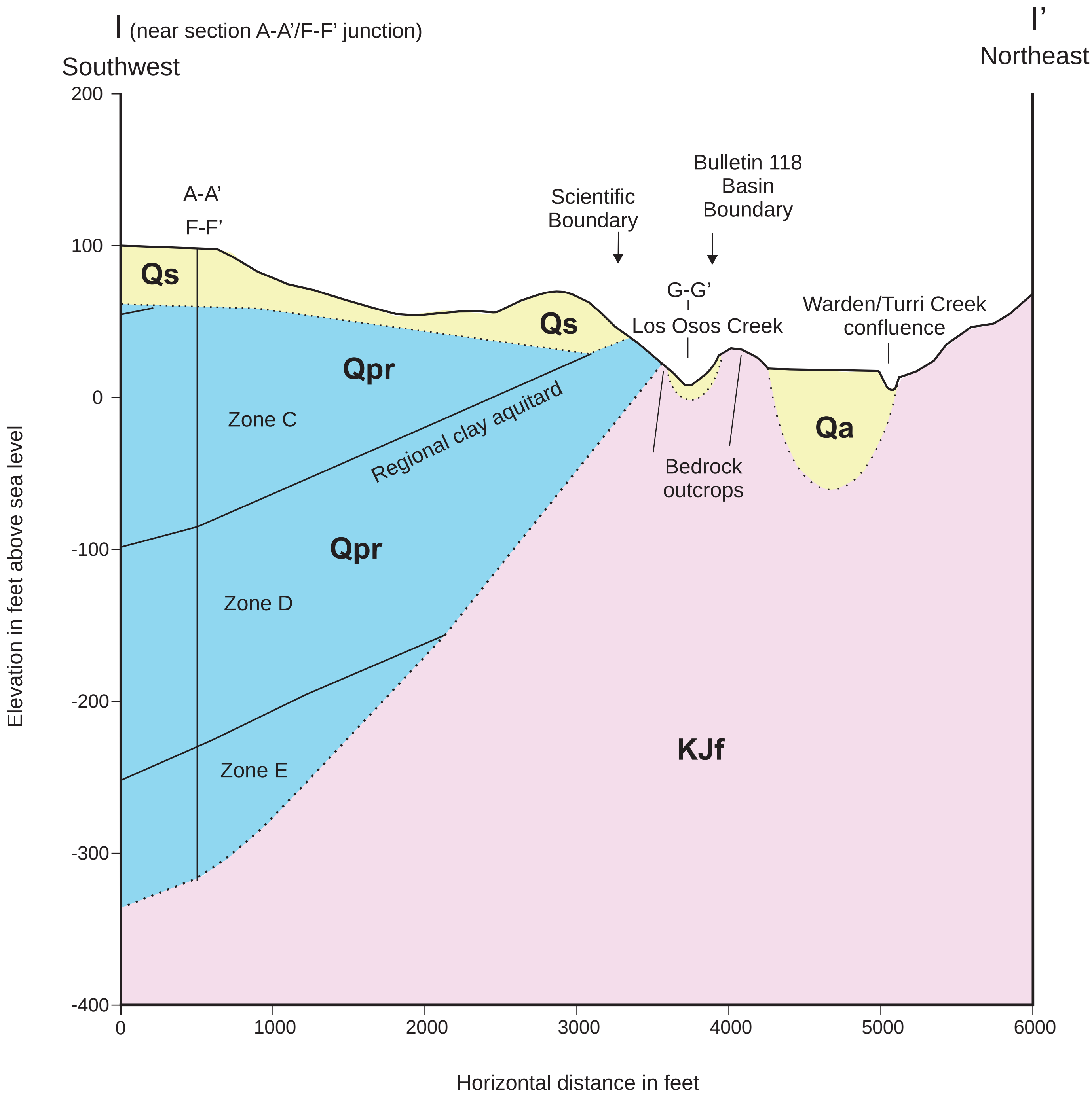
Los Osos Valley Groundwater Basin Fringe Areas Characterization

County of San Luis Obispo

Cleath-Harris Geologists



Explanation	
Sand / Gravel	Figure 17
Clay	Cross Section Q-Q'
Mixed Sediments	
Bedrock	Los Osos Valley Groundwater
Qa Quaternary Alluvium	Basin Fringe Areas Characterization
Qs Dune Sands	San Luis Obispo County
KJf Franciscan Bedrock	Cleath-Harris Geologists
Perforations	
Well data from Well Completion Reports	



Explanation	
Qa Quaternary Alluvium **Qs** Dune Sands **Qpr** Paso Robles Formation **KJf** Franciscan Bedrock Full cross-section I-I' in Figure B10, Appendix B	Figure 18 Cross Section I-I' (Portion) Los Osos Valley Groundwater Basin Fringe Areas Characterization San Luis Obispo County Cleath-Harris Geologists

beneath the larger of the two minor fringe areas while Figure 18 shows the subsurface at the bedrock narrows. The base elevation of the stream channel alluvial deposits in the minor fringe areas is assumed to be approximately 60 feet below sea level, based maintaining a relatively flat to seaward gradient on the buried channel bottom downstream of Warden Lake.

At the bedrock narrows, Los Osos Creek is interpreted from surface geology to have moved west of the historic channel and is now flowing through the narrows in a shallower, more recent alluvial channel (Figure 18). The new channel was occupied by Los Osos Creek between 1949 and 1959, based on a review of aerial imagery. The alluvial aquifer in the minor fringe areas is under estuarine influence and subject to seawater intrusion, based on surface water quality (MBNEP, 2016) and historical groundwater quality from a ranch well completed in alluvial deposits east of Turri Road (DWR, 1972).

3.3 Lateral Boundaries and Restrictions to Flow

Eastern Valley Fringe Area

The lateral boundary for the Eastern Valley fringe area encompasses the mapped extent of Quaternary sediments in the Los Osos Valley that are east of the Los Osos Adjudicated Plan Area. As presented in Bulletin 118, the lateral boundary traces formation contacts shown on the 1959 geologic map, resulting in minor discrepancies when compared to the current geologic map (Figures 2 and 4). The (external) lateral boundary separates from the north end of the Adjudicated Plan Area boundary near the narrows on Los Osos Creek, extending part way up the south-facing slopes of Park Ridge, where older dune sands overlie bedrock. The boundary returns to the valley floor and continues east along the edge of the alluvial deposits to the drainage divide with the San Luis Obispo Creek watershed. Crossing the valley near the divide, the boundary then turns west, following the alluvial contact with bedrock at the base of the Irish Hills, until reaching the south end of the Adjudicated Plan Area boundary (Figure 4).

The lateral boundaries on the north and south are bedrock contacts, while the boundaries on the east and west are shared by the San Luis Obispo Valley Groundwater Basin and the Adjudicated Plan Area boundary, respectively.

The topographic saddle that creates the drainage divide separating the Los Osos Creek/Warden Creek watershed and the San Luis Obispo Creek watershed also coincides with a groundwater divide, based on available groundwater levels and the occurrence of a bedrock high in the same general location (Figure 6 and Figure 9).

Subsurface Flow between Eastern Valley Fringe Area and Adjudicated Plan Area

Groundwater flow between the Eastern Valley fringe area and the Adjudicated Plan Area is restricted by a structural bedrock high resulting from the east-west tilting of the base of permeable sediments within the Adjudicated Plan Area. Bedrock approaches ground surface along the eastern edge of the Cemetery Mesa, which is a topographic bench between the Los Osos Creek Valley and the Warden Lake area (Figure 1, Figure 5, and Figures B2, B3, and B4 in Appendix B). The bedrock high was recognized in the late 1980's by the Morro Group (1987), U.S. Geological Survey (Yates, 1988) and the DWR (1989), which led directly to the exclusion of the Eastern Valley from the Adjudicated Plan Area.

Less than 5 acre-feet per year (AFY) of subsurface flow, based on the hydraulic gradient, moves from the Adjudicated Plan Area into the Eastern Valley fringe area along the edge of Cemetery Mesa. The wetland at Warden Lake acts as a natural sink, evapotranspiring shallow water.

Montaña de Oro Fringe Area

The lateral boundary for the Montaña de Oro fringe area encompasses the mapped extent of Quaternary sediments along the coast, south of the Adjudicated Plan Area (Figure 11). Separating from the east end of the Adjudicated Plan Area on a ridge overlooking Hazard Canyon, the fringe area boundary extends south to Islay Creek along the contact between bedrock and marine terrace deposits. At the bluff overlooking Islay Creek, the boundary turns west toward the coast, and follows the coastline north to rejoin the west end of the Adjudicated Plan Area boundary.

Marine Terraces as Lateral Boundaries

Mostly obscured beneath dune sands, a series of wave-cut platforms on bedrock rise from the shoreline to the east as uplifted marine terraces. There are several terrace levels mapped in the Montaña de Oro fringe area (Lettis and Hall, 1994). The first terrace (Q1) above the modern wave-cut platform is correlated with marine oxygen isotope Substage 5a, dated at 80,000 years ago. The altitude of the Q1 terrace base is approximately 30 feet above sea level. The next terrace to the east (Q2) corresponds to Substage 5e, dated at 106,000 years ago, with an approximate base altitude of 100 feet above sea level. Terrace Q3 is dated at 214,000 years ago with a base altitude of 150 feet above sea level, and Q4 is dated to 330,000 year ago with a base altitude of 280 feet above sea level. Marine terrace correlations are shown in Figures C-1 and C-2 (Appendix C).

The geologic cross-sections in Figures 12 through 15 show the marine terraces between the coast and the Montaña de Oro fringe area boundary. The available subsurface borehole and water level data information are limited due to the area being part of Montaña de Oro State

Park. The available data, however, support a hydrogeologic conceptual model of marine terraces overlain by mostly unsaturated dune sands.

Subsurface Flow between Montaña de Oro Fringe Area and Adjudicated Plan Area

Subsurface lithologic data indicates a major fault offset is present north of the boundary between the Montaña de Oro fringe area and the Adjudicated Plan Area that acts as a significant subsurface barrier to groundwater flow. The offset is caused by movement along the Los Osos fault (DWR, 1973; Brown and Caldwell, 1974; Lettis and Hall, 1994). Uplift of the Irish Hills and tectonic subsidence of the Los Osos Valley juxtaposes the principal aquifers within the Adjudicated Plan Area north of the Los Oos fault against soft shale and siltstone bedrock in the Montaña de Oro fringe area. The fault boundary not only creates a subsurface restriction to flow, but also truncates all Quaternary basin sediments north of the fault except the dune sands and other marine terrace deposits, which are uplifted and mostly unsaturated in the fringe area.

Some prior investigators (e.g. Yates and Weise, 1988 and Lettis and Hall, 1994) have interpreted the DWR (1972) deep borehole at MBO-2 (Figure 11 and Figure 12) as being on the north side of the Los Osos fault, and drilled into basin sediments. DWR (1973), Brown & Caldwell (1974; 1983) and Cleath & Associates (2003) interpreted the borehole as being on the south side of the fault and drilled in Pismo Formation (Miguelito member) sediments below the shallow dune sand aquifer. The latter interpretation of MBO-2 being south of the Los Osos fault (and associated flow barrier) is considered correct based on the available lithologic, geophysical, and water quality data, as discussed below.

DWR Borehole MBO-2 Lithology

The lithologic log for MBO-2 extends to a depth of 631 feet. Below the shallow dune sands (70 feet thick), the log indicates silt, clay, and/or shale, with less than 20 feet of sand and gravel. Other adjacent deep well logs that are actually in basin sediments show hundreds of feet of permeable sands and gravels (Figure 12). Furthermore, the silts and clays logged at MBO-2 contained an abundance of diatoms and radiolarians, which suggest Tertiary-age sediments, consistent with the diatomaceous shale of the Pismo Formation (DWR, 1973). According to the 1973 DWR report, occurrence of the type of sediments logged at MBO-2 were unknown elsewhere within the basin study area. A monitoring well was installed at MBO-2 (23C1) to depth of 142 feet, but there was insufficient water to develop the well or obtain a water level; material below the dune sands at MBO-2 is non-water bearing (DWR, 1972).

Geophysical data

Geophysical data is available as an electrical resistivity line and a seismic refraction line (Gasch & Associates, 2000). These geophysical lines were part of the Worldcom's Morro Bay fiber optic cable landing project, and covered roughly 6,000 linear feet along the beach opposite the location of MBO-2. The geophysical data were interpreted to indicate shallow bedrock (approximately 30 feet or less depth) throughout the profiles (Figure C-4, Appendix C). Potential faults with normal-motion were mapped both north and south of MBO-2, which is indicative of the Edna fault zone. The Los Osos fault is a reverse-motion fault and lies north of the Edna fault zone (PG&E, 2014). Shallow bedrock and normal-motion faulting indicated by geophysics supports the Los Osos fault being located north of both MBO-2 and the geophysical lines.

Water levels

Inland of the coast, the location of the Los Osos fault is constrained by information from a water well. The log for well 23H, located along Pecho Valley Road near the fringe area boundary, reported a water level in July 1971 of 185 feet depth (approximately 115 feet above sea level). The well was completed to 220 feet depth, and is interpreted to tap shale bedrock beginning at a depth of 200 feet (100 feet above sea level) below basin sands and terrace deposits. By comparison, basin water levels along Pecho Valley Road north of the Los Osos fault were at approximate elevations between 5 and 20 feet above sea level in 1973 (DWR, 1973; Figure C-5, Appendix C). Well 23H was equipped and operational in 2017, therefore water levels have remained 100+ feet above sea level at that location, evidence of a significant barrier to flow north of the well.

Water Quality

Seawater intrusion at the coast was interpreted from geophysical logs along a cross-section of deep boreholes on the Morro Bay sandspit and MBO-2 (DWR, 1979). The cross-section shows brackish water zones (separated into <9,000 mg/L and >9,000 mg/L chloride) below sea level in groundwater basin aquifers beneath the sandspit (Figure C-6, Appendix C). At MBO-2, however, freshwater is present near the coast to a depth of 400 feet below sea level. In other words, there is considerable seawater intrusion in the Adjudicated Plan Area aquifers north of the Los Osos fault, but not south of the fault, which is evidence of a potential flow barrier across the fault (between MBO-2 and the sandspit wells). The inferred water level in November 1970 at MBO-2, based on the pressure required to maintain freshwater at depth per the Ghyben-Herzberg relation, would be 10 feet above sea level. In comparison, pressure heads in the permeable brackish water aquifers at sandspit wells in 1977 were between 0.5 and 3 feet above sea level (DWR, 1979).

Offshore Bedrock

Shale bedrock is mapped on the ocean floor west of the Morro Bay sandspit (Racal Pelagos, 1999; PG&E 2014). The occurrence of large areas of Pliocene shale bedrock on the ocean floor, which is the same unit comprising the marine terraces south of the Los Osos fault, indicates that the Los Osos fault zone, and associated lateral boundary to flow, turns to the northwest from its east-west alignment in the Irish Hills. The point of departure from the east-west fault alignment was projected by Cleath & Associates (2005) by connecting the offshore and onshore outcrops (Figure C-7, Appendix C).

3.4 Definable Bottom of the Basin

Eastern Valley Fringe Area

The bottom of the groundwater basin in the Eastern Valley fringe area consists of Mesozoic-age Franciscan Assemblage bedrock, including greywacke sandstones, shale, mélange, and metavolcanics. Elevation contours on the base of permeable sediments is shown in Figure 9 for the Eastern Valley fringe area.

Montaña de Oro Fringe Area

In the Montaña de Oro fringe area, the basin bottom consists of Tertiary-age Pismo Formation (Hall et al., 1979) or Monterey Formation (Dibblee, 2004) bedrock. Bedrock underlies dune sands and terrace deposits, and are visible in outcrop within and surrounding the fringe area boundaries.

Minor Fringe Areas

The minor fringe areas near the confluence of Los Osos Creek and Morro Bay estuary include portions of an alluvial channel incised directly into Franciscan Assemblage bedrock, which is the definable bottom of the basin. Dune sands immediately adjacent to the alluvial channel overlie the regional aquitard and bedrock.

3.5 Structural Features Impacting Groundwater Flow

Eastern Valley Fringe Area

Groundwater flow within the Eastern Valley fringe area is controlled primarily by alluvial aquifer transmissivity. The aquifer transmissivities are greatest where the alluvium is deepest, which is generally along the central axis of the alluvial valley north of, and sub-parallel to, Los Osos Valley Road (Figures 4, 6, 7, and 8). Shallow bedrock, along with more clay in the upper portion of the alluvial deposits restricts groundwater flow outside of the main alluvial channel. Aquifer transmissivity and hydraulic conductivity decrease across the boundary with the Adjudicate Plan Area (Zone E pumping test, Table 1). The bedrock high along the east edge of the Cemetery Mesa also creates a structural feature restricting groundwater flow (see geologic cross-sections in Appendix B, Figures B1, B2, B3, and B4).

Montaña de Oro Fringe Area

Groundwater flow within the Montaña de Oro fringe area is controlled by dune sand aquifer transmissivity, which depends on saturated aquifer thickness. The dune sands are saturated along the shoreline where overlying the modern wave-cut platform, which is limited to the stretch between the Adjudicated Plan Area boundary and the beginning of the coastal reef approximately 2,500 feet north of Hazard Canyon (Figure 11 and geologic cross-sections in Figures 13 and 14). As previously mentioned, dune sands and other sediments overlying marine terraces are interpreted to be mostly dry, with locally perched water lenses on top of bedrock. Where saturated along the shoreline, the freshwater head in the dune/beach sand aquifer would depend on seasonal recharge and outflow from bedrock. The first marine terrace extends to the coastal bluff south of Hazard Canyon, eliminating the dune sand aquifer (Figure 15).

Minor Fringe Areas

Groundwater flow within the alluvial channel underlying the minor fringe areas is constrained by bedrock and the regional aquitard, and likely subject to seawater intrusion due to the low elevations of the channel profile and tidal influence (Figure 16 and geologic cross-sections in Figures 17 and 18). Morro Bay National Estuary Program (MBNEP) surface water monitoring site SBY is located at the larger of the two minor fringe areas and is treated as an estuarine/marine monitoring site (MBNEP, 2016).

3.6 Primary Uses of Aquifers

Eastern Valley Fringe Area

An estimated 98 percent of groundwater production from the alluvial aquifer (and underlying bedrock) in the Eastern Valley fringe area is used for agricultural irrigation on fields north of Los Osos Valley Road, with the remainder used for domestic purposes. Groundwater production from bedrock wells south of Los Osos Valley Road is also used primarily for agriculture, with limited domestic use.

Montaña de Oro and Minor Fringe Areas

There is no documented use of groundwater from the dune sand aquifer in the Montaña de Oro fringe area. The only two known wells in the fringe area are bedrock wells. There are no wells within the minor fringe areas.

3.7 Water Quality of Principal Aquifers

Eastern Valley Fringe Area

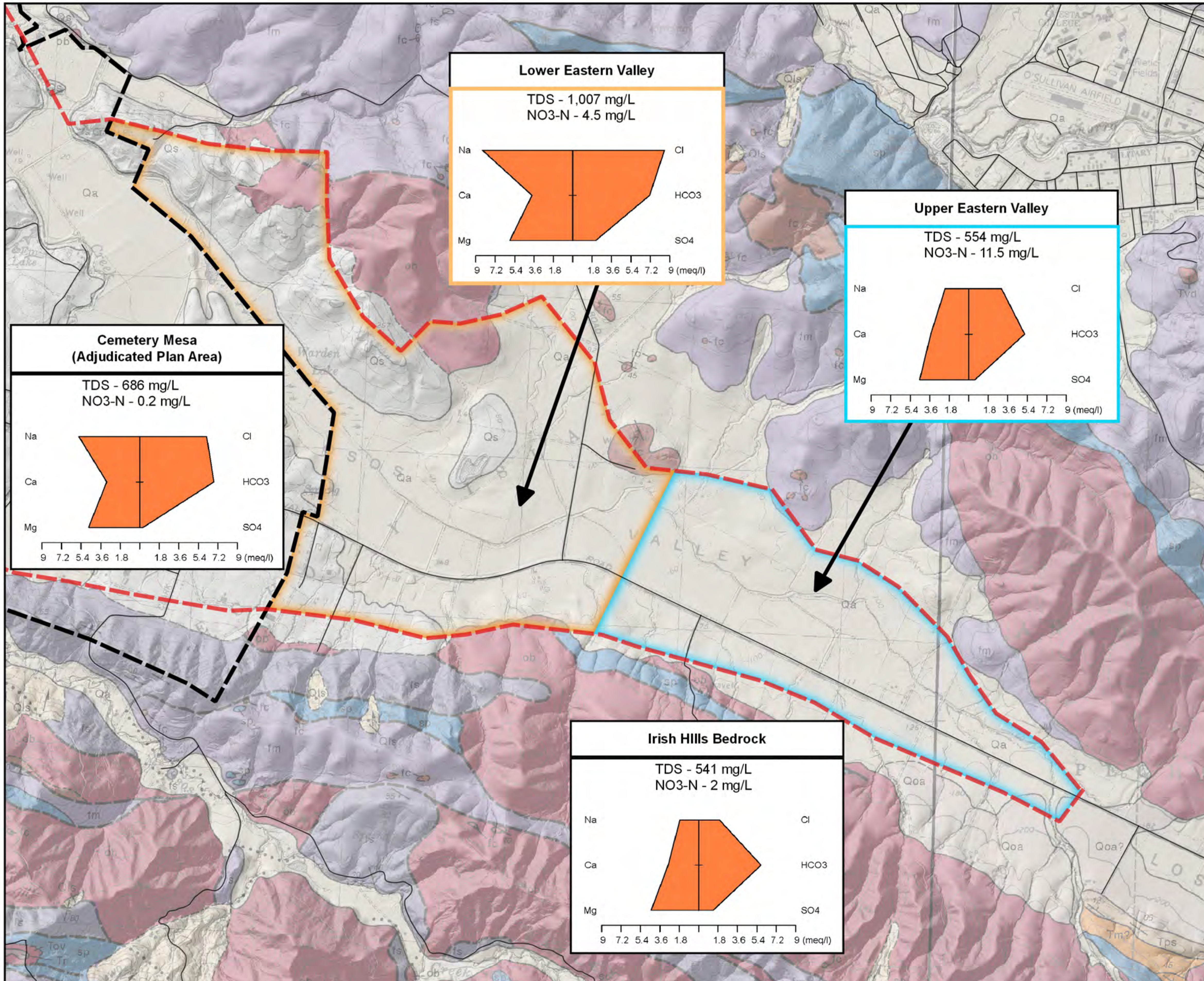
Water samples from 18 wells were analyzed for quality during the Summer 2017 field investigation. Eight wells were sampled within the Eastern Valley fringe area, four wells were sampled in the adjacent Adjudicated Plan Area, and six wells were sampled that tap bedrock sources south of the fringe area. Data for an additional 16 wells were available between 2013 and 2016 from the Irrigated Lands Regulatory Program database. Four of these wells were within the fringe area, three wells were in the Cemetery Mesa portion of the Adjudicated Plan Area, and nine wells were from bedrock sources adjacent to the fringe area. Table 2 summarizes the available water quality data collected between 2013 and 2017. Figure 19 shows the upper and lower Eastern Valley areas used to aggregate water quality data, along with stiff diagrams for each area.

Table 2
Groundwater Quality 2013-2017
Eastern Valley Fringe Area and Vicinity

Total No. Samples	Area - Aquifer	TDS	Na	K	Mg	Ca	Cl	SO_4	HCO_3	NO_3-N
		Average milligrams per liter (mg/L)								
12	Eastern Valley Fringe Area Average	781	121	1	63	73	204	65	375	7.9
6	Lower Eastern Valley Alluvial Aquifer	**1,007**	193	3	71	76	**302**	102	436	4.5
6	Upper Eastern Valley Alluvial Aquifer	554	50	0	55	70	107	28	314	**11.5**
7	Cemetery Mesa Lower Aquifer Zone E	686	125	4	50	50	161	41	385	0.2
15	Base of Irish Hills Bedrock Aquifer	541	56	1	58	54	94	46	361	2

Areas shown in Figure 4
TDS - total dissolved solids; Na - sodium; K - potassium; Mg - magnesium; Ca - calcium; Cl - chloride
SO4 - sulfate; HCO3 - bicarbonate; NO_3-N - nitrate as nitrogen; mg/L - milligrams per liter; MCL - Maximum Contaminant Level
Bolded values exceed the following State drinking water standards: TDS (1,000 mg/l upper limit, secondary standard); Chloride (250 mg/L recommended limit, secondary standard), and NO_3-N (10 mg/L, primary standard).

The major solutes of general minerals, along with nitrate, comprise approximately 95 percent of the total dissolved solids in water samples from the Eastern Valley fringe area, and are useful for comparing water quality from different source aquifers. Average groundwater quality in the



Explanation

Adjudicated Plan Area

Bulletin 118 Basin Boundary-
Los Osos Valley Groundwater Basin

Eastern Vallay Fringe Subareas

Lower Eastern Valley

Upper Eastern Valley

Water quality data was averaged for 34 samples collected between 2013 and 2017:

Upper Eastern Valley:	6 samples
Lower Eastern Valley:	6 samples
Cemetery Mesa:	7 samples
Irish Hills Bedrock:	15 samples

Basemap: Geologic Map of the Morro Bay South Quadrangle, San Luis Obispo County, California - Dibblee Geological Foundation, 2006

0 2000 4000 ft
NORTH

Figure 19 - Water Quality - Eastern Valley Fringe Area

Los Osos Valley Groundwater Basin Fringe Areas Characterization

County of San Luis Obispo

Cleath-Harris Geologists

upper Eastern Valley alluvial aquifer is similar to water quality in the bedrock aquifer, with the exception of nitrates, which are much greater in the alluvial aquifer and exceed the State drinking water standard of 10 milligrams per liter (mg/L) nitrate as nitrogen. The general mineral character of groundwater in both areas is magnesium bicarbonate, with total dissolved solids (TDS) close to 550 mg/L.

Surface water quality in Warden Creek, as measured at the Turri Road bridge, has a history of elevated nitrate concentrations. Surface water quality monitoring by the MBNEP on Warden Creek is focused on the nutrient suite for Total Maximum Daily Load monitoring. Total nitrogen concentrations for 57 samples collected at the Turri Road bridge averaged 11.4 mg/L between 2002 and 2016, comparable to the 11.5 mg/L average nitrate as nitrogen concentration in upper Eastern Valley alluvial aquifer samples collected between 2013 and 2017 (MBNEP data in electronic database; see Appendix A).

Groundwater quality in the lower Eastern Valley area and the adjacent Cemetery Mesa shows a pronounced sodium chloride influence. The mineral character is sodium-magnesium chloride-bicarbonate in the lower Eastern Valley alluvial aquifer, with a similar character in Lower Aquifer Zone E beneath the adjacent Cemetery Mesa. TDS and nitrate concentrations are greater, however, in the lower Eastern Valley fringe area compared to the Cemetery Mesa. TDS averaged 1,007 mg/L (slightly above the drinking water standard of 1,000 mg/l), with 4.2 mg/L nitrate as nitrogen in the lower Eastern Valley area, compared to 686 mg/L TDS and 0.2 mg/L nitrate as nitrogen in groundwater from wells on the Cemetery Mesa (Table 2).

Very low average nitrate concentrations and lower TDS in groundwater beneath the Cemetery Mesa, compared to the adjacent Eastern Valley fringe area, support a flow restriction between the two areas. Groundwater is interpreted to move from the Cemetery Mesa into the lower Eastern Valley fringe area (Figure 10), but not in significant quantities due to low hydraulic conductivity (Table 1) and limited saturated thickness. Salt and nutrient loading to groundwater includes natural, agricultural, residential, and animal sources.

Montaña de Oro Fringe Area

Groundwater quality in the Montaña de Oro fringe area is available beginning in 1994 for two wells serving the Montana de Oro water system, which are both bedrock source wells. The most recent general mineral analysis is from September 2013. Water from the primary supply well has a sodium-chloride bicarbonate character, with total dissolved solids measured at 640 milligrams per liter. The constituents tested, including general physical (pH, color, odor, turbidity), general mineral, and selected metals met drinking water standards, except for manganese. The Montaña de Oro water system has an iron/manganese filtration system in operation. Nitrate concentrations are generally not detected. Table 3 presents water quality for the bedrock source aquifer serving the Montaña de Oro fringe area. No water quality is available for the dune sand aquifer along the coast in the Montaña de Oro fringe area.

Table 3
Groundwater Quality
Montaña de Oro Bedrock Aquifer

Sample date	Area - Aquifer	TDS	Na	K	Mg	Ca	Cl	SO_4	HCO_3	NO_3-N
		Average milligrams per liter (mg/L)								
9/17/2013	Monterey Shale Aquifer	640	110	2.5	40	72	180	13	430	ND

TDS - total dissolved solids; Na - sodium; K - potassium; Mg - magnesium; Ca - calcium;
Cl -chloride; SO4 - sulfate; HCO3 - bicarbonate; NO3-N - nitrate as nitrogen

Minor Fringe Areas

There are no wells within the minor fringe areas, although there was historically one ranch well completed in alluvial sediments (8J1) east of Turri Road, approximately 1,500 feet east of the minor fringe areas. Water quality measured at Well 8J1 included chloride measurements of 790-1,090 milligrams per liter (mg/L), which was attributed to seawater intrusion (DWR, 1972).

4.0 WATER BALANCE

A water balance is an accounting of the hydrologic budget items that add water (inflow) or remove water (outflow) from a groundwater basin or study area, which is then reconciled to represent system equilibrium based on the following relationship:

Inflow - Outflow = Change in Storage

When there is no net change to groundwater in storage over a representative hydrologic base period (a series of years with cumulative average climate), the elements of inflow and outflow are in balance. Due to the dynamic nature of groundwater systems, an increase in outflow (such as pumping) may cause an increase in inflow (such as stream seepage). Therefore, the groundwater system may be in balance over a wide range of values for inflow and outflow. The tipping point at which additional outflow cannot capture an equivalent amount of inflow or would cause an undesirable result is considered the safe yield of the groundwater system.

A preliminary water balance was only prepared for the alluvial aquifer in the Eastern Valley fringe area. There is insufficient data to develop a meaningful water balance for the dune sand aquifer in Montaña de Oro fringe area. Neither the dune sand aquifer in Montaña de Oro nor the alluvial aquifer beneath the minor fringe areas are considered suitable for development as a groundwater resource due to the high potential for seawater intrusion and lack of accessibility.

Preliminary estimates for portions of the water balance have been developed for the Eastern Valley fringe area based on a soil-moisture budget, irrigation efficiencies, and boundary flow estimates using Darcy's Law. These water balance estimates help identify data gaps and provide an indication of the current groundwater conditions in the fringe area.

This preliminary water balance does not include surface water entering or leaving the basin (except base flow). Current budget item estimates could be refined with the assistance of streamflow data and a numerical watershed/groundwater flow model.

4.1 Inflow

Elements of Inflow to the fringe areas include:

- Percolation of precipitation
- Return flow from applied irrigation and domestic water use
- Stream seepage
- Subsurface inflow from adjacent areas

Percolation of Precipitation

The Eastern Valley fringe area is mostly agricultural land (Figure 20). Deep percolation of precipitation refers to the portion of rainfall that percolates through soils and reaches groundwater. The majority of rainfall evaporates from the soils, is consumed by plants (evapotranspiration), or flows out of the area as surface water runoff. Precipitation deep percolates to groundwater once the soil-moisture deficit is satisfied and the water holding capacity of the vegetative root zones are filled.

A monthly soil-moisture budget between October 2005 and September 2017 was used to estimate percolation of precipitation. The areas for various types of land cover were extracted from GIS coverage in the fringe area (Figure 20). Table 4 below summarizes land cover in the Eastern Valley fringe area.

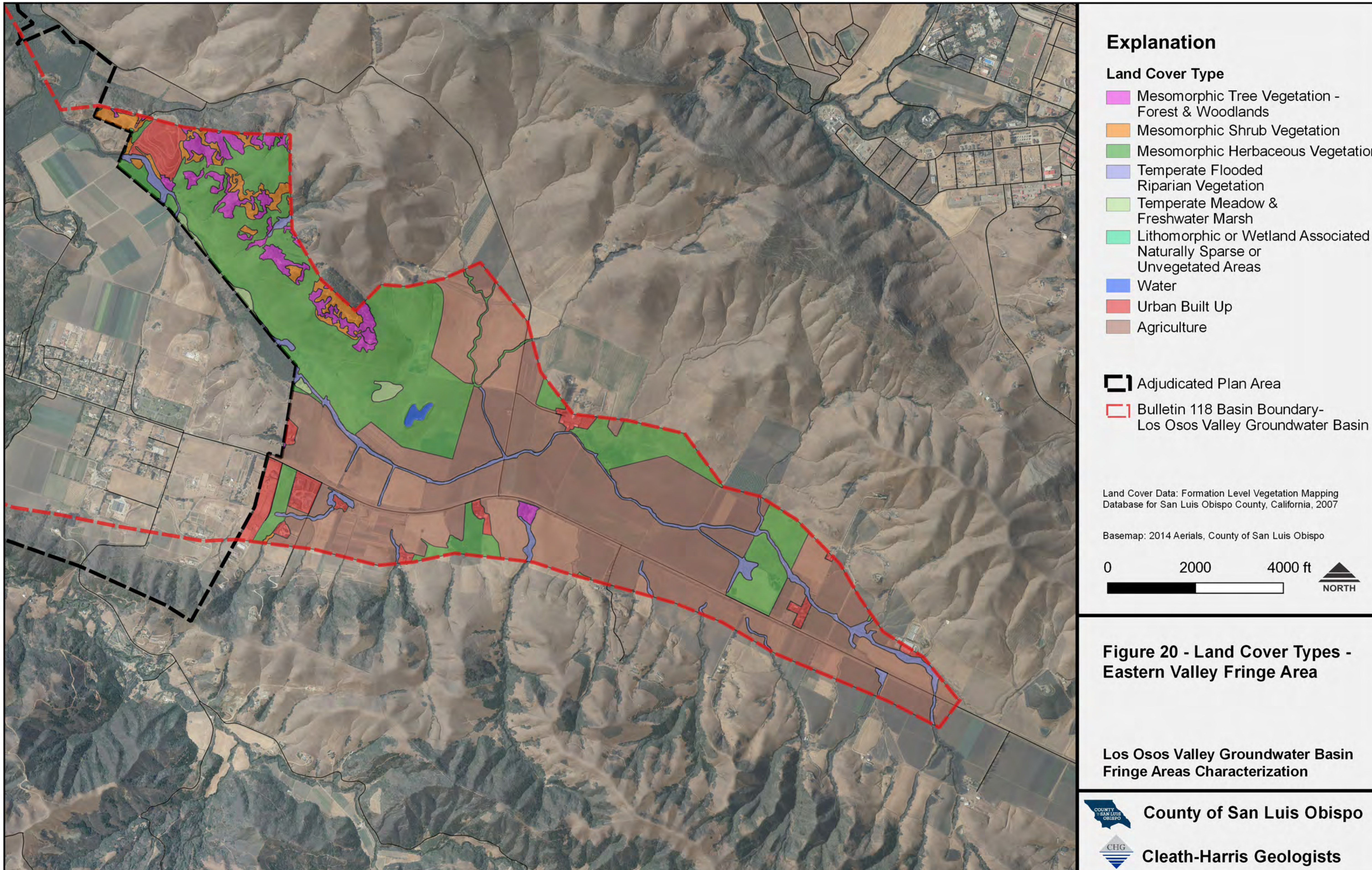

Explanation
Land Cover Type
Mesomorphic Tree Vegetation - Forest & Woodlands
Mesomorphic Shrub Vegetation
Mesomorphic Herbaceous Vegetation
Temperate Flooded Riparian Vegetation
Temperate Meadow & Freshwater Marsh
Lithomorphic or Wetland Associated Naturally Sparse or Unvegetated Areas
Water
Urban Built Up
Agriculture
Adjudicated Plan Area
Bulletin 118 Basin Boundary- Los Osos Valley Groundwater Basin
Land Cover Data: Formation Level Vegetation Mapping Database for San Luis Obispo County, California, 2007
Basemap: 2014 Aerials, County of San Luis Obispo
0
2000
4000 ft
NORTH
Figure 20 - Land Cover Types - Eastern Valley Fringe Area
Los Osos Valley Groundwater Basin Fringe Areas Characterization
County of San Luis Obispo
Cleath-Harris Geologists

Table 4
Land Cover Types
Eastern Valley Fringe Area[1]

Parameters	Land Cover in Fringe Area - 2007					
	Urban Built Up	Trees	Herbaceous	Ag	Riparian	Wetland
Area (acres)	75.2	64.4	580.5	955.7	91.2	45.6
Percent of Area	4%	4%	33%	54%	5%	3%
Land Cover types used in Soil Moisture Budget						
Impervious	30%	--	--	--	--	--
Trees	--	100%	--	--	--	--
Brush	20%	--	60%	--	--	--
Bare/Fallow	10%	--	20%	64%	--	--
Ornamentals	20%	--	--	--	--	--
Turf/Pasture	10%	--	--	3%	--	--
Crop	--	--	--	33%	--	--
Native Grasses/Weeds	--	--	20%	--	--	--
Riparian	--	--	--	--	100%	--
Wetland Marsh	--	--	--	--	--	100%

[1]NOTE: Area for soil moisture budget calculation includes approximately 52 acres of riparian and wetland land cover at Warden Lake within Adjudicated Plan Area.

Average rainfall for the Eastern Valley fringe area over the last 12 years was 15.8 inches, from a low of 6.8 inches in the 2013 rainfall (July 2012-June 2013) year to a high of 31.8 inches in the 2011 rainfall year (July 2010 to June 2011). Monthly precipitation for the Los Osos landfill (County rain gage 740; Figure 1) and evapotranspiration records for CIMIS Station 160 (San Luis Obispo West) were used to populate the soil-moisture budget, results of which are in Appendix D.

The soil-moisture budget was used to estimate percolation of precipitation, phreatophyte uptake in wetland marsh areas, and as an alternative approach to estimating irrigation well production. Soil-moisture budget methodology involves precipitation, the water holding capacity of the soils, and the rooting depths and evaportanspiration rates for various land cover types. Table 5 below presents the percolation of precipitation estimates.

Table 5
Percolation of Precipitation
Eastern Valley Fringe Area

Land Cover Type	Percolation of precipitation (AFY)
Urban Built Up	15
Trees	2
Herbaceous	126
Agriculture	244
Riparian	4
TOTAL	391

Total precipitation volume over the Eastern Valley fringe area averaged 2,312 AFY. A deep percolation volume of 391 AFY, based on the soil-moisture budget methodology, results in approximately 17 percent net percolation of precipitation.

Return Flow

Return flow from applied irrigation water depends primarily on the irrigation efficiency. Irrigation efficiencies for systems with excellent irrigation design and average management ranges from 75 percent for sprinkler irrigation to 85 percent for micro-irrigation systems. Leaching fraction requirements in coastal areas are assumed to be met by rainfall (Carrollo, 2012).

The losses attributable to applied water inefficiency can increase with poor design or management due to uneven or excessive water distribution. Irrigation water losses include crop canopy interception and evaporation, air and soil evaporation not accounted for in crop evapotranspiration estimates, surface runoff, and deep percolation. Deep percolation and surface water runoff are typically the greatest component of irrigation water loss. The irrigation return flows are based on a nominal 10 percent of applied irrigation for agriculture, representing 50 percent of the total losses based on 80 percent average efficiency. The applied water includes irrigation on all lands overlying the fringe area, including water pumped from bedrock wells to irrigate fields on the south side of Los Osos Valley Road. Total applied irrigation over Eastern Valley fringe area is estimated at 840 AFY (detailed below in well production section under outflow). The resulting return flow from irrigation is estimated at 84 AFY.

There are also approximately 26 residences overlying the Eastern Valley fringe area, based on a review of aerial images from 2017. Return flow to groundwater from septic systems has been estimated based on the average 0.33 AFY indoor use for residences on large parcels (1+ acre) in the Adjudicated Plan Area (CHG, 2009). The resulting return flow from indoor use at 26 the Adjudicated Plan Area (CHG, 2009). The resulting return flow from indoor use at 26 residences overlying the Eastern Valley fringe area would be 8.6 AFY. Return flow from residential irrigation in the fringe has been estimated based on 10 percent deep percolation of the average outdoor water use for large parcels in the Adjudicated Plan Area. A field survey and metered connection analysis of large parcels in 2009 concluded that an average 0.44 AFY was used outdoors on parcels with medium-use landscaping (CHG, 2009). The resulting return flow for outdoor use at approximately 26 residences in the Eastern Valley fringe area would be 1.1 AFY. The combined applied agricultural irrigation and residential return flow is estimated at 93 AFY.

<u>Stream Seepage</u>

Inflow to the alluvial aquifer from stream seepage has been estimated based on the percolation capacity of the primary drainage channels and the number of days when storm water runoff is present. Portions of Warden Creek are wet year round, but active inflow is only assumed to occur when channels have surface water above the local groundwater elevations, which occurs during storm runoff periods.

The length of Warden Creek in the Eastern Valley upstream of Warden Lake is approximately 17,000 feet. An addition 6,000 feet of tributary drainage channels would also provide stream seepage capacity. A nominal 10 feet channel width and 0.2 hydraulic gradient (mound) is assumed during runoff periods. Warden Creek is incised into the shallow clay layer and includes stream channel deposits. The hydraulic conductivity for stream bed conductance is assumed to be 3 feet per day, which is between the hydraulic conductivity of the alluvial aquifer and the middle of the range for fine grained soils (Freeze and Cherry, 1979).

Storm water runoff depends on land cover, slope, soil moisture, and rainfall intensity. A watershed model (U.S. Army Corps of Engineers HEC-1 model) was developed that included the Eastern Valley fringe area by prior investigators as part of regional studies on storm water runoff events in the Morro Bay watershed (Tetra Tech, 1998). The 1998 model allowed simulation of runoff hydrographs in response to measured storm events. The model report contains an example of model output, with the full model archived in digital form.

For the purposes of a preliminary water balance, the average number of days with runoff (flow) from storm events has been estimated by reviewing precipitation records for Los Osos Creek (County stream gage 751; Figure 1), which is the closest stream gage. Days of recorded streamflow ranged from no flow during drought years to over five months of flow in wet years. The average flow duration for 11 years of data was approximately two months per year (67 days). The resulting average stream seepage in the eastern valley fringe area is estimated to be 212 AFY.

Subsurface inflow from Bedrock

Subsurface inflow to the Eastern Valley fringe area is primarily from fractured bedrock along the southern fringe area boundary. An estimate of this inflow has been developed based on Darcy's Law using the estimated cross-sectional area, hydraulic gradient, and permeability along the fringe area boundary.

The length of the fringe area south boundary is approximately 16,000 feet, extending from the Cemetery Mesa on the west to the San Luis Obispo Valley Groundwater Basin boundary on the east. Alluvial aquifer thickness (horizontal cross-sectional area below the shallow clay layer) is up to 50 feet along the deepest portions of the buried alluvial channel. The steeper hydraulic gradients along the fringe area south boundary, however, are interpreted to result from pressure building up behind a zone of lower permeability between the fractured metavolcanics and the alluvial aquifer. A hydraulic conductivity of 0.25 ft/day is used for the inflow estimates, with a hydraulic gradient of 0.03 feet per foot, resulting in an inflow of approximately 50 AFY.

Subsurface inflow from Cemetery Mesa

A minor amount of inflow is interpreted to come from the Cemetery Mesa portion of the Adjudicated Plan Area. The length of the boundary is approximately 5,000 feet, with a saturated cross-sectional area of less than 20 feet of mostly clay. The resulting inflow, based on a hydraulic gradient of 0.01 ft/ft is 4 AFY.

4.2 Outflow

Elements of outflow from the fringe areas include:

- Production from wells
- Wetland evapotranspiration
- Base flow to streams
- Subsurface outflow to adjacent areas

Production from wells

Groundwater production from wells is the largest component of outflow from the alluvial aquifer. The most recent land use survey by the DWR (2014) was used to estimate current irrigated acreages. Groundwater production was estimated based on applied irrigation water estimates from a soil-moisture budget with local data input.

The land use survey map for 2014 is shown on Figure 21. Tabulation of the acreages north and south of Los Osos Valley Road for the 2014 crop survey is presented in Table 6 below.

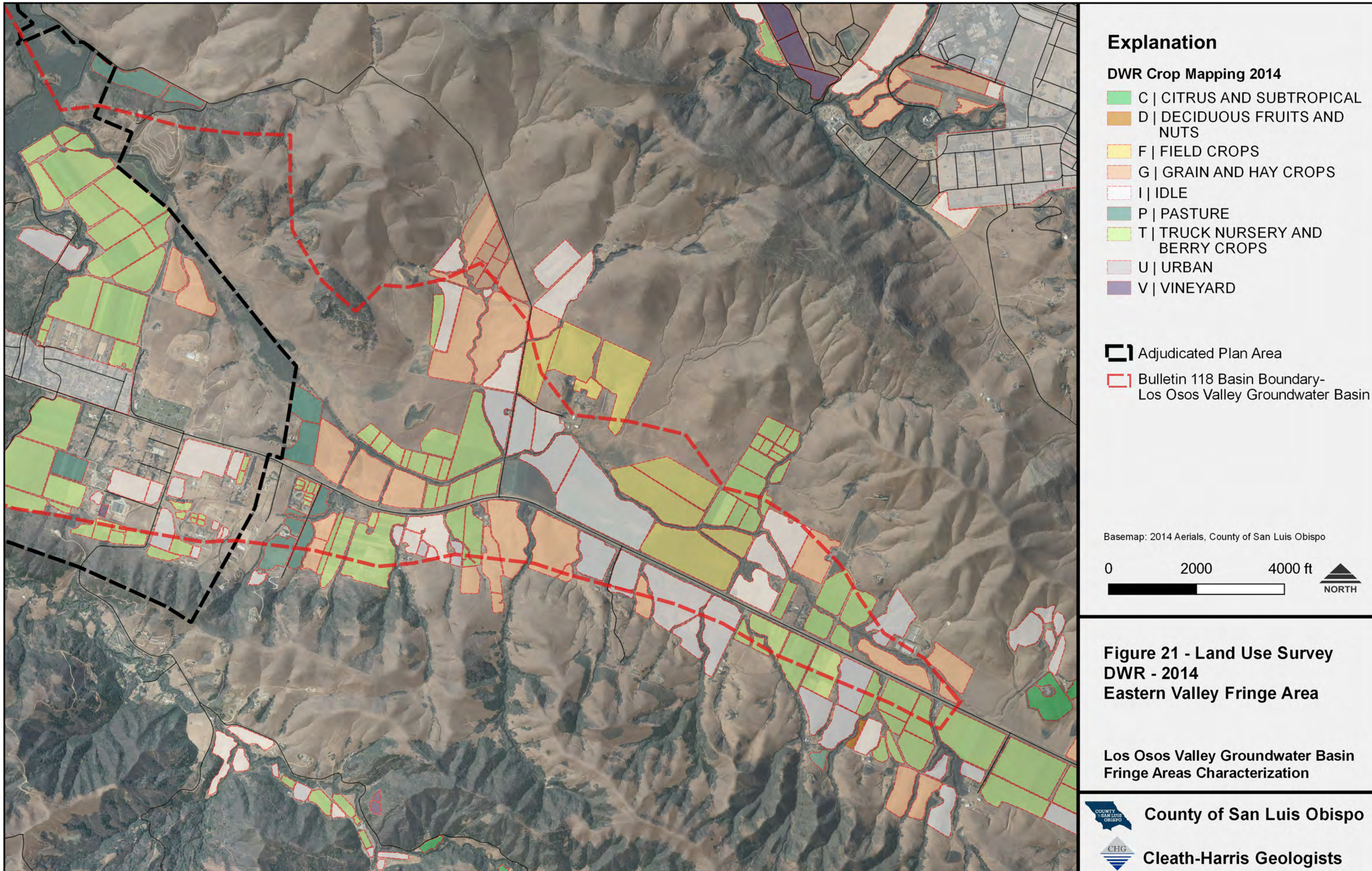


Figure 21 - Land Use Survey DWR - 2014 Eastern Valley Fringe Area

Los Osos Valley Groundwater Basin Fringe Areas Characterization

County of San Luis Obispo

Cleath-Harris Geologists

Table 6
2014 DWR Crop Survey
Eastern Valley Fringe Area

Crop Type / Land Use	North of Los Osos Valley Rd.	South of Los Osos Valley Rd.
	Acres[1]	
Pasture	25	27
Vegetables	191	160
Avocado[2]	21	0
Nursery[2]	4	3
Field/Grain[3]	401	109
Idle	232	174
Total	874	473

Notes: [1] 2014 survey covered one growing season
[2] Avocado and nursery acreage added to 2014 DWR survey data
[3] Generally non-irrigated in the Eastern Valley fringe area

Crop acreages listed in Table 6 include fields adjacent to the fringe area boundary, not just fields overlying the basin (Figure 21). Comparing agricultural acreage listed in Table 6 (1,347 acres for 2014) with acreage from Table 4 for the fringe area (956 acres) indicates that roughly 390 acres of farmed fields are outside of the fringe area boundary.

Avocado orchards north of Los Osos Valley Road were planted after the 2014 survey and added to Table 6. Nursery (and greenhouses) were also added to or reclassified in the 2014 DWR survey area to reflect current conditions.

Cropping information for roughly one-third of the farmed land in the Eastern Valley fringe area was obtained during the 2017 field investigation and indicated that approximately 25 to 36 percent of the fields are typically farmed during the year with irrigated crops. The corresponding values for the DWR 2014 survey in Table 6 above are 28 percent of the fields were in irrigated crops north of Los Osos Valley Road and 40 percent of the fields were in irrigated crops south of Los Osos Valley Road.

Applied water for vegetable crops and pasture was estimated using the 2005-2017 monthly soil-water budget developed using local evapotranspiration and precipitation data. Irrigation was applied to offset soil moisture deficits after accounting for crop evapotranspiration, rainfall, rooting depths, and soil holding capacities. The resulting average annual applied water for vegetables was 1.8 acre-feet per acre (assuming year-round production), or 0.6 acre-feet per acre per growing season. This is close to the high range of applied irrigation values listed for the Los Osos water planning area (Carollo, 2012). The estimated applied water on pasture was

3 acre-feet per acre, which is close to the medium range of applied irrigation values listed for the water planning area. Avocado orchard irrigation was assumed to be 1.8 AFY per acre, corresponding to the high range of values for citrus/avocado in the Los Osos water planning area. Nursery/greenhouse water use was assumed to be 2 AFY per acre, also at the high range of the values listed for the Los Osos water planning area. Groundwater production north of Los Osos Valley Road comes mostly from wells tapping alluvial basin sediments in the fringe area, while the groundwater production south of the road comes mostly from bedrock wells along the base of the Irish Hills. Groundwater in fractured bedrock is included in the alluvial aquifer water balance as subsurface inflow, and as return flow from fringe area irrigation using bedrock wells south of Los Osos Valley Road.

Groundwater production for domestic uses in the Eastern Valley Fringe area is estimated at 0.77 AFY per residence. This value is the sum of 0.44 AFY outdoor use and 0.33 indoor use (value for large lots with medium-use landscaping in adjudicated area; CHG 2009). Out of the approximate 26 residences counted in the fringe area, 11 residences are north of Los Osos Valley Road, and 15 are south of the road. The corresponding residential water use is estimated at 8 AFY north of Los Osos Valley Road and 12 AFY south of the road. Residences south of Los Osos Valley Road obtain water from bedrock sources. Table 7 below summarizes the estimated irrigation and residential water use in the Los Osos Fringe Valley.

Table 7
2014 Applied irrigation and Residential Water Use Estimates
Eastern Valley Fringe Area

Crop Type / Land Use	North of Los Osos Valley Rd. (basin well production)			South of Los Osos Valley Rd. (bedrock well production)		
	Acres[1]	AFY/acre	AFY	Acres	AFY/acre	AFY
Pasture	25	3	75	27	3	81
Vegetables[2]	191	1.8	344	160	1.8	288
Avocado	21	1.8	38	0	1.8	0
Nursery	4	2	8	3	2	6
Field/Grain	401	0	0	109	0	0
Idle	232	0	0	174	0	0
Residential	--	--	8	--	--	12
Total	874		473	473		387

Notes: [1] Avocado and nursery added
[2] Assumes vegetable acreage in production year-round through crop and field rotation.

Wetland Evapotranspiration

Phreatophytes (such as willows) that have roots extending to the water table can use groundwater directly for evapotranspiration. The Warden Lake wetland area covers approximately 51 acres with a combination of riparian and marsh vegetation. Groundwater is within a few feet of ground surface, and can be consumed by phyreatophytes. The average groundwater uptake for the wetland is estimated to be 3 AFY/acre, based on meeting the evapotraspiration demand in the 2005-2017 soil-moisture budget after accounting for precipitation. Although phreatophytes don't depend on precipitation and the holding capacity of soils, rainfall that is not used for evapotranspiration by phreatophytes can recharge groundwater and is an offset to basin outflow. A total of 153 AFY is estimated to be consumed by phreathophytes in the Warden Lake wetland and riparian area.

Base Flow to Streams

Once direct surface runoff is completed following storm runoff events, natural base flow in a stream can continue for days or months as the groundwater reservoir is drained. The USGS estimated average annual base flow to Warden Creek at 0.17 cubic feet per second, equivalent to 123 AFY (Yates and Wiese, 1988). Base flow is generally not a constant rate, but follows a recession curve.

Subsurface Outflow to Adjacent Areas

Subsurface outflow would be most likely to occur through the alluvial deposits beneath Warden Creek at the confluence with the Los Osos Creek Valley. Water levels in Summer 2017 measured upstream and downstream of the confluence, however, indicate a slight (1.5-foot) groundwater depression in the Warden Lake area, which suggests static conditions and no significant subsurface flow from the fringe area at that time. Some subsurface outflow (along with base flow) would be expected during and following the rainy season, but given that the hydraulic gradient would still be relatively flat (0.001 feet per foot), the amount of subsurface outflow would likely be negligible, as most of the groundwater discharge at the confluence rises into Warden Creek as base flow.

4.3 Groundwater in Storage

Water level measurements were used to prepare a groundwater elevation contour map (Figure 10). This surface was gridded, along with the base of permeable sediments (Figure 9), using Surfer software to calculate the saturated volume of basin material. A weighted average of specific yield for the producing aquifer zone and saturated alluvial deposits was also performed based on a review of lithology. The results estimate the average specific yield of the aquifer zone at 15 percent, and the average specific yield of the saturated materials at 12 percent.

Based on the field water level measurements and an average specific yield of 12 percent, there is an estimated 5,200 acre-feet of groundwater storage in the Eastern Valley fringe area. Specific yield calculations are in Appendix E. Storage volume computations are in Appendix F.

4.4 Water Balance Summary

A summary of the Eastern Valley water balance is presented in Table 8. The water balance is a preliminary effort that helps identify data gaps and provides some input for a future groundwater model. The balance assumes that the alluvial aquifer is not in a state of overdraft and groundwater in storage is stable over time. This assumption is supported by the historical use of the shallow alluvial aquifer for agriculture, even during drought, as observed through aerial imagery review and by the DWR 2014 land use survey. There is no seawater intrusion in the Eastern Valley fringe area.

Table 8
Preliminary Water Balance Summary
Eastern Valley Fringe Area Alluvial Aquifer

INFLOW ITEMS	AFY
Percolation of precipitation	390
Return flow	95
Stream seepage	210
Subsurface	55
TOTAL INFLOW	750
OUTFLOW ITEMS	AFY
Wells	470
Wetland ET	155
Subsurface	<1
Base flow	125
TOTAL OUTFLOW	750

5.0 KEY SURFACE WATER BODIES AND SIGNIFCANT RECHARGE SOURCES

Eastern Valley Fringe area

The principal surface water bodies within the Eastern Valley fringe area include Warden Lake and Warden Creek. Warden Creek is the drainage that flows down the middle of the fringe area, through Warden Lake, and joins Turri Creek below the bedrock narrows. Warden Lake is a marshy depression where surface water ponds along the riparian corridor. Development of the marsh has been attributed to impoundment as a result of possible faulting (Treiman, 1989) and to alluvial fan deposit buildup in the Los Osos Creek valley (Balance Hydrologics, 2003). There are also a few agricultural reservoirs near Warden Lake. Los Osos Creek recharges the Adjudicated Plan Area and is not present in the Eastern Valley fringe area.

The Eastern Valley watershed encompasses approximately 9 square miles. Stream seepage of surface water runoff along unnamed tributaries is a significant source of recharge to the fringe area. Surface water runoff from this watershed to creeks was estimated by the U.S. Geological Survey at 870 acre-feet per year for water years between 1970 and 1977 (Yates and Wiese, 1988).

Montaña de Oro Fringe area

The only key surface water body within the Montaña de Oro fringe area is the creek channel in Hazard Canyon, which drains a watershed area of approximately 1.5 square miles. The Pacific Ocean coastline forms the western fringe area boundary. Islay Creek, one of the principal coastal streams emerging from the Irish Hills, lies south of the fringe area boundary. Stream seepage in Hazard Canyon and direct percolation of precipitation into permeable dune sands are considered significant recharge sources.

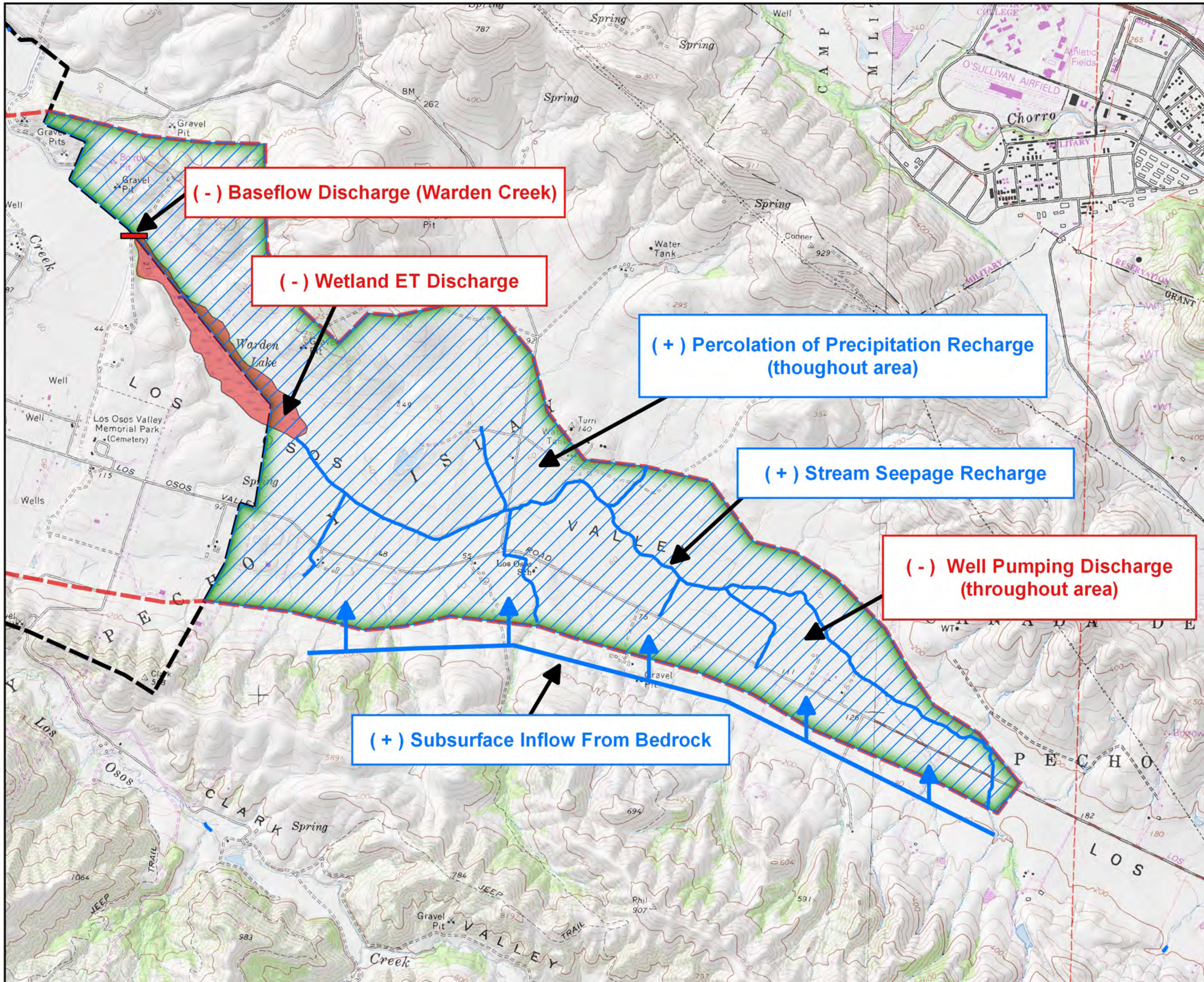
5.1 Recharge and Discharge Areas

Eastern Valley Fringe area

The majority of recharge to the Eastern Valley fringe area (from Table 8) consists of the following elements:

- Direct percolation of precipitation
- Stream seepage from Warden Creek and tributaries
- Return flow from agricultural irrigation
- Subsurface inflow across fringe area external boundaries

The primary natural components of fringe area discharge are surface outflow on Warden Creek and evapotranspiration by riparian vegetation in the Warden Lake. Figure 22 presents recharge and discharge areas for the Eastern Valley fringe area.



Explanation

- Adjudicated Plan Area
- Bulletin 118 Basin Boundary- Los Osos Valley Groundwater Basin
- Eastern Valley Fringe Area

Basemap: ESRI National Geographic USA Topo Maps

0 2000 4000 ft

NORTH

Figure 22 - Recharge/Discharge Areas - Eastern Valley Fringe Area

Los Osos Valley Groundwater Basin Fringe Areas Characterization

County of San Luis Obispo

Cleath-Harris Geologists

Montaña de Oro Fringe area

The majority of recharge to the Montaña de Oro fringe area consists of the following elements:

- Direct percolation of precipitation, including localized runoff into natural depressions
- Stream seepage along Hazard Canyon

Permeable dune sands and inter-dune depressions would percolate much of the rainfall that is not lost to the atmosphere or evapotranspired by vegetation. Hazard Canyon drains an area of 1.5 square miles and flows through the fringe area for approximately 4,500 feet. Groundwater development in the dune sands is not considered feasible due to a general lack of saturation and the fringe area location, which is entirely within Montaña de Oro State Park.

The primary natural components of fringe area discharge are surface outflow from Hazard Canyon and at seeps along the base of the terrace deposits, and from subsurface outflow through beach sands to the ocean. Figure 23 presents recharge and discharge areas for the Eastern Valley fringe area.

5.2 Potential Recharge Areas

A spatial site suitability analysis was performed for the fringe areas to determine locations in the basin where recharge potential with surface water infiltration was likely to be the most effective. Data collection included the following spatial datasets and are included in Appendix A:

- A one-meter-resolution LiDAR elevation raster dataset from a 2011 flight by Watershed Sciences for Pacific Gas and Electric (PG&E) of the Los Osos area.
- A countywide soil-type shapefile available from the SLO DataFinder website, developed by the Natural Resource Conservation Service (NRCS).
- A countywide surface-geology shapefile available from the SLO DataFinder website, developed by San Luis Obispo County Planning & Building Department.
- Water level elevation surface data interpolated from Summer 2017 field measurements.

A raster layer representing slope in degrees was calculated from the elevation dataset. This resulted in four major factors for recharge analysis: Slope, Soil-type, Geology, and Depth-to-Water. Classes were developed for each of the factors, representing their effectiveness for recharge, and then numerical recharge scores were assigned to each factor's classes, with lower numbers representing higher potential for recharge. The following shows a table of the factors, classes and scores used:

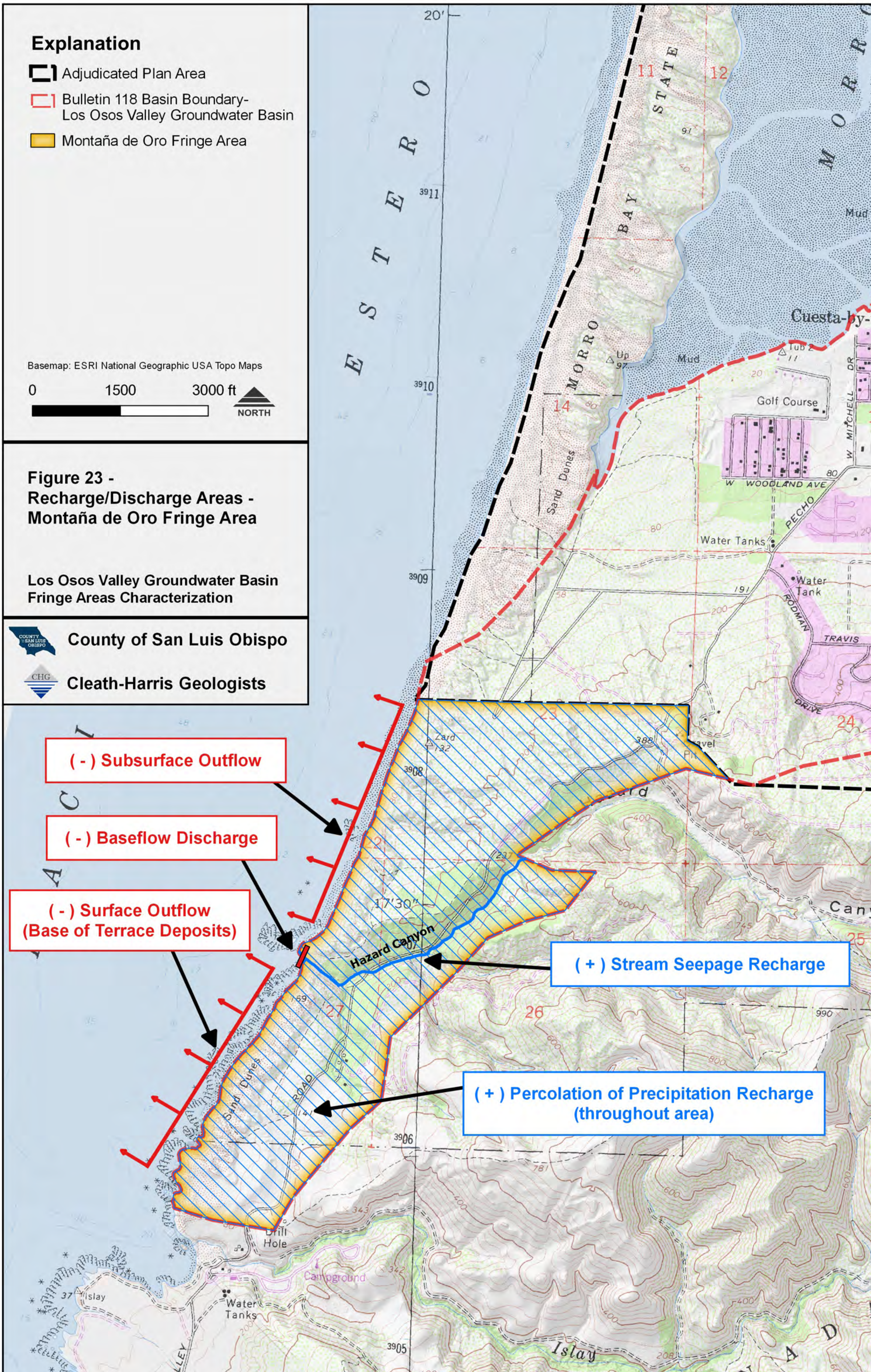

Explanation
Adjudicated Plan Area
Bulletin 118 Basin Boundary-
Los Osos Valley Groundwater Basin
Montaña de Oro Fringe Area
Basemap: ESRI National Geographic USA Topo Maps
0 1500 3000 ft
NORTH
Figure 23 -
Recharge/Discharge Areas -
Montaña de Oro Fringe Area
Los Osos Valley Groundwater Basin
Fringe Areas Characterization
County of San Luis Obispo
Cleath-Harris Geologists
(-) Subsurface Outflow
(-) Baseflow Discharge
(-) Surface Outflow
(Base of Terrace Deposits)
(+) Stream Seepage Recharge
(+) Percolation of Precipitation Recharge
(throughout area)
Hazard Canyon
ESTERO
MORRO BAY STATE
Sand Dunes
Golf Course
W WOODLAND AVE
PECHO
Water Tanks
Water Tank
RODMAN
TRAVIS
DRIVE
W MITCHELL DR
Cuesta-by-t
Mud
Campground
Drill Hole
Islay
Water Tanks
ROAD
VALLEY

Table 9
Potential Recharge Areas
Factors used for Spatial Analysis

Factor	Recharge Class	Score
Slope	< 3°	1
	3° - 6°	2
	> 6°	3
Soil-Type	Drainage Class A	1
	Drainage Class B	2
	Drainage Class C	5
	Drainage Class D	6
Surface Geology	Dune Sand	1
	Alluvium	2
	Bedrock	10
Depth to Water	Qualitative evaluation	

All datasets were then spatially homogenized so that raster surface layers could be summed to determine relative recharge effectiveness. This was performed using the following GIS methodology:

1. Convert all vector data layers to numerical single-band raster data layers based upon relevant attributes
2. Resample each raster to have the same cell size
3. Align and clip each raster layer to the same spatial grid extent

A map of the result of summation of raster values for the following factors: slope, soil-type and surface geology is included in Figure G1 (Appendix G). Water level depth was not used in the numerical raster summation because of its variability related to topographic highs and lows, but was instead analyzed qualitatively after summation of the other factors (Figure G2, Appendix G). The areas with highest recharge potential based on the numerical spatial analysis (Figure G1) have problems due to shallow groundwater and other considerations, as listed below:

A. The sandy base of the hills northwest of Warden Lake.

- This shows the highest scores for recharge potential and is driven by the capacity of sandy soil to infiltrate. However, recharge in this area has the potential to flow down to the low areas around Warden Lake which can saturate in wet conditions. In addition, springs emanating from these sands higher up on the slope (C&A, 2008) are evidence of shallow bedrock and may limit subsurface percolation capacity.

B. A raised sandy area around west of Turri Road.

- Relatively shallow surrounding groundwater levels and an existing agricultural reservoir at the location indicate difficulty of infiltration and siting facilities despite the raised sandy knob in this area. Also, clay directly underlies the windblown sands, which would significantly limit subsurface percolations (geologic cross-section K-K' Figure 7).

C. Agricultural fields on the south side of Warden Creek upstream of Warden Lake.

- Although this area has a good recharge potential score, shallow groundwater levels indicate that there would not be much room for water to infiltrate. Existing agricultural operations could also make it difficult for recharge implementation.

The results of this local site suitability analysis were compared with maps from The Soil Agricultural Groundwater Banking Index (SAGBI) from UC Davis which rates areas in one of the following categories of recharge potential: Very Poor, Poor, Moderately Poor, Moderately Good, Good and Excellent (Appendix G). The “Modified” SAGBI layer was used for comparison, which assumes that areas with water restrictive soil horizons have been modified with deep tillage. This map shows generally the same areas (A, B and C above) as having “moderately good” recharge potential, which is the highest rating class within the fringe area. The eastern part of the fringe area, shows low recharge potential in the site suitability analysis map and the SAGBI map.

Based on the recharge suitability analysis, none of the areas identified by SAGBI as having a "moderately good" potential for groundwater banking are considered suitable for enhanced recharge projects. One preferred alternative with "moderately good" recharge potential would be surface discharges during dry periods into Warden Creek tributary drainages, particularly the drainages in the upper Eastern Valley south of Los Osos Valley Road (see Figure G1). The greatest source of fractured "red rock" gravels are mainly in the Irish Hills. Alluvial fans developed along drainages emanating from the Irish Hills would be expected to have a higher percentage of coarse sediments, compared to fans developed from the softer (melange) bedrock on the north side of the valley. Surface discharge to one or more tributary drainages in the upper Eastern Valley would increase recharge from stream seepage into the alluvial aquifer.

6.0 FIELD INVESTIGATIONS

6.1 Eastern Valley Fringe Area

Field investigation in the Eastern Valley was performed from August through October 2017. Access agreements were provided to landowners for granting permission for CHG to collect and use hydrologic data from wells on the property. Some of the field data has been aggregated into an upper valley and lower valley designation for reporting. The upper valley extends from the drainage divide with the San Luis Obispo Creek watershed to the bend in Los Osos Valley Road east of Turri Road. The lower valley extends from the Turri Road area west to the Adjudicated Plan Area boundary.

Water Level Monitoring

CHG measured static water levels at 26 wells as part of fringe area characterization between August and October 2017. Twelve of the wells visited were within the Eastern Valley fringe area, six wells were on the Cemetery Mesa in the Adjacent Plan Area, and eight were in bedrock wells along the base of the Irish Hills (out of the basin). Measurements of well casing height above ground surface and high-resolution topographic data from Light Detection and Ranging (LiDAR) data were used to convert depth to water measurements to groundwater elevations. The vertical accuracy of the Los Osos LiDAR data set elevations is 2.8 centimeters (1 inch), with the elevations reported at one square meter spatial resolution (2011, PGE). A groundwater elevation contour map based on the field investigation is shown in Figure 10.

Nine of the fringe area wells where static water levels were measured in 2017 also had available historical water level data. The water level differences range from 4.5 feet higher elevation to 16 feet lower elevation when comparing 2017 water levels to prior years. The average difference in elevation at the nine wells is 4 feet lower elevation in 2017 compared to prior years. Table 10 summarizes the water level comparison.

Table 10
Historical Groundwater Level Comparison
Eastern Valley Fringe Area

Area	Historical Water Level Date	Recent Water Level Date	Water Level Change (feet)
Lower Valley Wells	9/16/1981	8/14/2017	-16
	7/26/1989	8/14/2017	-10.8
	5/21/1990	8/14/2017	-7.8
Upper Valley Wells	7/27/1998	8/14/2017	-5.0
	11/3/2000	10/12/2017	4.5
	11/20/2001	8/14/2017	-2.6
	7/30/2002	9/7/2017	0.3
	10/8/2004	10/12/2017	4.3
	10/11/2004	10/12/2017	-2.2
Average difference between historical and recent level (feet)			-4

Lower Valley - from Turri Road area west to Adjudicated Plan Area
Upper Valley - from Turri Road area east to boundary with San Luis Obispo Valley Groundwater Basin

The water level declines shown in Table 10 are greatest when comparing the oldest available water levels with 2017 levels, which also correspond to the water levels in the lower valley portion of the fringe area. The information in Table 10 is relatively limited for interpreting groundwater conditions, but the overall water level declines are not considered an indication of overdraft from a sustainable management perspective, considering that the above historical levels were measured prior to putting each well into service, and the 2017 static water level measurements were measured between pumping cycles.

Pressure transducers were installed in two unequipped wells, one in the upper Eastern Valley and one on the Cemetery Mesa at the edge of the lower Eastern Valley. The transducers were programmed to record water levels once per hour. Hydrographs showing water level fluctuations since August 2017 are in Appendix H. The hydrograph at well 21Bb at the boundary between the Adjudicated Plan Area and the Eastern Valley fringe area shows a seasonal decline of approximately 8 feet between July and October 2017, followed by an equal water level rise through February 2018. Subsequent fluctuations of 3-feet decline followed by a 6-foot rise were recorded through March 2018 (Figure H-1, Appendix H). The hydrograph for the well in the upper Eastern Valley fringe area shows a seasonal decline of one foot between August and October 2017, followed by an equivalent rise through mid-March 2018, when late season storm events temporarily increased water levels by over two feet (Figure H-2, Appendix H). These hydrographs indicate relatively minor seasonal water level fluctuations, which would support a sustainably managed condition.

Water Quality Monitoring

CHG collected groundwater samples from 18 wells in 2017 for fringe area water quality characterization. Eight wells were sampled within the Eastern Valley fringe area, four wells were sampled in the adjacent Adjudicated Plan Area, and six wells were sampled that tap bedrock sources south of the fringe area. A general mineral analysis for each sample was conducted by Fruit Grower's Laboratory. The water quality data has been aggregated for interpretation (see report Section 3.6).

Fringe Boundary Pumping Tests

Data from six existing pumping tests were obtained and analyzed to characterize hydraulic parameters of the alluvial aquifer in the Eastern Valley fringe area, along with pumping test data from two local bedrock wells, and a Lower Aquifer Zone E well in the Adjudicated Plan Area near the fringe area boundary (Table 1). To supplement the existing data and help characterize aquifer parameters along the western fringe area boundary, an 8-hour constant discharge test was conducted on July 10, 2017. Test data is included in Appendix I.

The July 2017 pumping test was performed on a well that is completed in lower aquifer (Zone E) fine sands and screened from 90 to 150 feet deep (21Ba). An older well located 26 feet away was used for observation during the test (21Bb). The observation well was sounded at 140.5 feet depth, and is also interpreted to tap the fine sand aquifer. A pressure transducer was set in the observation well.

Static water level prior to the test was measured at 62.45 feet depth in the pumping well and 60.85 feet depth in the observation well. Flow was maintained at approximately 12 gallons per minute (gpm) during pumping. At 5.5 hours into the test, the water level in the pumping well fell below an obstruction that prevented further measurements. The pumping water level at that point was measured at 84.7 feet depth (22.3 feet of drawdown below static). The test was continued with measurements being collected from the observation well. At the conclusion of the 8-hour test, water level in the observation well measured 64.8 feet depth (3.9 feet of drawdown from static level). The water level in the pumping well recovered to 65.1 feet depth one hour after pump shut down. Pumping test results are included on Table 1 and in Appendix I, and shows that transmissivity and hydraulic conductivity are significantly lower in aquifer Zone E (along the east Adjudicated Plan Area boundary) compared to the alluvial aquifer in the Eastern Valley fringe area.

6.2 Montaña de Oro Fringe Area

The Montaña de Oro fringe area is entirely within the State Parks system. Information received from State Parks shows that the park maintains two wells completed into bedrock, and not in the basin sediments. No field investigation was performed within the State Park.

Field reconnaissance was conducted outside of the park boundary to locate wells and contact potential well owners near the fringe area boundary for groundwater monitoring. Verbal communications with a local homeowner and a vacation rental agency helped locate two older wells, although permission for field monitoring was not granted. No other wells were found in the boundary area of interest, as Golden State Water Company provides water to homes along Pecho Valley Road.

7.0 REFERENCES

Balance Hydrologics, 2003, Conceptual Plan for Intercepting Sediment in the Lower Los Osos and Warden Valleys, Morro Bay Area, San Luis Obispo County, California, prepared for Morro Bay National Estuary Program, January 2003.

Brown and Caldwell, 1974, Preliminary Groundwater Basin Management Study, prepared for San Luis Obispo County Services Area No. 9, October 1974.

Brown and Caldwell, 1983, Los Osos - Baywood Park Phase I Water Quality Management Study, April 1983.

Carollo Engineers, 2012, San Luis Obispo County Master Water Report, prepared for San Luis Obispo County Flood Control and Water Conservation District, May 2012

Cleath & Associates, 2003, Geologic Structure of the Los Osos Valley Ground Water Basin, prepared for the Los Osos Community Services District, November 2003.

Cleath & Associates, 2005, Sea Water Intrusion Assessment and Lower Aquifer Source Investigation of the Los Osos Valley Ground Water Basin, San Luis Obispo County, California, prepared for the Los Osos Community Services District, October 2005.

Cleath & Associates, 2008, Tonini Site Reconnaissance, technical memorandum prepared for San Luis Obispo County, June 4, 2008.

Cleath-Harris Geologists (CHG), 2009, Water Use Estimates for Private Domestic Wells, Technical Memorandum prepared for the Los Osos ISJ Group, July 29, 2009.

Cleath-Harris Geologists (CHG), 2017, 2016 Annual Groundwater Monitoring Report, Los Osos Groundwater Basin, Technical Memorandum prepared for the Los Osos Basin Management Committee, June 2017.

Department of Water Resources (DWR), State of California, 1972, Sea Water Intrusion: Morro Bay Area, San Luis Obispo County, Bulletin 63-6, February 1972.

Department of Water Resources (DWR), State of California, 1973, Los Osos-Baywood Ground Water Protection Study, Southern District Report, October 1973.

Department of Water Resources (DWR), State of California, 1979, Morro Bay Sandspit Investigation, Southern District Report, August 1979.

Department of Water Resources (DWR), State of California, 1989, Geohydrogology and Management of Los Osos Valley Ground Water Basin, San Luis Obispo County, Southern District Report, July 1989.

Department of Water Resources (DWR), State of California, 2003, California's Groundwater, Bulletin 118 Update 2003, October 2003.

Department of Water Resources (DWR), State of California, 2010, Groundwater Elevation Monitoring Guidelines, , December 2010.

Department of Water Resources (DWR), State of California, 2014, California Groundwater Elevation Monitoring Basin Prioritization Process, Appendix A, June 2014.

Department of Water Resources (DWR), State of California, 2016, California's Groundwater, Working Toward Sustainability, Bulletin 118 Interim Update 2016, December 22, 2016.

Dibblee, T. W., Jr., 2006, Geologic Map of the Morro Bay South Quadrangle, San Luis Obispo County, California, Dibblee Geology Center Map #DF-214, April 2006.

Gasch & Associates, 2000, Worldcom's Morro Bay Fiber Optic Cable Landing Project Geophysical Investigation, Morro Bay, California, November 2000.

Hall, C. A., Ernst, W. G., Prior, S. W., and Wiese, J. H., Geologic Map of the San Luis Obispo-San Simeon Region, California, U. S. Geological Survey Miscellaneous Investigations Series MAP I-1097, 1979.

ISJ Group, 2015, Updated Basin Plan for the Los Osos Groundwater Basin, January 2015.

Johnson, A. I., 1967, Specific Yield - Compilation of Specific Yields for Various Materials, U.S. Geological Survey Water-Supply paper 1662-D.

Lettis, W.R., and Hall, N.T., 1994, Los Osos fault zone, San Luis Obispo County, California *in* Alterman, I.B., McMullen, R.B., Cluff, L.S., and Slemmons, D.B. (editors), *Seismotectonics of the Central California Coast Ranges*, Geological Society of America Special Paper 292.

Los Osos Community Services District v. Golden State Water Company, S&T Mutual Water Company, County of San Luis Obispo, Does 1 though 500, inclusive, 2015, Stipulated Judgment, Case No. CV 040126, Superior Court of the State of California for the County of San Luis Obispo, September 2015.

Morro Group, 1987, Los Osos Wastewater Project Environmental Impacts Report, SCH# 84121914, August 1987.

Morro Bay National Estuary Program, 2016, Morro Bay National Estuary Program's Implementation Effectiveness program for the Morro Bay Watershed, 2015 Data Summary Report, January 2016.

Pacific Gas and Electric (PG&E), 2011, 2011 Pacific Gas and Electric Diablo Canyon Power Plant (DCPP) LiDAR: Los Osos, CA Central Coast, National Oceanic and Atmospheric Administration (NOAA) Digital Coast Data Access Viewer, Charleston, SC

Pacific Gas and Electric (PG&E), 2014, Geologic Mapping and data Compilation for the Interpretation of Onshore Seismic-reflection Data, PG&E Geosciences Department Technical Report GEO.DCPP.TR.14.01, June 30, 2014.

Racal Pelagos, Inc. 1999, Draft Pre-Installation Geophysical Survey Preliminary Interpretation, Morro Bay, California, prepared for Southern Cross Cable Network.

Treiman, J.A., 1989, Los Osos Fault Zone, San Luis Obispo County, California Division of Mines and Geology Fault Evaluation Report FER-200.

San Luis Obispo County Flood Control & Water Conservation District, 2014, CASGEM Monitoring Plan for High and Medium Priority Groundwater Basins, September 2014.

Yates, E.G., and Wiese, J. H., 1988, Hydrogeology and Water Resources of the Los Osos Valley Ground-Water Basin, San Luis Obispo County, California, U. S. Geological Survey, Water-Resources Investigations Report 88-4081.

APPENDIX A

Database Inventory
Data Gaps and Recommendations

Hydrogeologic and Geologic Studies in Chronological Order

State of California Department of Water Resources Division of Resource Planning, 1958, San Luis Obispo County Investigation. State Water Resources Board Bulletin #18; Volume 1: Text and Plates, May 1958.

State of California Department of Water Resources; Bulletin No. 63-6, 1972, Sea Water Intrusion: Morro Bay Area San Luis Obispo County, February 1972.

State of California Department of Water Resources, Southern District, 1973, Los Osos - Baywood Ground Water Protection Study. District Report, October 1973.

Brown and Caldwell Consulting Engineers, 1974, Preliminary Groundwater Basin Management Study, prepared for San Luis Obispo County Service Area No. 9, October 1974.

State of California Department of Water Resources Southern District, 1979, Morro Bay Sandspit Investigation, August 1979.

Brown and Caldwell Consulting Engineers, 1983, Los Osos-Baywood Park Phase 1 Water Quality Management Study; Volume 1 - Project Report, prepared for San Luis Obispo County Service Area No. 9, April 1983.

Brown and Caldwell Consulting Engineers, 1983, Los Osos-Baywood Park Phase 1 Water Quality Management Study; Volume 2 - Appendices, prepared for San Luis Obispo County Service Area No. 9, April 1983.

The Morro Group, 1987, Community Services Area No. 9; Wastewater Treatment Facilities, Los Osos, Baywood Park, Cuesta-by-the-Sea, San Luis Obispo County, California , August 1987.

Yates, Eugene B., and Wiese, John H, 1988, Hydrogeology and Water Resources of the Los Osos Valley Ground-Water Basin, San Luis Obispo County, California, United States Geological Survey Water-Resources Investigations Report 88-4081.

The Morro Group and Tenera Environmental Services, 1990, Freshwater Influences on Morro Bay; San Luis Obispo County, California. June 1990.

Emcon Associates, 1994, Hydrogeologic Site Characterization, Los Osos Landfill, San Luis Obispo County, California, prepared for San Luis Obispo County, April 1994.

Donald O. Asquith, 1997, Review of Potentially Problematic Faults in San Luis Obispo County, prepared for Fugro West, Inc., January 28, 1997.

Cleath & Associates, 2003, Scenic Way Investigation with East Side Wastewater Disposal, prepared for the Los Osos Community Services District., July 2003.

Cleath & Associates, 2003, Geologic Structure of the Los Osos Valley Ground Water Basin, prepared for the Los Osos Community Services District, November 2003.

Cleath & Associates, 2005, Sea Water Intrusion Assessment and Lower Aquifer Source Investigation of the Los Osos Valley Ground Water Basin, San Luis Obispo County, California, prepared for the Los Osos Community Services District, October 2005.

Cleath & Associates, 2008, Tonini Site Reconnaissance, technical memorandum prepared for San Luis Obispo County, June 4, 2008.

Fugro West, 2007, Preliminary Geotechnical Report, Los Osos Wastewater Project; Los Osos Mortuary, Giacomazzi, and Branin Properties, San Luis Obispo County California, prepared for San Luis Obispo County, July 17, 2007.

San Luis Obispo County Los Osos Wastewater Project Development, 2008, Technical Memorandum Effluent Reuse and Disposal Alternatives, July 2008.

Michael Brandman Associates, 2008, Draft Environmental Impacts Report; County of San Luis Obispo Los Osos Wastewater Project, State Clearinghouse No. 2007121034, November 14, 2008.

Fugro West, Inc., 2009, Preliminary Geotechnical Report, Los Osos Wastewater Project, Tonini Property 3515 Turri Road, San Luis Obispo County, California, prepared for San Luis Obispo County, January 29, 2009.

Cleath-Harris Geologists, 2016, Los Osos Valley Groundwater Basin Boundary Modification Request, Technical Memorandum March 2016, prepared for San Luis Obispo County Department of Public Works, March 25, 2016.

Treiman, Jerome A., 1989, Los Osos Fault Zone, San Luis Obispo County, for the California Division of Mines and Geology Fault Evaluation Report FER-200, January 23, 1989.

Cleath-Harris Geologists, Technical Memorandum, 2014, Recycled Water Discharges to Los Osos Creek , prepared for Los Osos ISJ Group, March 18, 2014.

Golder Associates, Inc., 2017, Los Osos Landfill, First Semiannual 2017 Monitoring Report, prepared for San Luis Obispo County Department of Public Works, July 2017.

Well Completion Reports

The compilation of well completion reports used in this report are largely un-redacted, so to observe confidentiality, they have been delivered separately to the County of San Luis Obispo.

Ground Water Quality Reports

Water quality reporting came from several sources including the field work as described in Task 2.6 of the scope of work, and on the Irrigated Lands Program (ILRP) provided by the interactive map on Geotracker and the Groundwater Ambient Monitoring and Assessment Program (GAMA). The link to this data is as follows:

http://geotracker.waterboards.ca.gov/gama/gamamap/public/default.asp?CMD=runreport&myaddress=los+osos+ca

To view the irrigated lands program wells, check the box on the left marked 'Irrigated Lands Program' and uncheck all others.

Surface Water Quality Reports

Tetra Tech, Inc., 1998, Watershed Streamflow Model, prepared for the Morro Bay National Estuary Program, April 24, 1998.

Morro Bay National Estuary Program, 2014, Morro Bay National Estuary Program's Implementation Effectiveness Program for the Morro Bay Watershed, Data Summary Report 2014, October 28, 2014.

Hecht, Barry and Malmon, Daniel, 2003, Conceptual Plan for Intercepting Sediment in the Lower Los Osos and Warden Valleys, Morro bay Area; San Luis Obispo County, California, prepared for the Morro Bay National Estuary Program, January 2003.

Stream Flow Data

There are currently no stream flow records available for the study area, the closest gauge is at Los Osos Creek Station # 751. Stream flow data was accessed from the San Luis Obispo County water website, under real-time water data. The following link displays graphical and spreadsheet data for Los Osos Creek, viewable in customizable time spans.

https://wr.slocountywater.org/sensor.php?site_id=39&site=84b42272-0c34-40cd-847e-d57085e7b8f9&device_id=1&device=f3763fbf-9a48-4852-81d8-914a12d62f8f

Precipitation Data

Precipitation data was obtained from Station #727 at the Los Osos Landfill. An updating monthly precipitation data is available in an online pdf for Station #727 at:

https://www.slocountywater.org/weather/alert/precipitation/pdf/727%20Los%20Osos%20Landfill%20Precipitation%20Data.pdf

CIMIS Weather Data

San Luis Obispo weather data is available from the California Irrigation Management Information System (CIMIS) website at:

http://wwwcimis.water.ca.gov/WSNReportCriteria.aspx

Scroll to Station #160, San Luis Obispo West, and click run report to access weather data for the year.

District Water Level Monitoring Program

At the present time, there are no wells monitored regularly by the district.

Land Use Data

Crop maps for Los Osos have been compiled into a metadata file for GIS mapping. The Department of Water Resources land use viewer provided shapefiles of land use, their website can be accessed at:

https://gis.water.ca.gov/app/CADWRLandUseViewer/

Color codes indicate the crop type typically planted in various locations. 2017 crop data is from field observations but is based on 2014 categories.

Vegetation data for San Luis Obispo County as of 2007 was used as a reference, and was found at the SLO Data Finder Website hosted by Cal Poly Library. The link will immediately download a shapefile after the prompt, it is found at:

http://gis.calpoly.edu/gis/data/slo_county%2Fenvironmental%2FPLN_VEG_SLOCO_2007%2FPLN_VEG_SLOCO_2007.zip

Metatadata for GIS mapping was accessed from:

http://gis.calpoly.edu/gis/data/slo_county%2Fenvironmental%2FPLN_VEG_SLOCO_2007%2FPLN_VEG_SLOCO_2007.htm

For an index of Metadata files for San Luis Obispo County, this is found at :

http://lib.calpoly.edu/gis/browse.jsp?by=th&th=6

Agricultural Irrigation Estimates

Regional irrigation estimates based on crop type in acre-feet per acre per year are presented in the applied water table. Los Osos is WPA #5.

GAMA, Geotracker and ILRP Data

Further groundwater data can be found by using the interactive map provided by GAMA at:

http://geotracker.waterboards.ca.gov/gama/gamamap/public/default.asp?CMD=runreport&myaddress=los+osos+ca

Selecting the data to display will influence the data sets that clicking a well icon will take you to.

STORET Data

The Environmental Protection Agency's Storage and Retrieval (STORET) program data was largely focused inside the adjudicated boundary, and was not applicable to the fringe areas.

The following link provides access water quality data for Los Osos and other regions. Highly specific search criteria required.

https://www.epa.gov/waterdata/water-quality-data-wqx

DATA GAPS AND RECOMMENDATIONS

Data gaps have been listed as high, medium, or low priority within the Eastern Valley and Montaña de Oro fringe areas. The priority level designation is intended to provide a means of ranking the data gaps for each fringe area. Access, existing land use, and available data indicates the potential for development of the dune sand aquifer within the Montaña de Oro fringe is low. Therefore, filling data gaps in the Eastern Valley fringe area would be considered a higher priority than in the Montaña de Oro fringe area.

High Priority Data Gaps

The highest priority for filling data gaps would be with respect to groundwater level monitoring. Water levels are fundamental to development of a hydrogeologic conceptual model, water budget, GSP, and a groundwater flow model.

There are no formal water level monitoring programs in the fringe areas. California Statewide Groundwater Elevation Monitoring (CASGEM) guidelines suggest a minimum density of 2-10 monitoring wells per 100 square miles of basin area, equivalent to up to one well per 10 square miles (DWR, 2010). Although the Los Osos fringe areas are a few square miles or less, from a practical standpoint monitoring more than one well would be needed for establishing a hydraulic gradient and a water surface. The Eastern Valley fringe area would benefit from at least 3-4 water level monitoring locations to characterize seasonal and long-term water level trends. The Montaña de Oro fringe would also benefit from a few monitoring wells, although basin sediments are likely unsaturated over much of the area.

In 2014, San Luis Obispo County Flood Control & Water Conservation District published a CASGEM Monitoring Plan for High and Medium Priority groundwater Basins, including the Los Osos Valley Groundwater Basin (San Luis Obispo County, 2014). The 2014 plan identified a vertical data gap in aquifer coverage, and recommended two first water monitoring wells added to the CASGEM program, bringing the total number of well in the County CASGEM program to nine. Beginning in 2016, the Los Osos BMC began CASGEM reporting, and added 21 more monitoring locations to the CASGEM program. None of the CASGEM program wells are located in the fringe areas, however. Wellhead elevation surveys would be recommended for well included in any fringe area water level monitoring program.

The other high priority data gap is water quality in the Montaña de Oro fringe. There are only two known wells in the fringe area, which are set back from the coast and actually tap bedrock sources. Available water quality data may not be representative of the coastal dune sand aquifer, which may be brackish along the coast. Monitoring wells developed for water level monitoring could also provide water quality data.

Medium Priority Data Gaps

Medium priority data gaps would include streamflow, well production, and aquifer definition. Each of the fringe areas could use some data infill for these data sets.

Streamflow is a fundamental component of fringe area characterization, and is needed for GSP water budgets and groundwater flow model development. There are no stream gages in the fringe areas, although computer modeling of surface flows for Warden Creek has been performed (Tetra Tech, 1998). While a permanent stream gage is ideal, even a temporary gage in operation during and following a few storm events, along with periodic base flow measurements over the course of a year, would provide valuable data for calibrating a watershed runoff model. Locations for steam flow measurements in the Eastern Valley fringe area would include Warden Creek at the Turri Road bridge, and the Warden Creek crossing immediately upstream of the former Los Osos landfill. In the Montaña de Oro fringe area, the road crossing over Hazard Canyon would be a suitable location for measuring creek flow.

Subsurface definition and hydraulic parameters are major components of a groundwater flow model. Subsurface definition in the Eastern Valley is based on a review of over 60 well logs. For the Montaña de Oro fringe area, however, only two logs are available, and the interpretation of depth to bedrock is based primarily on the surface mapping of marine terraces. The subsurface geometry of the dune sand aquifer in the Montaña de Oro fringe could be confirmed with test holes (including cone penetration testing) and/or geophysics.

Hydraulic parameters for unconfined aquifers include hydraulic conductivity and specific yield. In the Eastern Valley fringe area, aquifer tests and lithologic logs provide information on hydraulic parameters. Spatial coverage of the aquifer tests in the Eastern valley fringe may be improved if more well owners agree to share data from existing tests. Hydraulic parameters for the dune sand aquifer in the Montaña de Oro fringe area are currently estimated from data for the Adjudicated Plan Area, and would benefit from a few local aquifer tests if monitoring wells were constructed.

Groundwater production is typically the largest component of subsurface outflow for developed areas. Agricultural wells are not metered in the Eastern Valley fringe area, and groundwater production estimates are based primarily on local land use/cropping, evapotranspiration, and precipitation. Improvements to the groundwater production estimates would benefit from more land use surveys that include cropping information for all growing seasons. The last survey performed in the area with year-round cropping information was the DWR survey from 1996. The Montaña de Oro fringe area is largely undeveloped (State Park) and groundwater production is not significant.

A monthly soil-moisture budget has been used to estimate percolation of precipitation and assist with irrigation pumping estimates. The soil-moisture budget could be expanded to daily time-steps using the available data. Daily time-steps can change percolation of precipitation estimates compared to monthly time steps, as precipitation takes place during discrete storm events, while the soil-moisture deficit accumulates daily. The GIS coverage for the Eastern valley fringe area can also be manually refined to incorporate paved roads and recent agricultural activities.

Low Priority Data Gaps

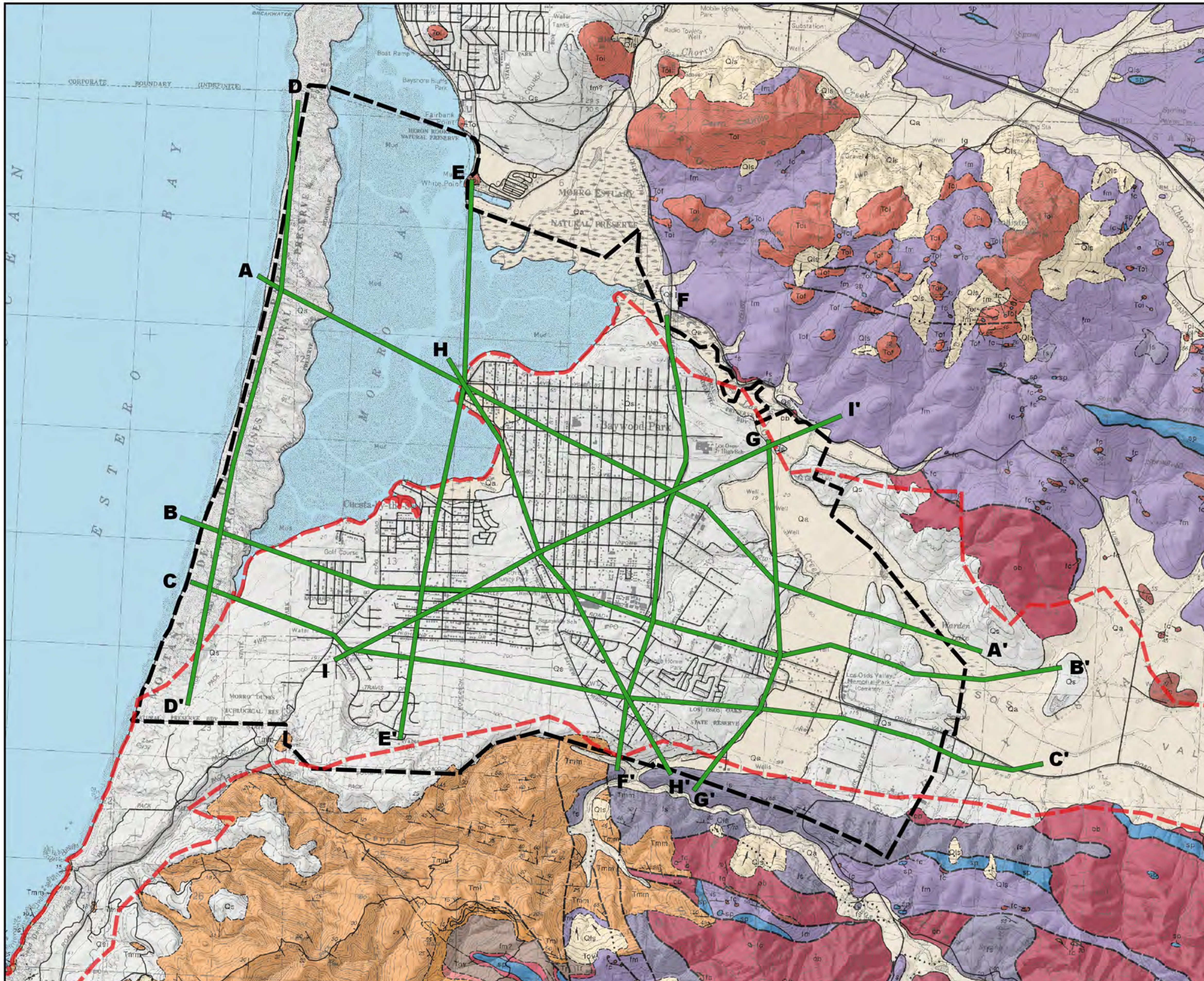
Low priority data gaps include refining the base of permeable sediments in the main fringe areas. The base of permeable sediments is a major factor in gross groundwater storage calculations, although generally not very important when estimating net changes in groundwater storage over time. Driller's logs for the Eastern Valley fringe area include descriptions of "fractured red rock" and "red rock gravel" beneath the valley floor, which are interpreted herein as alluvial gravels and therefore basin sediments for the hydrogeologic conceptual model. A sonic-rig drilling program in the Eastern Valley fringe area would provide the information needed to confirm that interpretation.

In the Montaña de Oro fringe area, the base of permeable sediments is inferred by projecting the elevations of wave-cut platforms that have been mapped at the base of the emergent marine terraces. A sonic-rig or direct push drilling program would provide the information needed to confirm elevations and locations for specific terraces.

Well head elevation surveys are another low priority data gap, and are used in groundwater storage and hydraulic gradient calculations. The current well head elevations are based on LiDar topographic datasets and physical measurements of casing (reference point) stick-up above ground surface, which is sufficient accuracy for the hydrogeologic conceptual model. Well head elevation surveys would be recommended for wells included in any fringe area water level monitoring program.

APPENDIX B

Geologic Cross-Sections
Adjudicated Plan Area



Explanation

Adjudicated Plan Area

Bulletin 118 Basin Boundary-
Los Osos Valley Groundwater Basin

Cross-section Line

Basemap: Geologic Map of the Morro Bay South Quadrangle, San Luis Obispo County, California - Dibblee Geological Foundation, 2006

0 3000 6000 ft

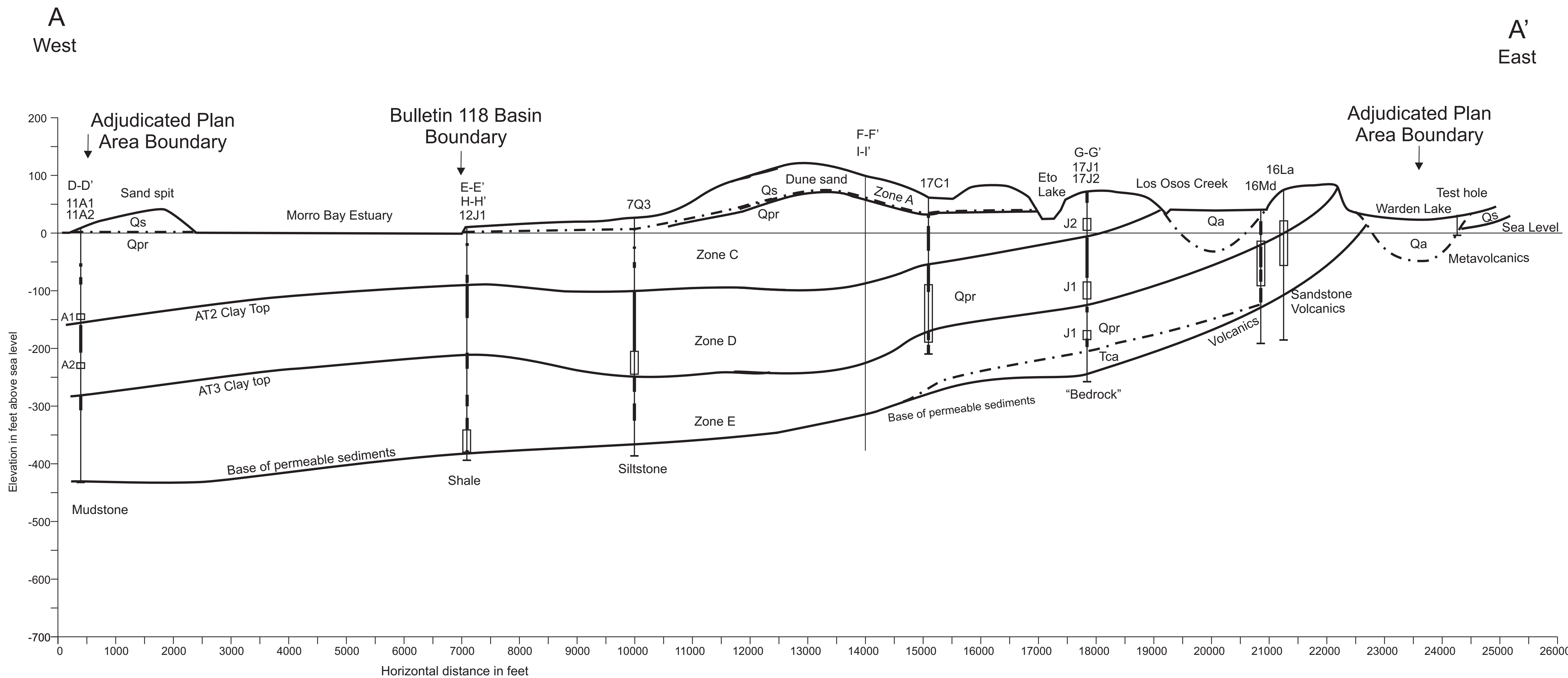
NORTH

Figure B1 - Geologic Cross-sections - Adjudicated Plan Area

Los Osos Valley Groundwater Basin Fringe Areas Characterization

County of San Luis Obispo

Cleath-Harris Geologists



Aquifer Zones:
Zone A - Perched Aquifer
Zone B - Transitional Aquifer
Zone C - Upper Aquifer
Zone D - Lower Aquifer (shallow)
Zone E - Lower Aquifer (deep)

Well data point
12J1 Well ID
Clay layer
Well screen

Formation:
Qa - alluvium
Qs - dune sand
Qpr - Paso Robles Formation
Tca - Careaga Formation

Figure B2

Cross-Section A-A'
Los Osos Valley
Groundwater Basin

San Luis Obispo County
February 2018 Revision

Cleath-Harris Geologists

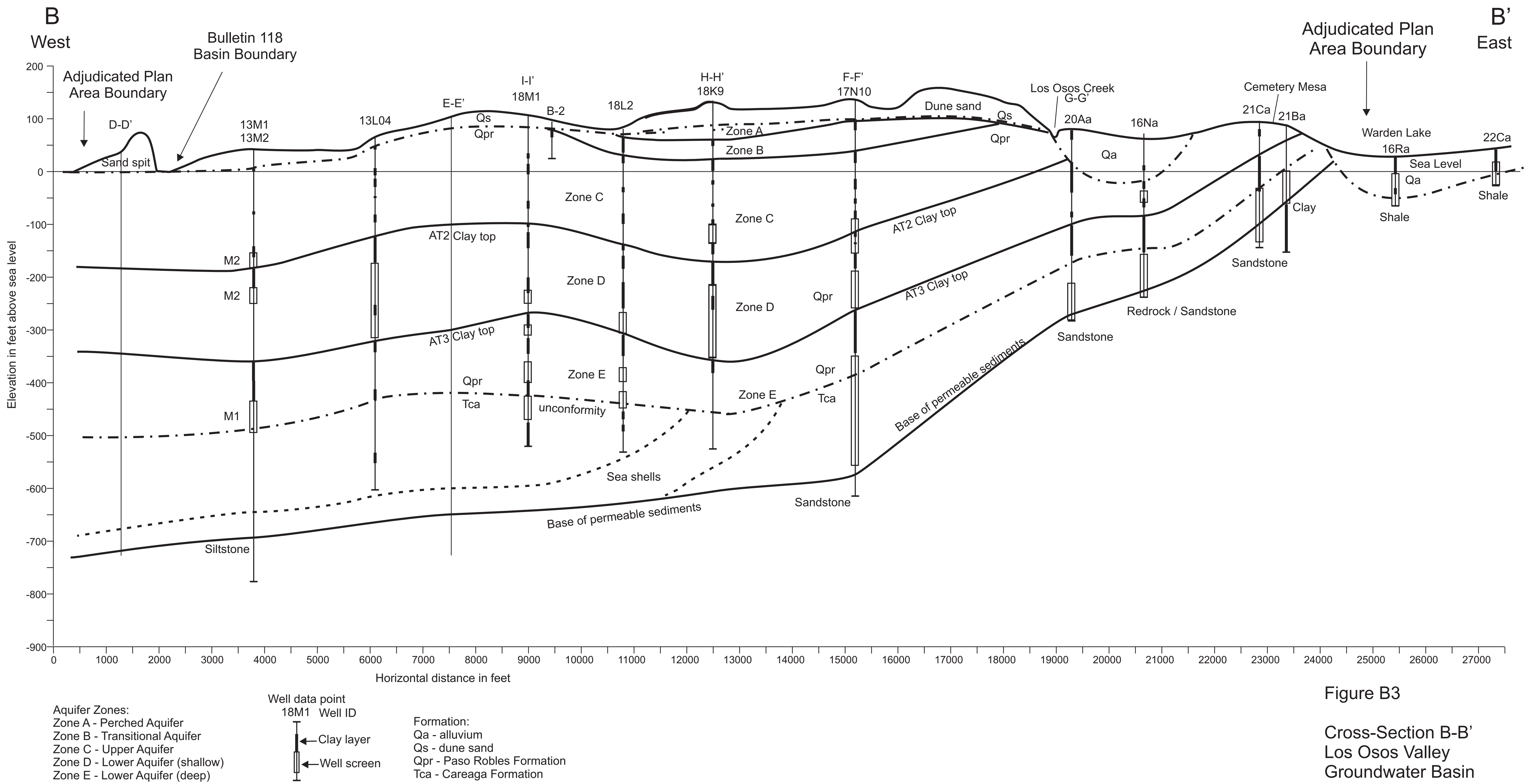
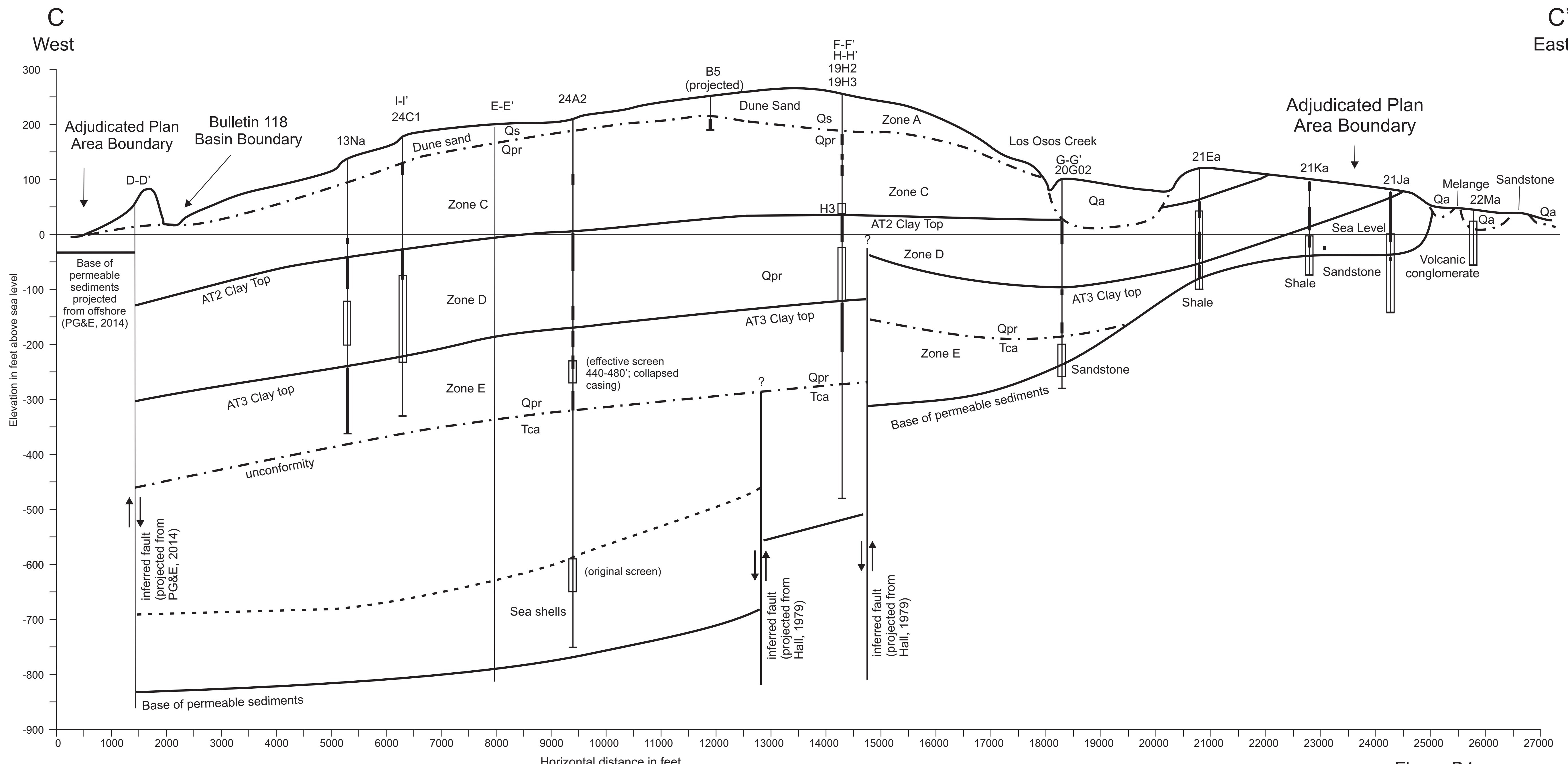


Figure B3

Cross-Section B-B'
Los Osos Valley
Groundwater Basin

San Luis Obispo County
February 2018 Revision

Cleath-Harris Geologists



Aquifer Zones:
Zone A - Perched Aquifer
Zone B - Transitional Aquifer
Zone C - Upper Aquifer
Zone D - Lower Aquifer (shallow)
Zone E - Lower Aquifer (deep)

Well data point
24A2 Well ID
Clay layer
Well screen

Formation:
Qa - alluvium
Qs - dune sand
Qpr - Paso Robles Formation
Tca - Careaga Formation

Figure B4

Cross-Section C-C'
Los Osos Valley
Groundwater Basin

San Luis Obispo County
February 2018 Revision

Cleath-Harris Geologists

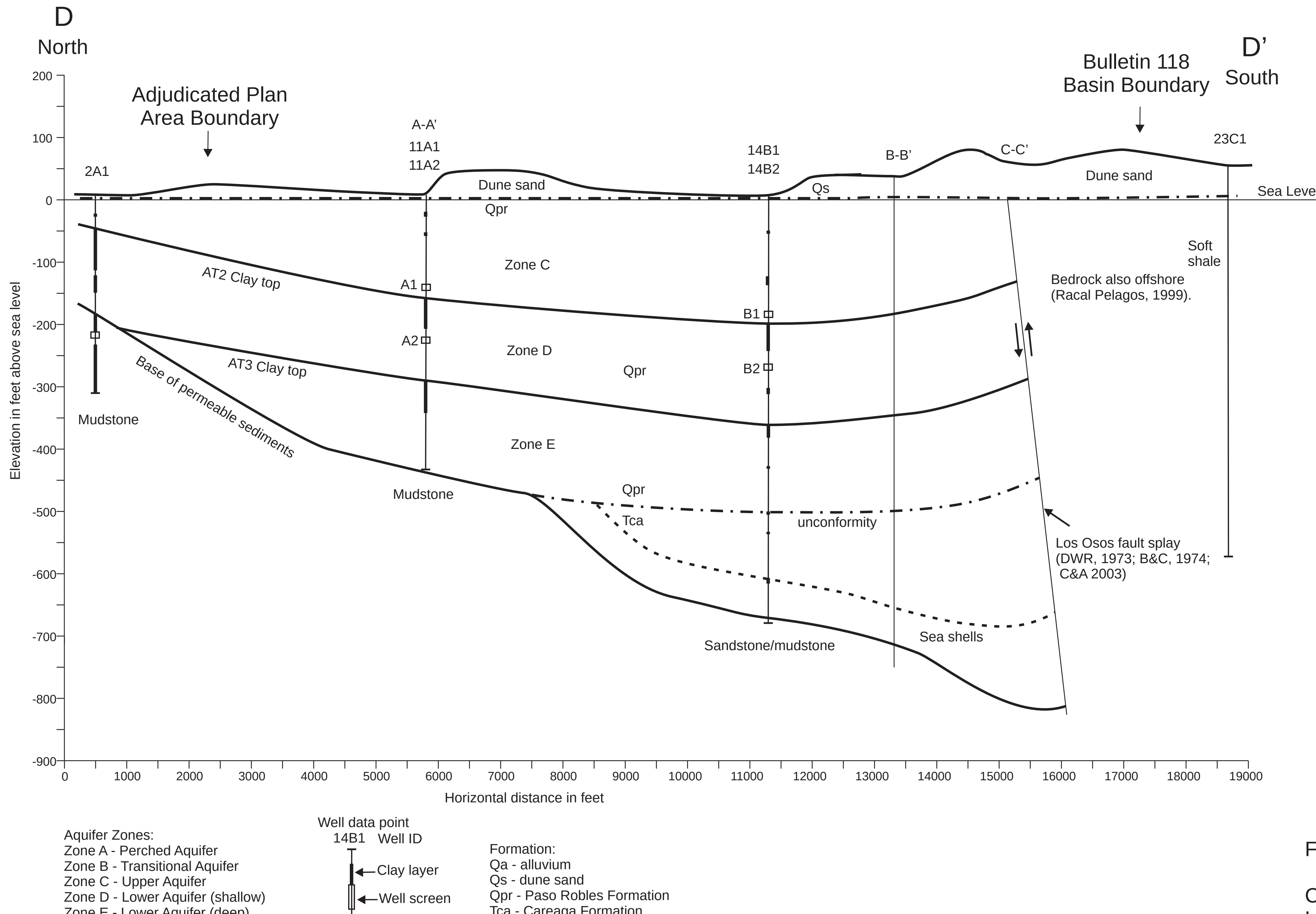


Figure B5

Cross-Section D-D'
Los Osos Valley
Groundwater Basin

San Luis Obispo County
February 2018 Revision

Cleath-Harris Geologists

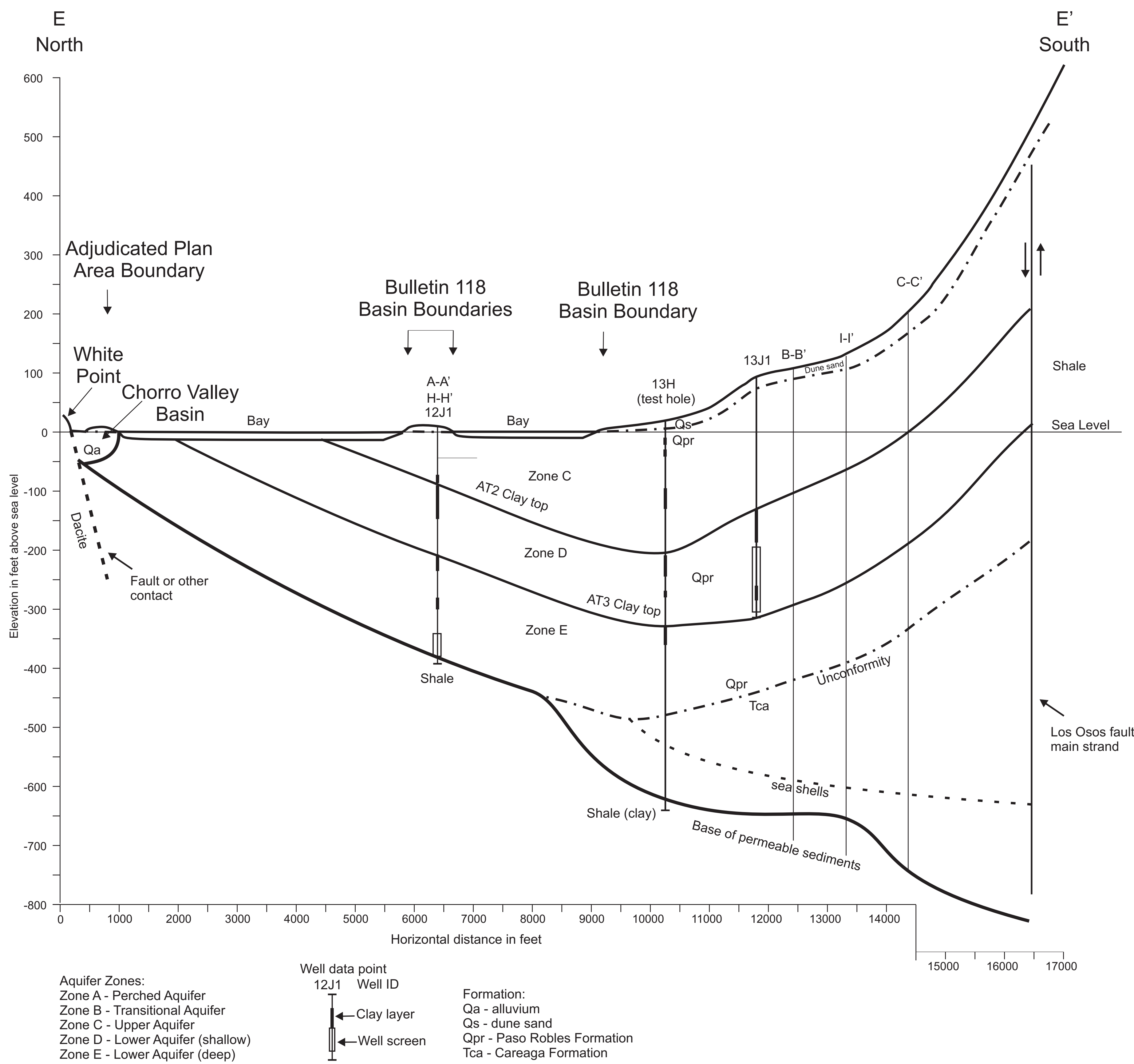


Figure B6

Cross-Section E-E'
Los Osos Valley
Groundwater Basin

San Luis Obispo County
February 2018 Revision

Cleath-Harris Geologsts

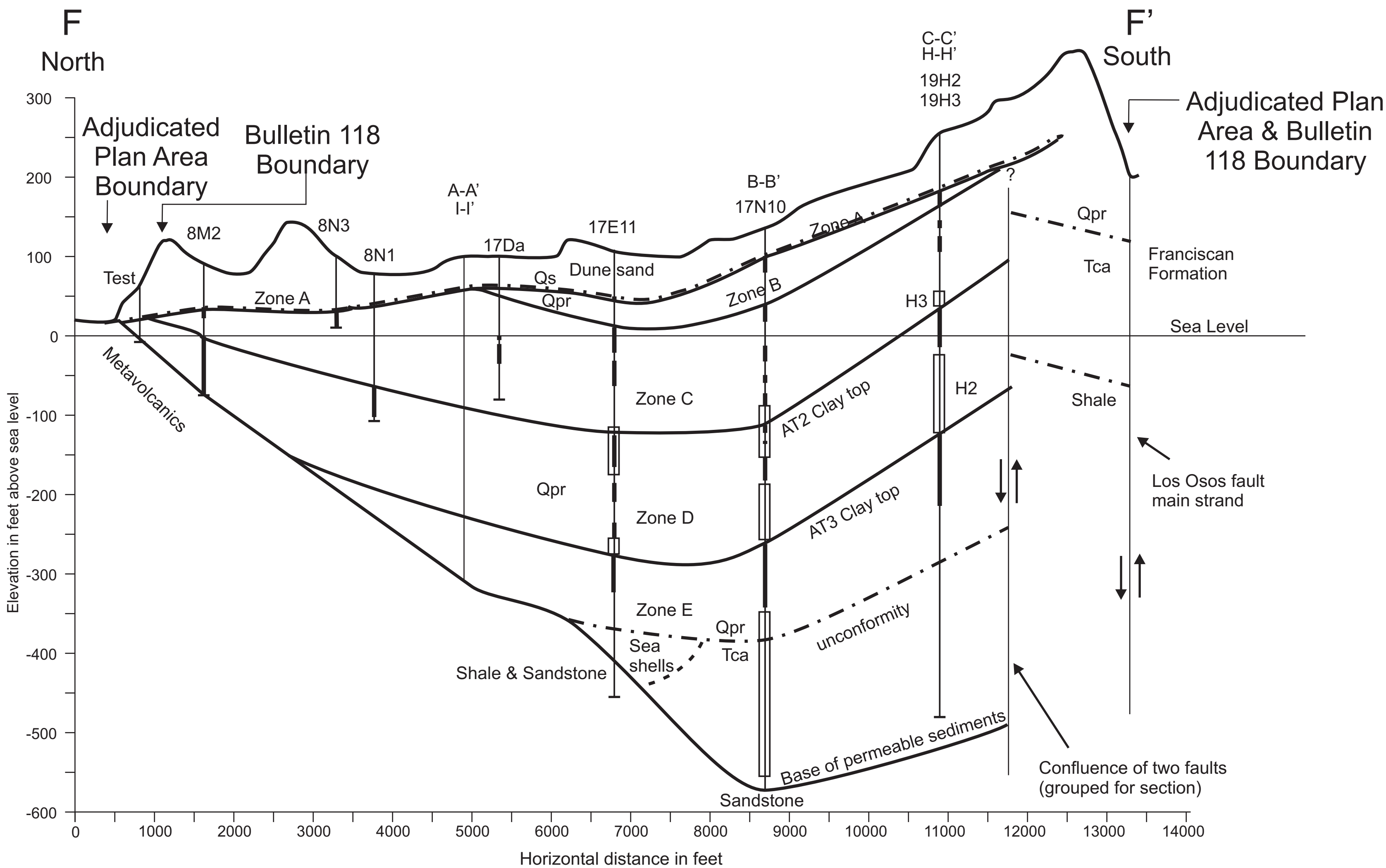


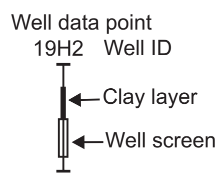
Figure B7

Cross-Section F-F'
Los Osos Valley
Groundwater Basin

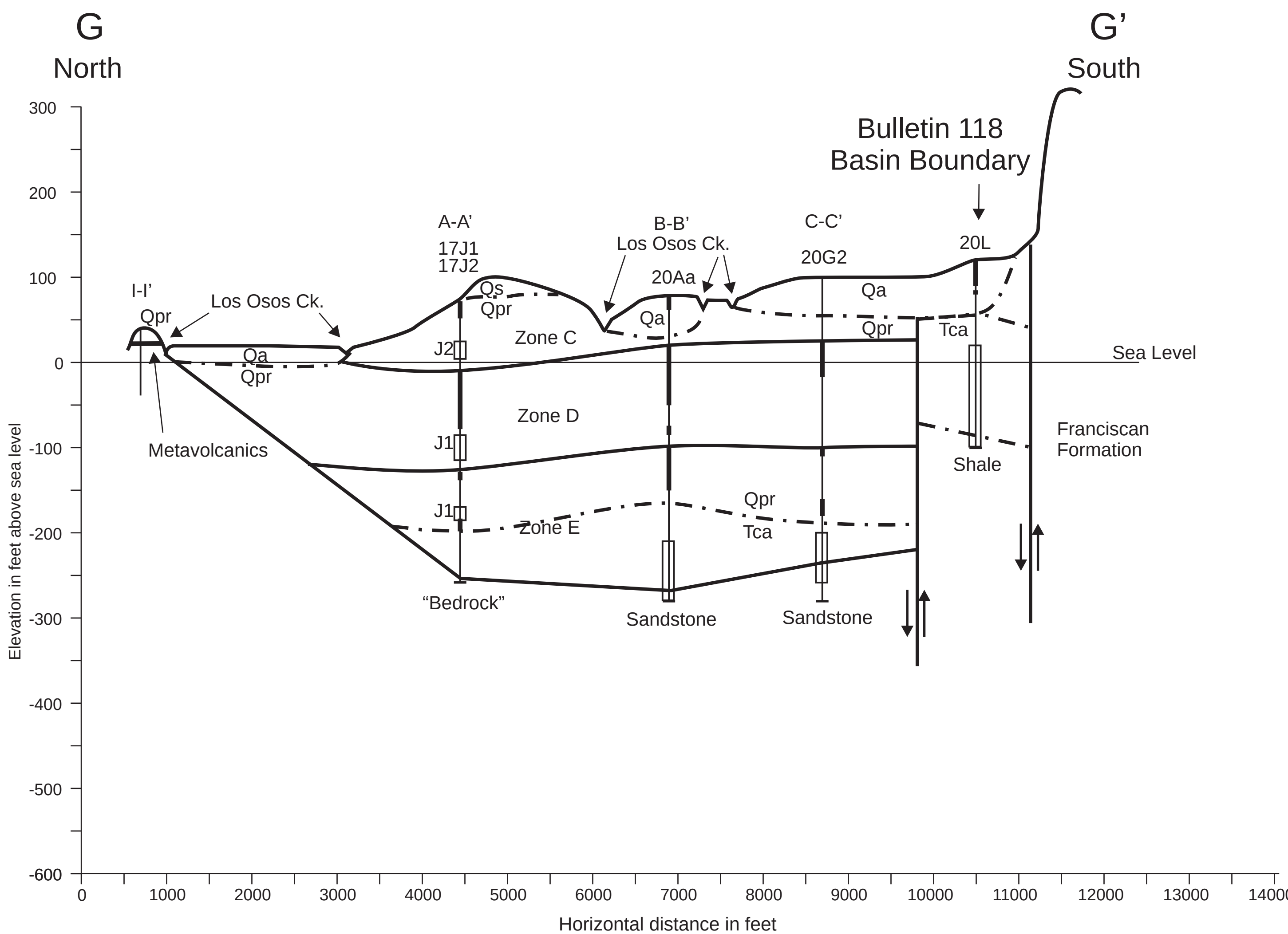
San Luis Obispo County
February 2018 Revision

Cleath-Harris Geologists

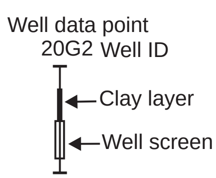
Aquifer Zones:
Zone A - Perched Aquifer
Zone B - Transitional Aquifer
Zone C - Upper Aquifer
Zone D - Lower Aquifer (shallow)
Zone E - Lower Aquifer (deep)



Formation:
Qa - alluvium
Qs - dune sand
Qpr - Paso Robles Formation
Tca - Careaga Formation



Aquifer Zones:
Zone A - Perched Aquifer
Zone B - Transitional Aquifer
Zone C - Upper Aquifer
Zone D - Lower Aquifer (shallow)
Zone E - Lower Aquifer (deep)



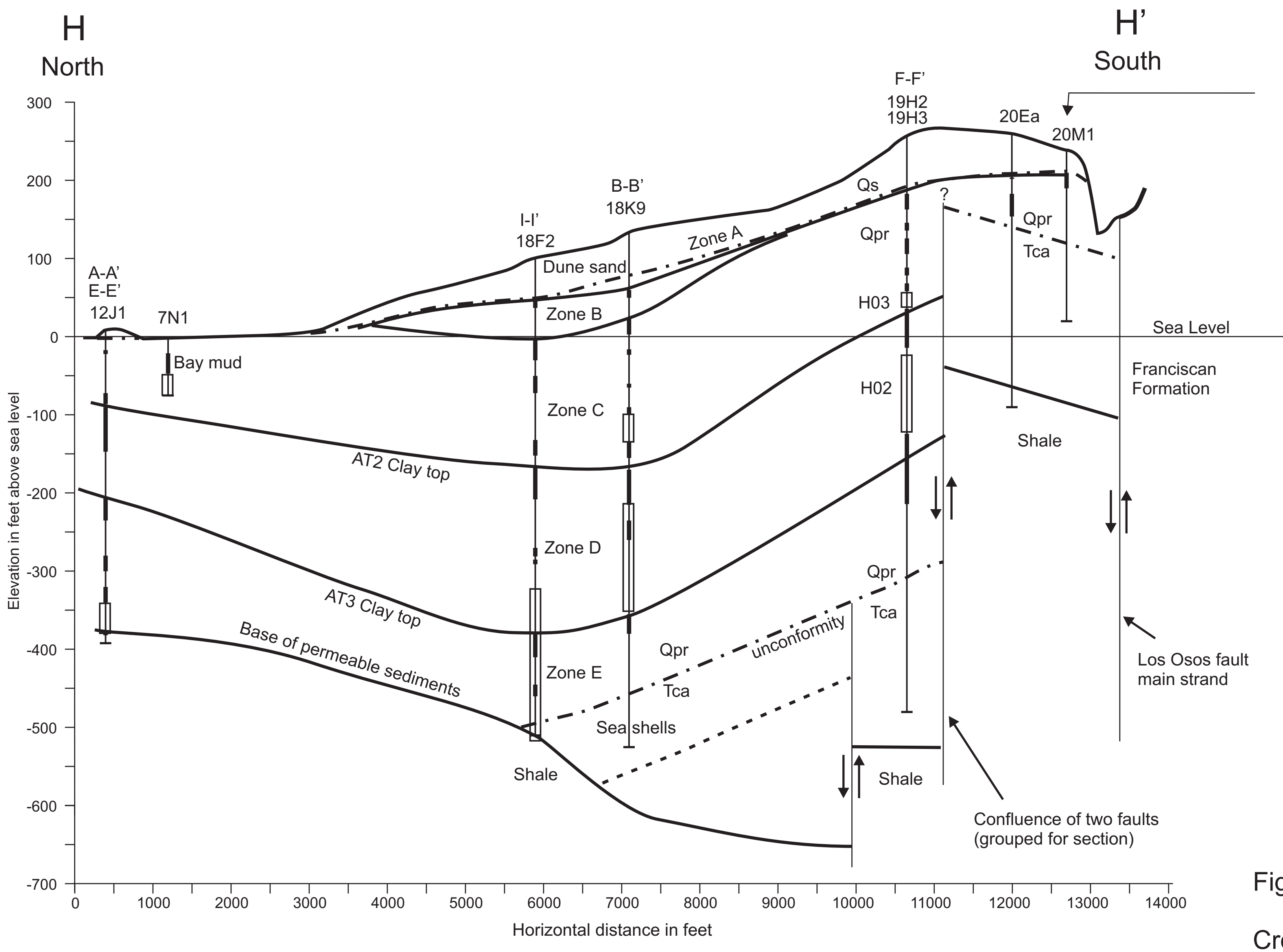
Formation:
Qa - alluvium
Qs - dune sand
Qpr - Paso Robles Formation
Tca - Careaga Formation

Figure B8

Cross-Section G-G'
Los Osos Valley
Groundwater Basin

San Luis Obispo County
February 2018 Revision

Cleath-Harris Geologists



Aquifer Zones:
Zone A - Perched Aquifer
Zone B - Transitional Aquifer
Zone C - Upper Aquifer
Zone D - Lower Aquifer (shallow)
Zone E - Lower Aquifer (deep)

Well data point
18F2 Well ID
Clay layer
Well screen

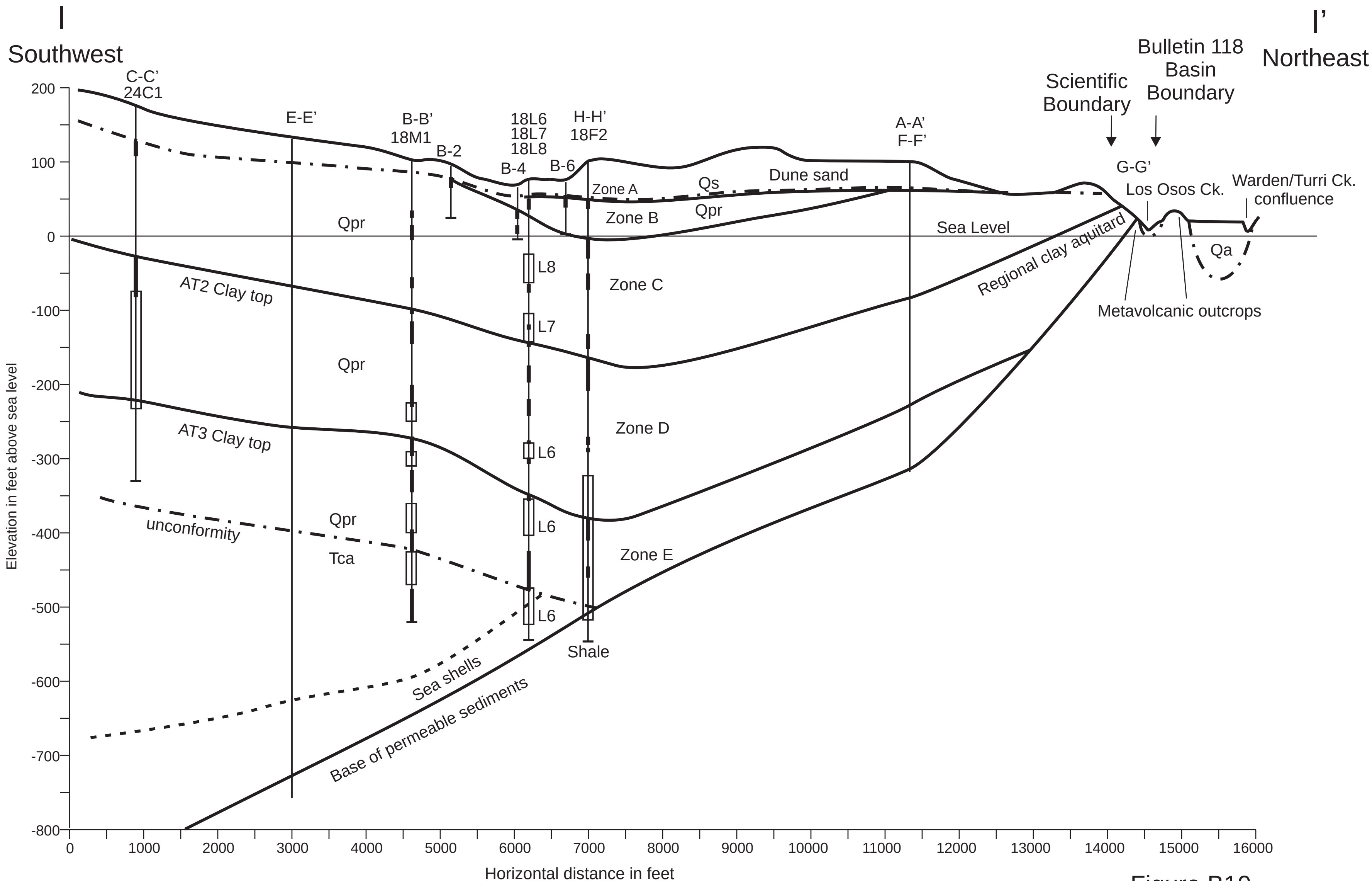
Formation:
Qa - alluvium
Qs - dune sand
Qpr - Paso Robles Formation
Tca - Careaga Formation

Figure B9

Cross-Section H-H'
Los Osos Valley
Groundwater Basin

February 2018 Revision

Cleath-Harris Geologists



Aquifer Zones:
Zone A - Perched Aquifer
Zone B - Transitional Aquifer
Zone C - Upper Aquifer
Zone D - Lower Aquifer (shallow)
Zone E - Lower Aquifer (deep)

Well data point
18M1 Well ID
Clay layer
Well screen

Formation:
Qa - alluvium
Qs - dune sand
Qpr - Paso Robles Formation
Tca - Careaga Formation

Figure B10

Cross-Section I-I’
Los Osos Valley
Groundwater Basin

San Luis Obispo County
February 2018 Revision

Cleath-Harris Geologists

APPENDIX C

Materials for Montaña de Oro Fringe area and Los Osos fault:
Marine Terrace Correlations
Geophysical Lines
DWR 1973 water levels and Los Osos fault location
DWR 1979 water quality interpretation
Cleath & Associates (2005) Figure 1

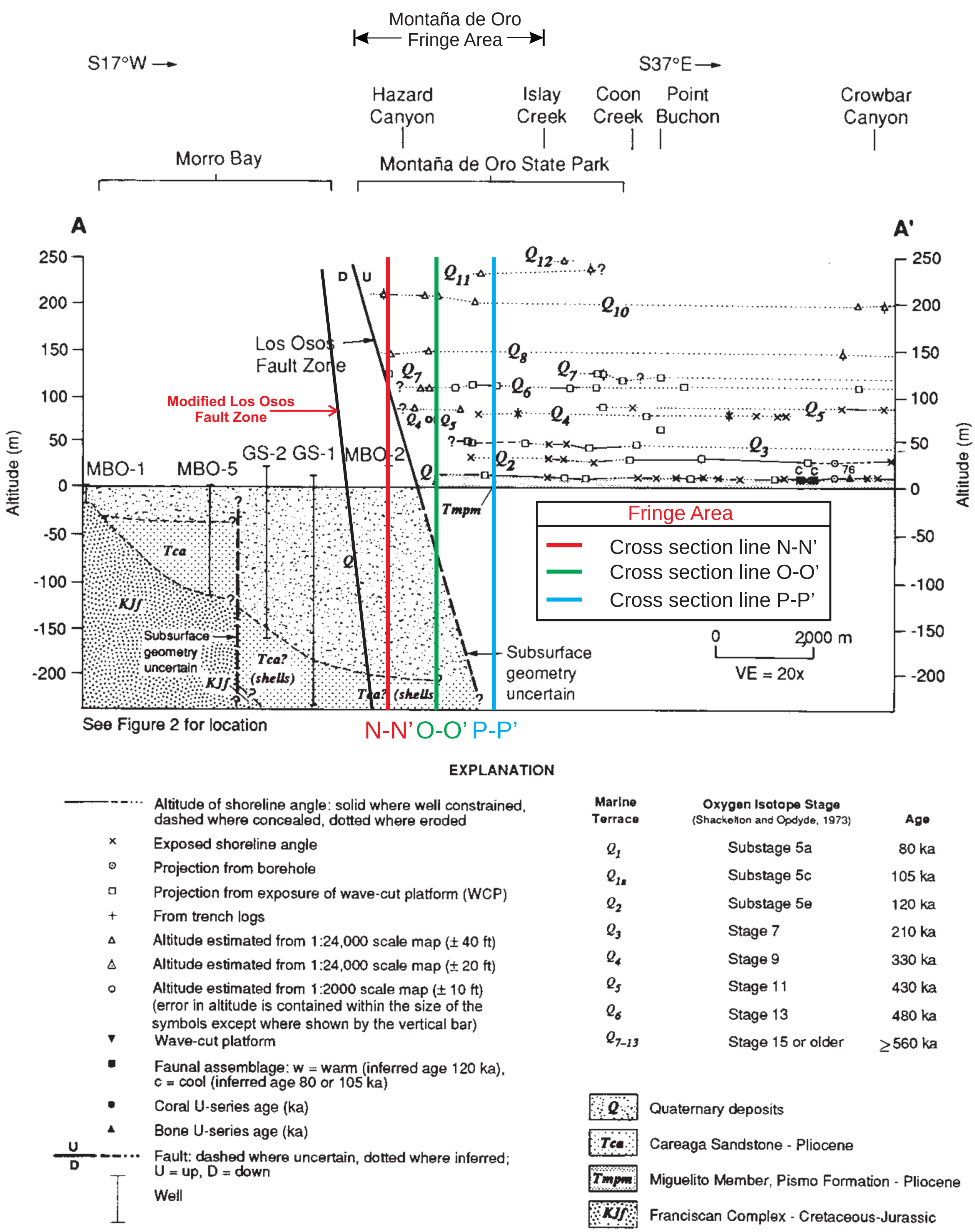


Figure 8. Shore-parallel profiles of marine terraces between Morro Bay and Crowbar Canyon, across the Los Osos fault zone. Borehole data in the Morro Bay area are shown in Figure 7. Note the abrupt truncation of marine terraces along the fault zone.

FIGURE C-1: Altitude of Marine Terraces in Montaña de Oro Fringe Area

Source: Lettis, W. R. and Hall, N. T., 1994, Los Osos Fault Zone, San Luis Obispo , California, *in* Alternman, I.B., McMullen, R.B., Cluff, L.S, and Slemmons, D.B., eds., Seismotectonics of the Central California Coast Ranges: Bouler, Colorado, Geological Society of America Special paper 292. **ANNOTATIONS FOR FRINGE STUDY SHOWN IN COLOR**

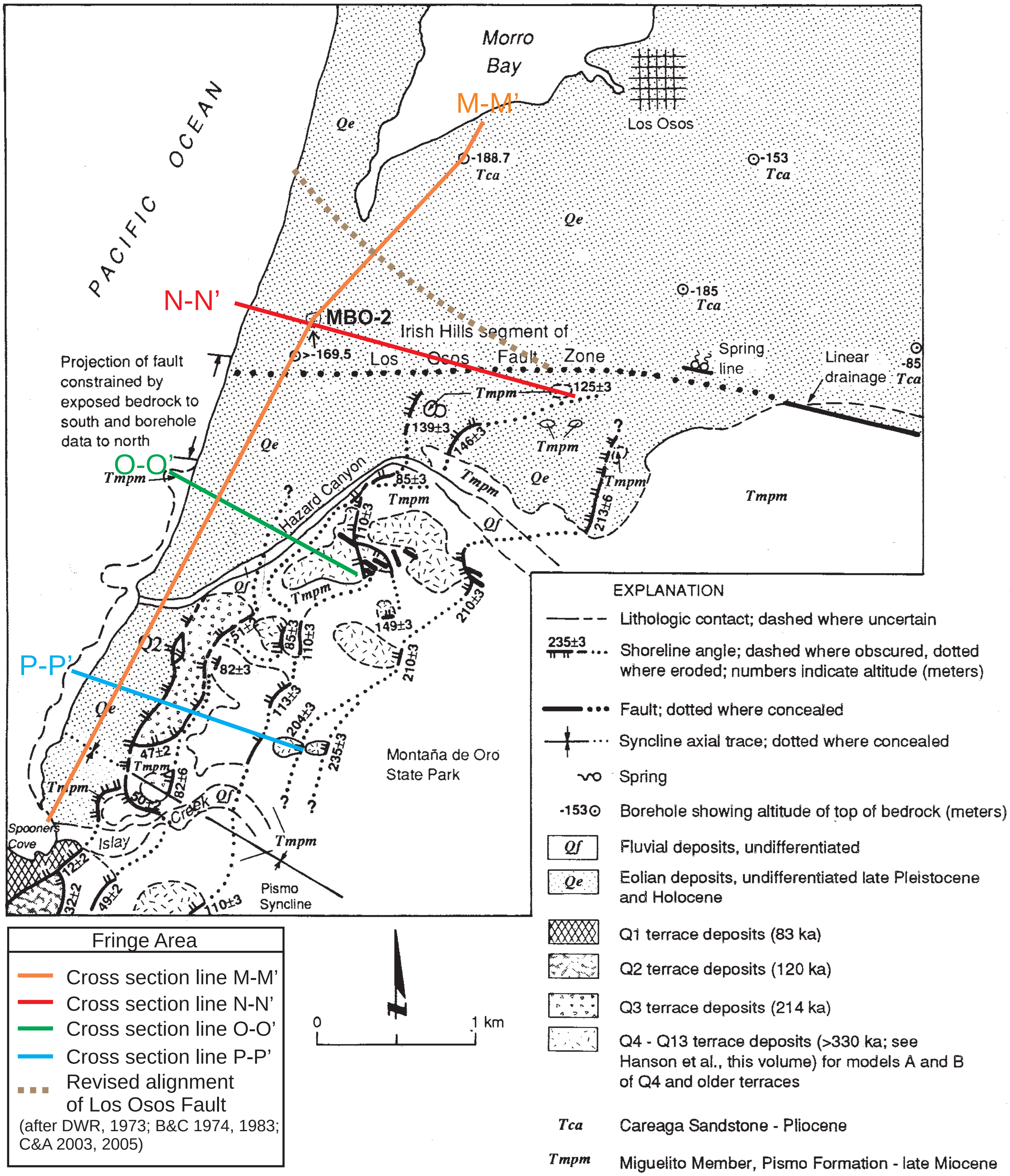


Figure 6. Generalized geologic map of Quaternary deposits in the Montaña de Oro and Morro Bay areas illustrating the distribution of marine terraces and interpreted location of the Los Osos fault zone. After Hanson et al., this volume.

FIGURE C-2: Distribution of Marine Terraces in Montaña de Oro Fringe Area

Source: Lettis, W. R. and Hall, N. T., 1994, Los Osos Fault Zone, San Luis Obispo , California, *in* Alternman, I.B., McMullen, R.B., Cluff, L.S, and Slemmons, D.B., eds., Seismotectonics of the Central California Coast Ranges: Bouler, Colorado, Geological Society of America Special paper 292. **ANNOTATIONS FOR FRINGE STUDY SHOWN IN COLOR**

Regional Site Map

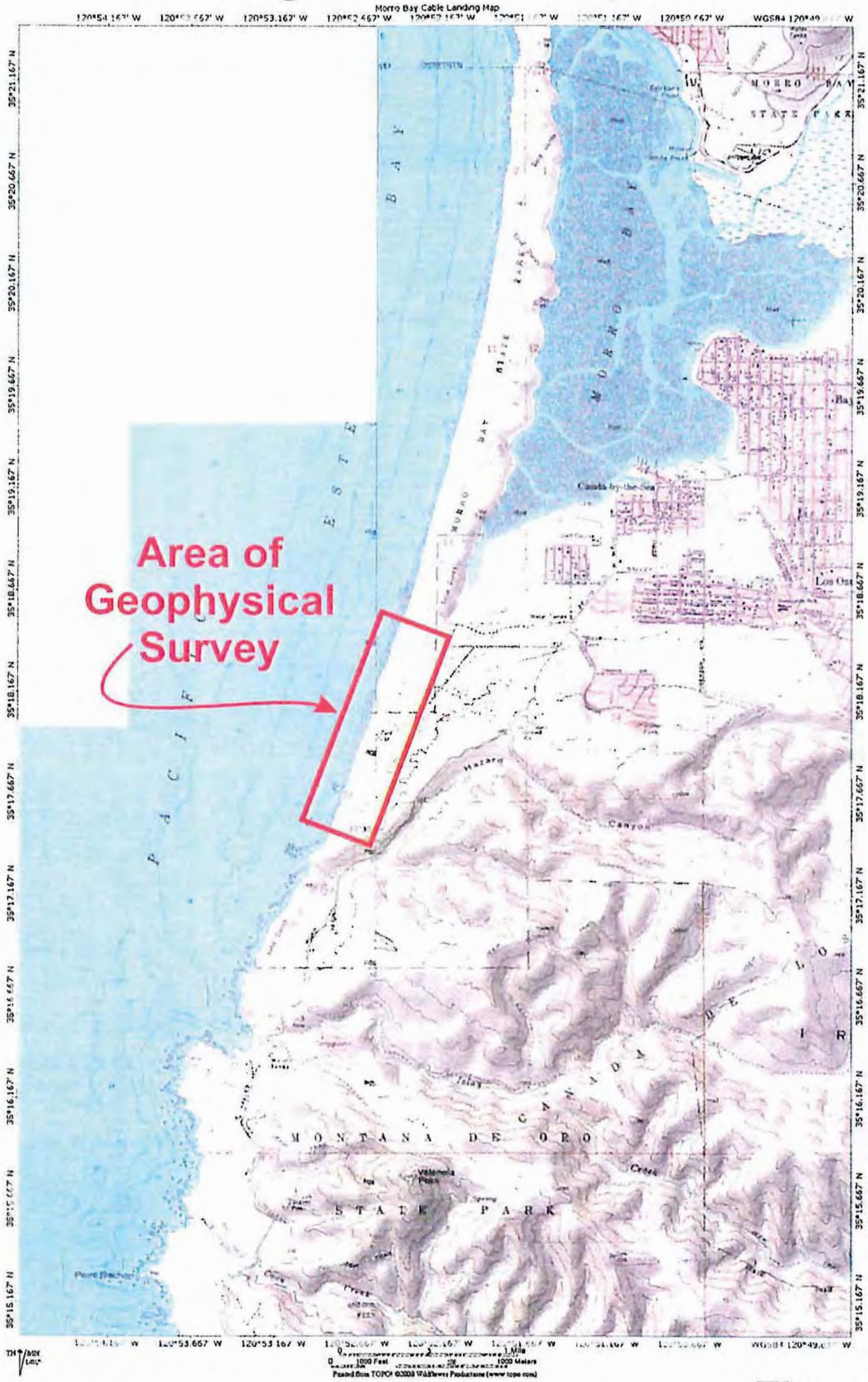


Figure 1

CONSULTANTS IN GEOPHYSICS AND GEOLOGY FOR THE ENGINEERING, GEOTECHNICAL ENVIRONMENTAL and LEGAL PROFESSIONS.

GASCH & ASSOCIATES

3174 Luyung Drive, Building #2
Rancho Cordova, California 95742 U.S.A.
(916) 635-8906 • FAX (916) 635-8907

North

WorldCom Morro Bay Landing Fiber Optic Project

Prepared for: Caprock Geology, Inc.

Project Number: 2000-52.01 **Date:** November, 2000

FIGURE C-3

Explanation*

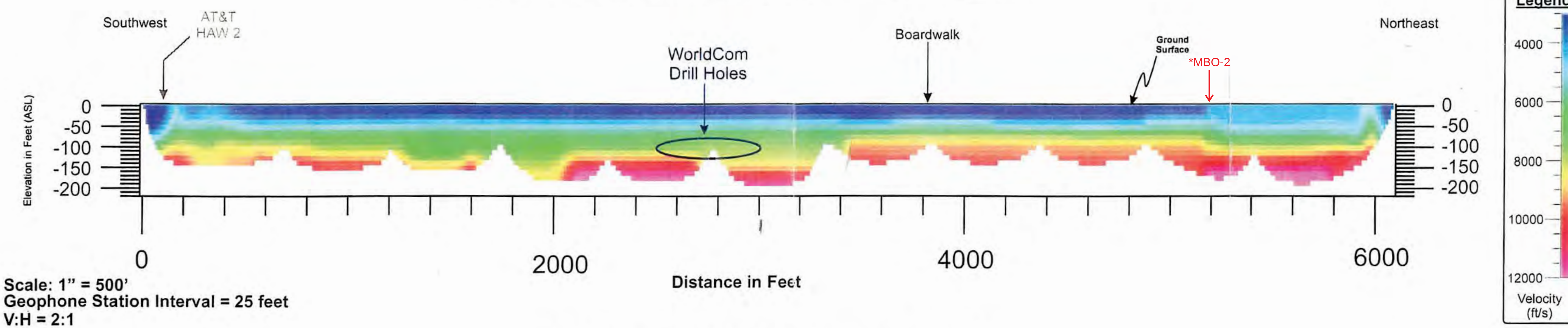
Darker Blues: 3,000 - 4,000 ft/sec = surficial beach sands and gravels.

Lighter Blues and Greens: 5,000 - 8,000 ft/sec = moderately weathered Monterey Formation or equivalent.

Yellows: ~8,500 ft/sec = Top of slightly weathered Monterey Formation.

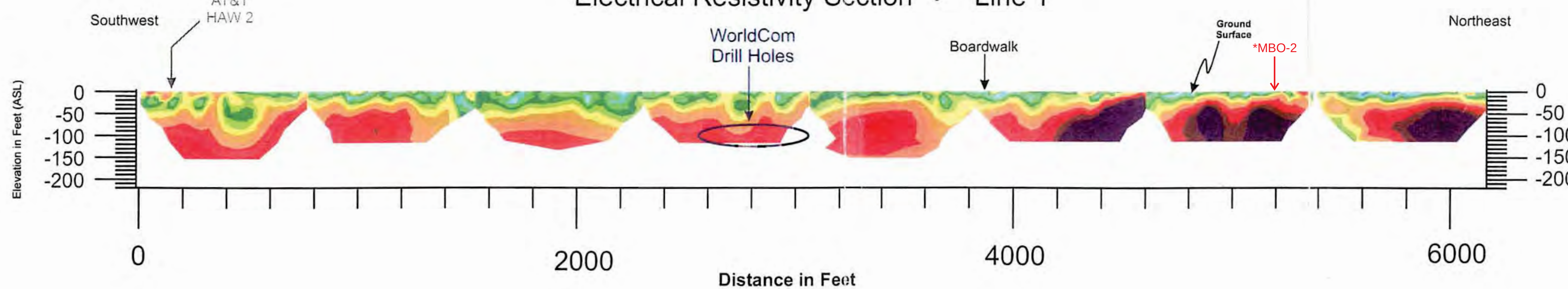
Light Reds, Pinks: >8,500 ft/sec = Un-weathered Monterey Formation.

Refraction Seismic Velocity Section • Line 1



Scale: 1" = 500'
Geophone Station Interval = 25 feet
V:H = 2:1

Electrical Resistivity Section • Line 1



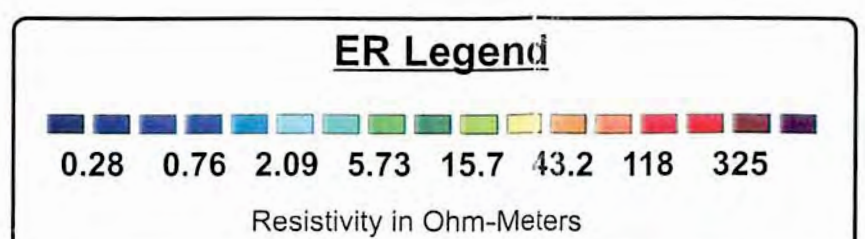
Scale: 1" = 500'
Electrode Spacing = 32.8 Feet (10 Meters)
V:H = 2:1

Explanation*

Dark Blues to Light Greens: saturated sands and Monterey Formation erosion deposits.

Yellow to Orange: Broken and weathered Monterey Formation, some moisture

Dark Orange to Purple: Slightly weathered Monterey Formation, low permeability and porosity, little moisture.



*Red explanations added by CHG from Geophysical Report text

FIGURE C-4
Results of Geophysical Lines

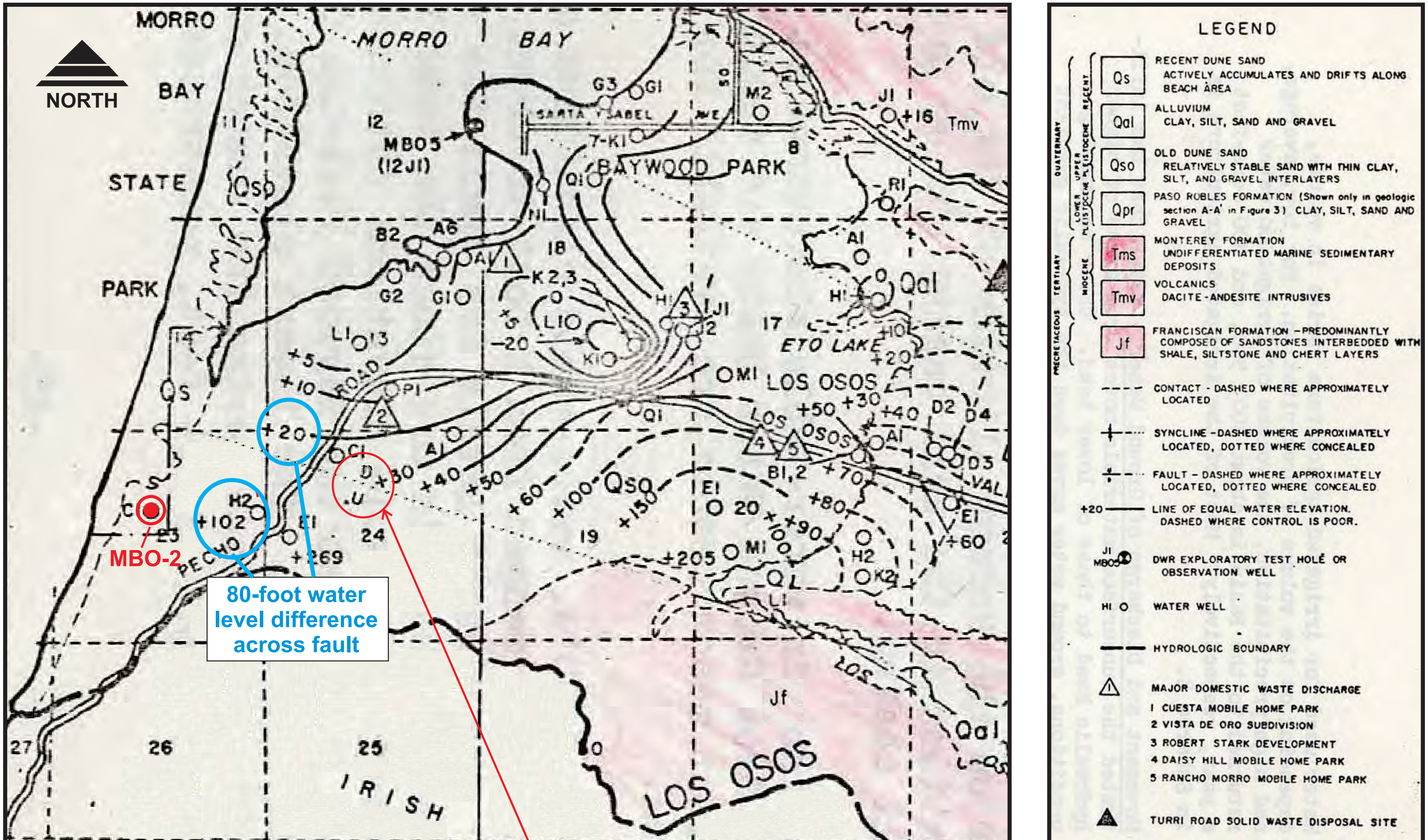
Figure 3

CONSULTANTS IN GEOPHYSICS AND GEOLOGY FOR THE ENGINEERING, GEOTECHNICAL and ENVIRONMENTAL INDUSTRIES
GASCH & ASSOCIATES
3174 Luyung Drive, Building #2
Rancho Cordova, California 95742 U.S.A.
(916) 635-8906 • FAX (916) 635-8907

WorldCom Morro Bay Landing Fiber Optic Project

Prepared for: Caprock Geology Inc.

Project Number: 2000-52.01 **Date:** November, 2000



Source: State of California Department of Water Resources; *Los Osos-Baywood Ground Water Protection Study.* District Report, page 26. October 1973

Additions by CHG for Fringe Study shown in color.

Orientation and up/down motion on the Los Osos Fault consistent with Brown and Caldwell (1974) and Cleath & Associates (2005).

FIGURE C-5: Historical water level difference across Los Osos fault supports flow barrier. Fault is mapped by DWR north of MBO-2.

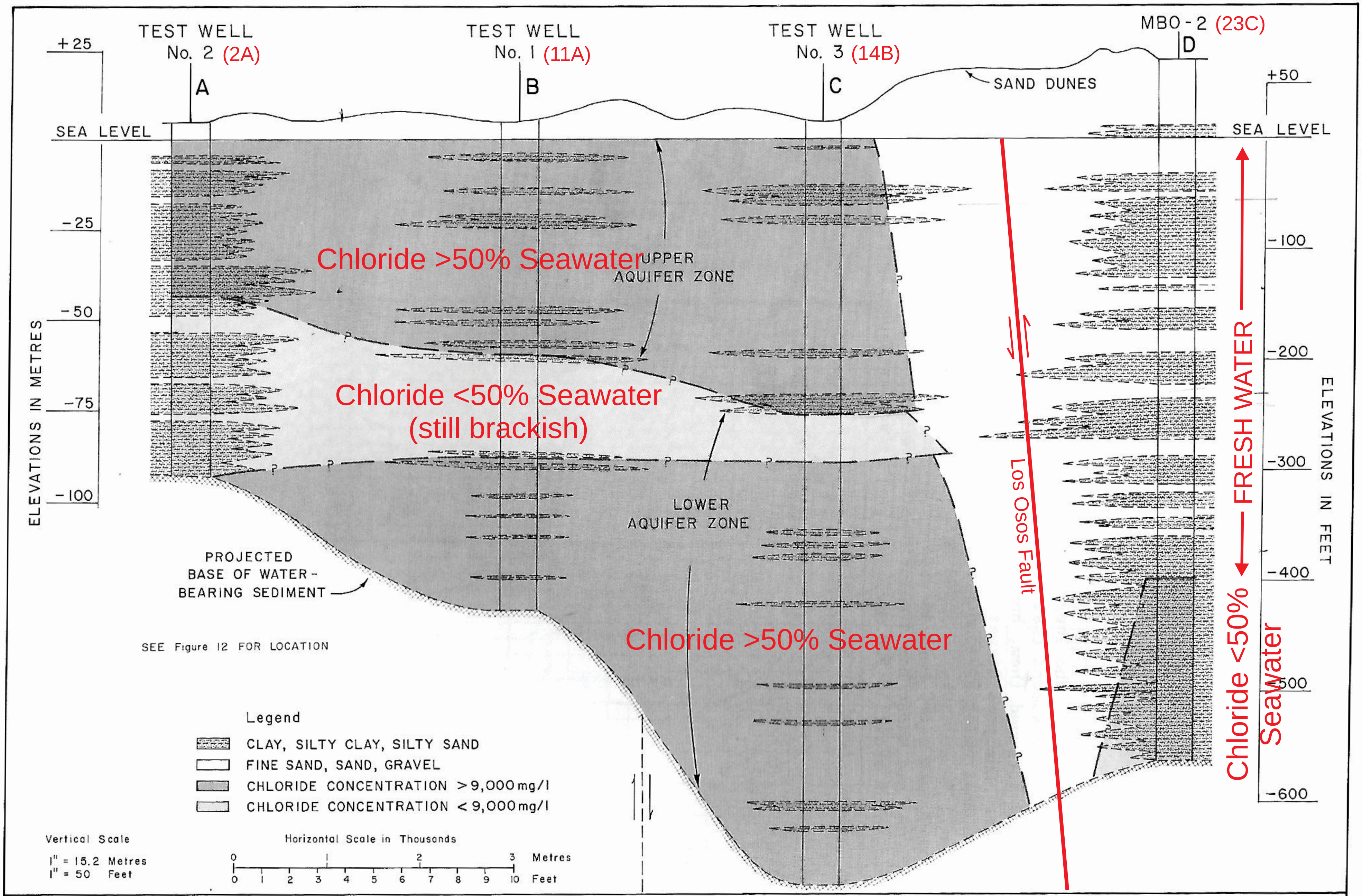


Figure II - SEA WATER INTRUSION SECTION A-B-C-D OF THE MORRO BAY SANDSPIT

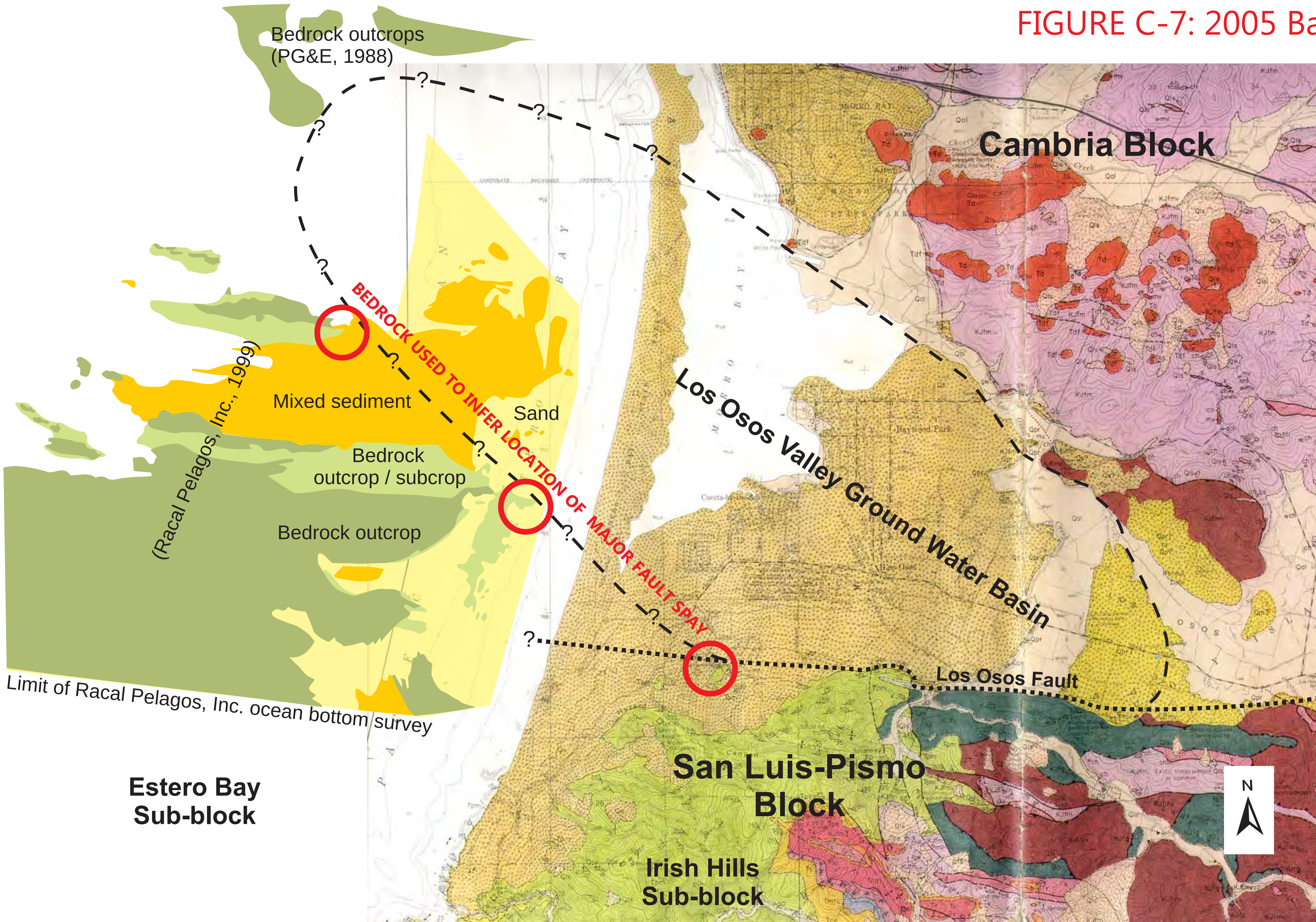
DEPARTMENT OF WATER RESOURCES, SOUTHERN DISTRICT, 1979

Source: DWR, 1979, Morro Bay Sandspit Investigations

Additions by CHG for Fringe Study shown in color.

FIGURE C-6: Water quality differences across Los Osos fault at coast.

FIGURE C-7: 2005 Basin Boundary



Map Geology:

(Onshore)
C.A. Hall, Jr., et al, 1979
Geologic Map of the
San Luis Obispo-
San Simeon Region,
California
U.S.G.S. Map I-1097

(Offshore)
Racal Pelagos, Inc. 1999
Draft Pre-Installation Geophysical
Survey Preliminary Interpretation
Morro Bay, California
Plate 5A

PG&E, 1988
Diablo Canyon Power Plant
Long-Term Seismic Program
Plate 4, Sheet 2

explanation of map symbols
and geologic units attached
seperately

Approximate Basin Limits

Main strand of Los Osos
fault (approximate location)

Scale: 1" = 4000'

Figure 1

Geology
Los Osos Area

DWR Grant Project
Los Osos CSD

Cleath & Associates

Source:
Cleath & Associates, 2005 Sea Water Intrusion Assessment
and Lower Source Investigation of the Los Osos Valley Ground Water Basin

Additions by CHG for Fringe Study shown in color.

APPENDIX D

Soil Moisture Budget Results
Eastern Valley Fringe Area

TABLE D-1

SOIL-MOISTURE BUDGET EXAMPLE - TURF/PASTURE Periods 1-5

Water Holding Capacity (WHC) (in/ft)	**2**	CLAY
Active Root Zone Depth (ft)	**1.5**	See USDA NRCS Irrigation Guide 210-V1-NEH 652, Amendment WA1, Jan 2005
WHC of Active Root Zone (in)	**3.0**	
Crop Coeficient (Kc)	**1**	

	[A]	[B]	[C]	[D]	[E]	[F]	[G]	[H]	[I]	[J]	[K]	[L]	[M]	[N]
Period	Year	Month	Potential ET (ETo) CIMIS 160	Crop Coefficient (Kc)	Crop ET (ETc)	Runoff Adjusted Precipitation	Total Precip	Water Available from Soil Profile	ETc met by Precip	ETc met by Profile	Precip Available for Profile	Soil Moisture Deficit	Monthly Percolation past Active Root Zone	Total Perc of Precip
	2010/2011		(in)	(in)	(in)	(in)	(in)	(in)	(in)	(in)	(in)	(in)	(in)	(in)
												0.00		
	2005	Oct	3.83	1.00	3.83	0.2		3.00	0.20	3.00	0.00	-3.00	0.00	
	2005	Nov	2.76	1.00	2.76	0.7		0.00	0.70	0.00	0.00	-3.00	0.00	
	2005	Dec	1.87	1.00	1.87	2.3		0.00	1.87	0.00	0.43	-2.57	0.00	
	2006	Jan	2.23	1.00	2.23	4.1		0.43	2.23	0.00	1.87	-0.70	0.00	
	2006	Feb	2.98	1.00	2.98	3.4		2.30	2.98	0.00	0.42	-0.28	0.00	
1	2006	Mar	2.98	1.00	2.98	3.6	**14.30**	2.72	2.98	0.00	0.62	0.00	0.34	**0.34**
	2006	Apr	3.3	1.00	3.30	3.4		3.00	3.30	0.00	0.10	0.00	0.10	
	2006	May	5.07	1.00	5.07	2.4		3.00	2.40	2.67	0.00	-2.67	0.00	
	2006	Jun	5.64	1.00	5.64	0		0.33	0.00	0.33	0.00	-3.00	0.00	
	2006	Jul	5.97	1.00	5.97	0		0.00	0.00	0.00	0.00	-3.00	0.00	
	2006	Aug	5.28	1.00	5.28	0		0.00	0.00	0.00	0.00	-3.00	0.00	
2	2006	Sep	4.3	1.00	4.30	0	**5.80**	0.00	0.00	0.00	0.00	-3.00	0.00	**0.10**
	2006	Oct	3.59	1.00	3.59	0.2		0.00	0.20	0.00	0.00	-3.00	0.00	
	2006	Nov	2.73	1.00	2.73	0.4		0.00	0.40	0.00	0.00	-3.00	0.00	
	2006	Dec	2.35	1.00	2.35	2.1		0.00	2.10	0.00	0.00	-3.00	0.00	
	2007	Jan	2.51	1.00	2.51	1.1		0.00	1.10	0.00	0.00	-3.00	0.00	
	2007	Feb	2.3	1.00	2.30	2.3		0.00	2.30	0.00	0.00	-3.00	0.00	
3	2007	Mar	4.01	1.00	4.01	0.4	**6.50**	0.00	0.40	0.00	0.00	-3.00	0.00	**0.00**
	2007	Apr	4.58	1.00	4.58	0.3		0.00	0.30	0.00	0.00	-3.00	0.00	
	2007	May	5.51	1.00	5.51	0		0.00	0.00	0.00	0.00	-3.00	0.00	
	2007	Jun	5.99	1.00	5.99	0		0.00	0.00	0.00	0.00	-3.00	0.00	
	2007	Jul	6.06	1.00	6.06	0		0.00	0.00	0.00	0.00	-3.00	0.00	
	2007	Aug	5.69	1.00	5.69	0		0.00	0.00	0.00	0.00	-3.00	0.00	
4	2007	Sep	4.88	1.00	4.88	0	**0.30**	0.00	0.00	0.00	0.00	-3.00	0.00	**0.00**
	2007	Oct	4.06	1.00	4.06	0.4		0.00	0.40	0.00	0.00	-3.00	0.00	
	2007	Nov	2.82	1.00	2.82	0.1		0.00	0.10	0.00	0.00	-3.00	0.00	
	2007	Dec	2.37	1.00	2.37	2.4		0.00	2.37	0.00	0.03	-2.97	0.00	
	2008	Jan	2.04	1.00	2.04	9.5		0.03	2.04	0.00	7.46	0.00	4.49	
	2008	Feb	2.73	1.00	2.73	2.7		3.00	2.70	0.03	0.00	-0.03	0.00	
5	2008	Mar	4.43	1.00	4.43	0	**15.10**	2.97	0.00	2.97	0.00	-3.00	0.00	**4.49**

Sample calculations:

TABLE D-1
Turf/Pasture soil moisture budget

March 2006:
ETo = 2.98 inches
Kc = 1
ETc = ETo*Kc = 2.98 inches
[F] Runoff-Adjusted Precipitation* = (3.9 inches * 0.91117) = 3.6 inches
[H] Water Available from Soil Profile = WHC of active root zone (3 inches) - soil moisture deficit in Feb 2006 (-0.28 inches) = 2.72 inches
[I] ETc met by precip = **[E]** ETc OR **[F]** Runoff-Adjusted Precip, whichever is smaller (in this case ETc) = 2.98 inches
[J] ETc met by profile = **[H]** Water available from profile OR (**[E]** ETc-**[I]** ETc met by precipitation), whichever is smaller (in this case ETc-ETc met by precip = 0 inches
[K] Precip available for profile = **[F]** Runoff-adjusted precip (3.6 inches) - **[I]** ETc met by precip (2.98 inches) = 0.62 inches
[M] Monthly Percolation past active root zone = whichever is greater between 0 inches and (Feb **[L]** soil moisture deficit (-0.28 inches) + **[F]** Precip available for soil profile (0.62 inches)) = 0.34 inches
[L] March 2006 soil moisture deficit = whichever is greater between -WHC of active root zone (-3.0 inches) and the minimum of either 0 inches or (Feb 2006 soil moisture deficit (-0.28 inches) - **[J]** ETc met by profile (0 inches) + **[K]** Precip avail for profile (0.62 inches)), in this case 0 inches.

<u>*Precip adjustment to account for runoff losses prior to soil moisture budget calculations:</u>
From USGS (Yates and Weise, 1988) Table 1, page 18:
Watershed area 5 (Eastern Valley) = 5,799 acres
Surface runoff to creeks = 870 acre-feet per year (1970-1977)
Average annual precip over period = 15.2 inches = 1.267 feet
Average annual precip over watershed = 1.267 feet * 5,799 acres = 7,347 acre-feet
Percent annual runoff = 870 acre-feet / 7,347 acre-feet = 0.1184 (11.84 percent)
Assume nominal 25 percent less runoff from valley area (1760 acres) compared to steeper watershed areas.
Percent annual runoff from valley area = 0.1184*0.75 = 0.08883 percent
Precip for soil moisture calculations = Precip (County gage) * (1-0.08883) = Precip * 0.91117

TABLE D-2
SOIL-MOISTURE BUDGET RESULTS
PERCOLATION OF PRECIPITATION
COMPILED INTO 6-MONTH PERIODS

	Period	1	2	3	4	5	6	7	8	9	10	11	12	TOTAL
	6-month period ending	Mar-06	Sep-06	Mar-07	Sep-07	Mar-08	Sep-08	Mar-09	Sep-09	Mar-10	Sep-10	Mar-11	Sep-11	
	Rainfall in period (in)	15.56	6.34	7.17	0.39	16.69	0.24	7.21	0.79	24.16	2.09	29.69	2.09	
Direct Perc of Precip (in)	Impervious (perc. along edge)	1.97	0.62	0.00	0.00	2.80	0.00	0.58	0.00	4.82	0.00	8.33	0.00	19.13
	Soil and Barren	3.57	3.12	0.00	0.00	1.18	0.00	0.00	0.00	2.94	0.00	12.26	0.00	23.07
	Trees and Forest	2.99	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.42
	Grass and Herbaceous	2.56	1.10	0.00	0.00	3.55	0.00	0.00	0.00	5.17	0.00	10.40	0.00	22.79
	Agriculture	4.68	3.00	0.00	0.00	2.72	0.00	0.00	0.00	5.02	0.00	13.51	0.00	28.93
	Riparian	0.98	0.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.33	0.00	4.07
Direct Perc of Precip (acre-feet)	Impervious (perc. along edge)	12.35	3.91	0.00	0.00	17.56	0.00	3.61	0.00	30.23	0.00	52.22	0.00	119.88
	Soil and Barren	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Trees and Forest	16.06	2.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	18.37
	Grass and Herbaceous	123.67	53.37	0.00	0.00	171.94	0.00	0.00	0.00	250.08	0.00	503.26	0.00	1102.32
	Agriculture	372.99	238.85	0.00	0.00	216.74	0.00	0.00	0.00	399.91	0.00	1075.84	0.00	2304.33
	Riparian	11.17	8.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26.54	0.00	46.38
	TOTAL	536.25	307.10	0.00	0.00	406.24	0.00	3.61	0.00	680.22	0.00	1657.86	0.00	3591.27

	1	2	3	4	5	6	7	8	9	10	11	12
Model Area Perc of Precip (ft/day)	0.001621	0.00093	0	0	0.00123	0	1.09E-05	0	0.00206	0	0.00501	0

	Period	13	14	15	16	17	18	19	20	21	22	23	24	TOTAL
	6-month period ending	Mar-12	Sep-12	Mar-13	Sep-13	Mar-14	Sep-14	Mar-15	Sep-15	Mar-16	Sep-16	Mar-17	Sep-17	
	Rainfall in period (in)	8.70	2.24	7.63	0.47	6.12	0.71	6.90	2.80	13.94	0.20	25.81	0.93	
Direct Perc of Precip (in)	Impervious (perc. along edge)	0.00	0.00	0.26	0.00	0.39	0.00	0.89	0.00	1.04	0.00	6.44	0.00	9.01
	Soil and Barren	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.16	0.00	4.91	0.00	5.25
	Trees and Forest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Grass and Herbaceous	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.48	0.00	7.55	0.00	8.58
	Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.87	0.00	6.87	0.00	7.78
	Riparian	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	0.00	0.54
Direct Perc of Precip (acre-feet)	Impervious (perc. along edge)	0.00	0.00	1.60	0.00	2.43	0.00	5.60	0.00	6.49	0.00	40.37	0.00	56.49
	Soil and Barren	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Trees and Forest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Grass and Herbaceous	0.00	0.00	0.00	0.00	0.00	0.00	26.18	0.00	23.28	0.00	365.41	0.00	414.86
	Agriculture	0.00	0.00	0.00	0.00	0.00	0.00	3.03	0.00	68.91	0.00	547.29	0.00	619.22
	Ripartian	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.11	0.00	6.11
	TOTAL	0.00	0.00	1.60	0.00	2.43	0.00	34.81	0.00	98.67	0.00	959.18	0.00	1096.68

Percolation of Precipitation Totals

Step 1) Multiply land cover percent from report Table 4 * total percolation of precipitation for each land cover type from soil moisture budget (in this example, TURF/PASTURE accounts for 10% of the URBAN BUILT-UP Land Cover Type).
Step 2) Sum the result of Step 1 together and enter into Table D-2.
Step 3) Total the acre-feet values for each land cover over the base period (12 years) and divide by 12 to obtain annual average percolation of precipitation:

Land Cover Type	Percolation of Precipitation (Acre-Feet)			
	Mar 06 - Sep 11 TOTAL from Table D-2	Mar 12 - Sep 17 TOTAL from Table D-2	Total for all 12 years	Per year
Urban Built Up	119.90	56.49	176.39	14.7
Trees	18.37	0.00	18.37	1.5
Herbaceous	1102.32	414.86	1517.19	126.4
Agriculture	2304.33	619.22	2923.55	243.6
Riparian	46.38	6.11	52.49	4.4
Total	3591.27	1096.68	4687.96	390.7

APPENDIX E

Specific Yield Analysis - Eastern Valley Fringe Area

TABLE E-1: WCR # 231405

Lithology	***Start Depth***	***End Depth***	***Thickness***	***Specific Yield (percent)****	***Zone***	***Weighted Specific Yields (percent)***
adobe	0	1	1	5	**Clay**	
brown clay	1	35	34	3		
blue clay	35	40	5	3		
red SS & shale	40	45	5	14	**Aquifer**	
red clay	45	49	4	3		
red SS & shale	49	50	1	14		
red clay	50	58	8	3		
red SS & shale	58	80	22	14		
brown clay	80	88	8	3		Aquifer Specific Yield
red SS & shale	88	94	6	14		9.9
blue clay	94	123	29	3	Bedrock	
Total Depth	123	Alluvial Saturated thickness	65	**SATURATED SPECIFIC YIELD (PERCENT)**		**8.7**

** Johnson, A. I., 1967, Specific Yield - Compilation of Specific Yields for Various Materials, U.S. Geological Survey Water Supply Paper 1662-D*

TABLE E-2: WCR # 327958						
Lithology	***Start Depth***	***End Depth***	***Thickness***	***Specific Yield (percent)****	***Zone***	***Weighted Specific Yields (percent)***
top soil	0	3	3	5	Clay	
brown clay	3	24	21	3		
gravel	24	35	11	21	Aquifer	
blue clay	35	42	7	3		
sand & gravel	42	45	3	21		
blue clay	45	68	23	3		
sand & gravel	67	76	9	21		Aquifer Specific Yield
yellow clay & gravel	76	95	19	7		9.8
frac blue SS	95	110	15		Bedrock	
Total Depth	110	Alluvial Saturated thickness	65	**SATURATED SPECIFIC YIELD (PERCENT)**		**8.6**

** Johnson, A. I., 1967, Specific Yield - Compilation of Specific Yields for Various Materials, U.S. Geological Survey Water Supply Paper 1662-D*

TABLE E-3: WCR # 327953						
Lithology	***Start Depth***	***End Depth***	***Thickness***	***Specific Yield (percent)****	***Zone***	***Weighted Specific Yields (percent)***
top soil	0	4	4	5	Clay	
gravel & yellow clay	4	17	13	7		
sand & gravel	17	36	19	21	Aquifer	
gravel	36	48	12	21		
blue clay	48	60	12	3		
sand & gravel	60	64	4	21		
yellow clay & gravel	64	70	6	7		
soft sandstone	70	85	15	18		Aquifer Specific Yield
clay & sand	85	92	7	5		14.9
clay & shale	92	100	8		Bedrock	
red / blue sh /rock	100	160	60			
Total Depth	160	Alluvial Saturated thickness	65	**SATURATED SPECIFIC YIELD (PERCENT)**		**14**

** Johnson, A. I., 1967, Specific Yield - Compilation of Specific Yields for Various Materials, U.S. Geological Survey Water Supply Paper 1662-D*

TABLE E-4: WCR # 576101						
Lithology	***Start Depth***	***End Depth***	***Thickness***	***Specific Yield (percent)****	***Zone***	***Weighted Specific Yields (percent)***
black adobe	0	3	3	3	Clay	
silty clay	3	21	18	5		
red rock	21	30	9	14	Aquifer	
sandy clay	30	40	10	5		Aquifer Specific Yield
frac serpentine	40	51	11	14		11
silty clay	51	55	4		Bedrock	
serpentine	55	100	45			
Total Depth	100	Alluvial Saturated thickness	45	**SATURATED SPECIFIC YIELD (PERCENT)**		**9**

** Johnson, A. I., 1967, Specific Yield - Compilation of Specific Yields for Various Materials, U.S. Geological Survey Water Supply Paper 1662-D*

TABLE E-5: WCR # 758424

Lithology	*Start Depth*	*End Depth*	*Thickness*	*Specific Yield (percent)**	*Zone*	*Weighted Specific Yields (percent)*
top soil	0	2	2	3	Clay	
adobe	2	5	3	5		
brown clay	5	25	20	3		
clay & gravel	25	30	5	7		Aquifer Specific Yield
sand & gravel	30	52	22	21	**Aquifer**	21
blue SS	52	60	8		**Bedrock**	
Total Depth	60	Alluvial Saturated thickness	35	**SATURATED SPECIFIC YIELD (PERCENT)**		**15.1**

** Johnson, A. I., 1967, Specific Yield - Compilation of Specific Yields for Various Materials, U.S. Geological Survey Water Supply Paper 1662-D*

TABLE E-6: WCR # E0081746

Lithology	*Start Depth*	*End Depth*	*Thickness*	*Specific Yield (percent)**	*Zone*	*Weighted Specific Yields (percent)*
adobe	0	3	3	5	Clay	
brown clay	3	30	27	3		Aquifer Specific Yield
red rock & sand	30	55	25	21	**Aquifer**	21
frac. rock	55	100	45		**Bedrock**	
Total Depth	100	Alluvial Saturated thickness	35	**SATURATED SPECIFIC YIELD (PERCENT)**		**15.9**

** Johnson, A. I., 1967, Specific Yield - Compilation of Specific Yields for Various Materials, U.S. Geological Survey Water Supply Paper 1662-D*

TABLE E-7: WCR # E0081755						
Lithology	***Start Depth***	***End Depth***	***Thickness***	***Specific Yield (percent)****	***Zone***	***Weighted Specific Yields (percent)***
adobe	0	3	3	5	**Clay**	
brown clay	3	30	27	3		
rock, clay, sand	30	42	12	7	**Aquifer**	Weighted Specific Yield
rock & sand	42	53	11	21		13.7
serpentinite	53	70	17		**Bedrock**	
Total Depth	70	Alluvial Saturated thickness	30	**SATURATED SPECIFIC YIELD (PERCENT)**		**11.2**

** Johnson, A. I., 1967, Specific Yield - Compilation of Specific Yields for Various Materials, U.S. Geological Survey Water Supply Paper 1662-D*

TABLE E-8: WCR # 1097929						
Lithology	***Start Depth***	***End Depth***	***Thickness***	***Specific Yield (percent)****	***Zone***	***Weighted Specific Yields (percent)***
clay	0	40	40	3	**Clay**	Aquifer Specific Yield
gravel & sand	40	76	36	21	**Aquifer**	21
hard shale	76	80	4		**Bedrock**	
Total Depth	80	Alluvial Saturated thickness	55	**SATURATED SPECIFIC YIELD (PERCENT)**		**14.8**

** Johnson, A. I., 1967, Specific Yield - Compilation of Specific Yields for Various Materials, U.S. Geological Survey Water Supply Paper 1662-D*

TABLE E-9: WCR # E0252274						
Lithology	***Start Depth***	***End Depth***	***Thickness***	***Specific Yield (percent)****	***Zone***	***Weighted Specific Yields (percent)***
soil	0	6	6	5	**Clay**	
brown clay	6	32	26	3		Aquifer Specific Yield
gravel	32	55	23	21	**Aquifer**	21
green rock	55	82	27		**Bedrock**	
Total Depth	82	Alluvial Saturated thickness	35	**SATURATED SPECIFIC YIELD (PERCENT)**		**15.5**

* *Johnson, A. I., 1967, Specific Yield - Compilation of Specific Yields for Various Materials, U.S. Geological Survey Water Supply Paper 1662-D*

TABLE E-10: WCR # E0143215						
Lithology	***Start Depth***	***End Depth***	***Thickness***	***Specific Yield (percent)****	***Zone***	***Weighted Specific Yields (percent)***
adobe	0	5	5	5	**Clay**	
brown clay	5	7	2	3		
red rock	7	9	2	14		
brown clay	9	25	16	3		
red rock with clay	25	56	31	7	**Aquifer**	Weighted Specific Yield
frac rock	56	63	7	14		8.3
red rock	63	74	11		**Bedrock**	
serpentinite	74	80	6			
Total Depth	80	Alluvial Saturated thickness	40	**SATURATED SPECIFIC YIELD (PERCENT)**		**8.2**

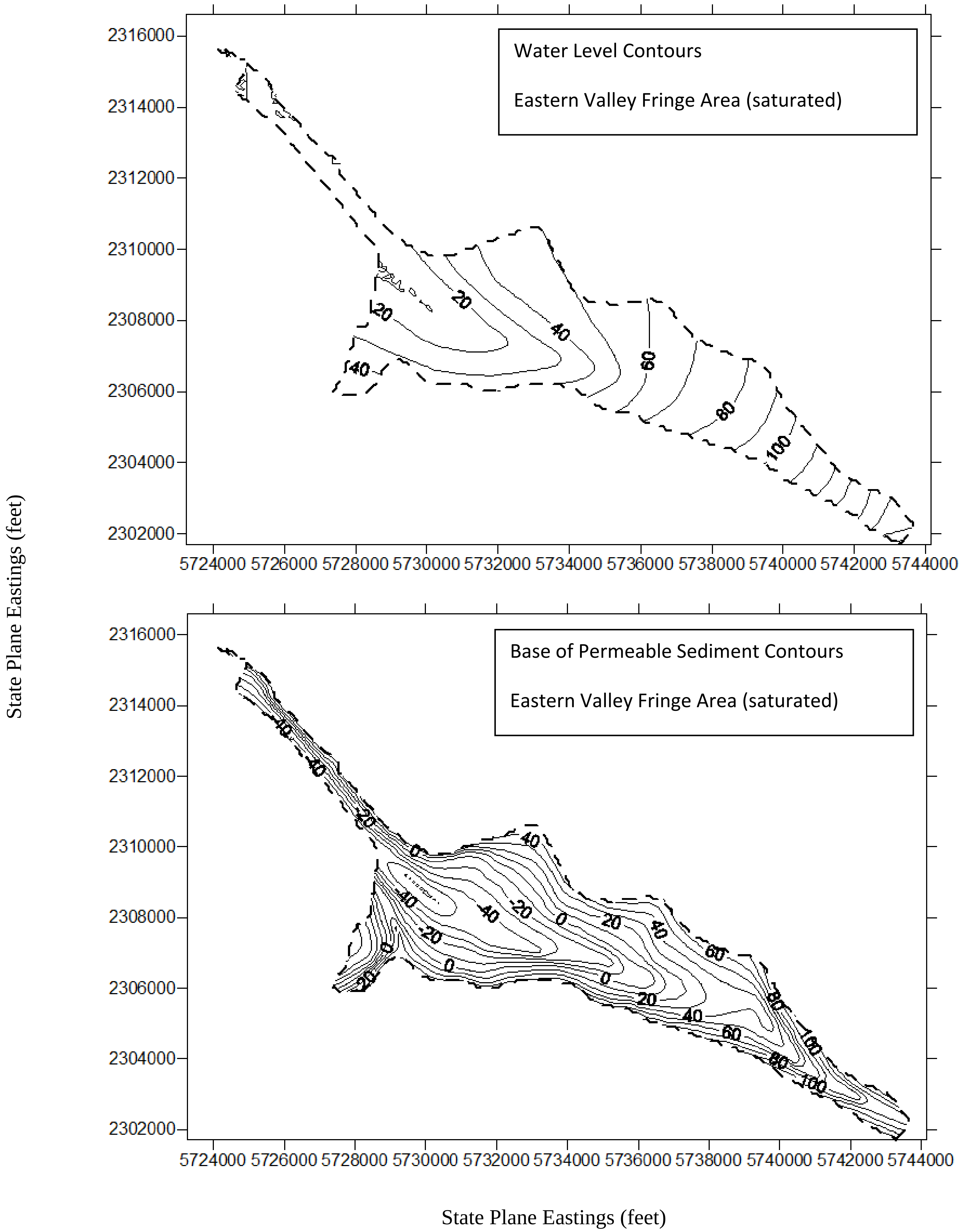
** Johnson, A. I., 1967, Specific Yield - Compilation of Specific Yields for Various Materials, U.S. Geological Survey Water Supply Paper 1662-D*

APPENDIX F

Groundwater in Storage Computations - Eastern Valley Fringe Area

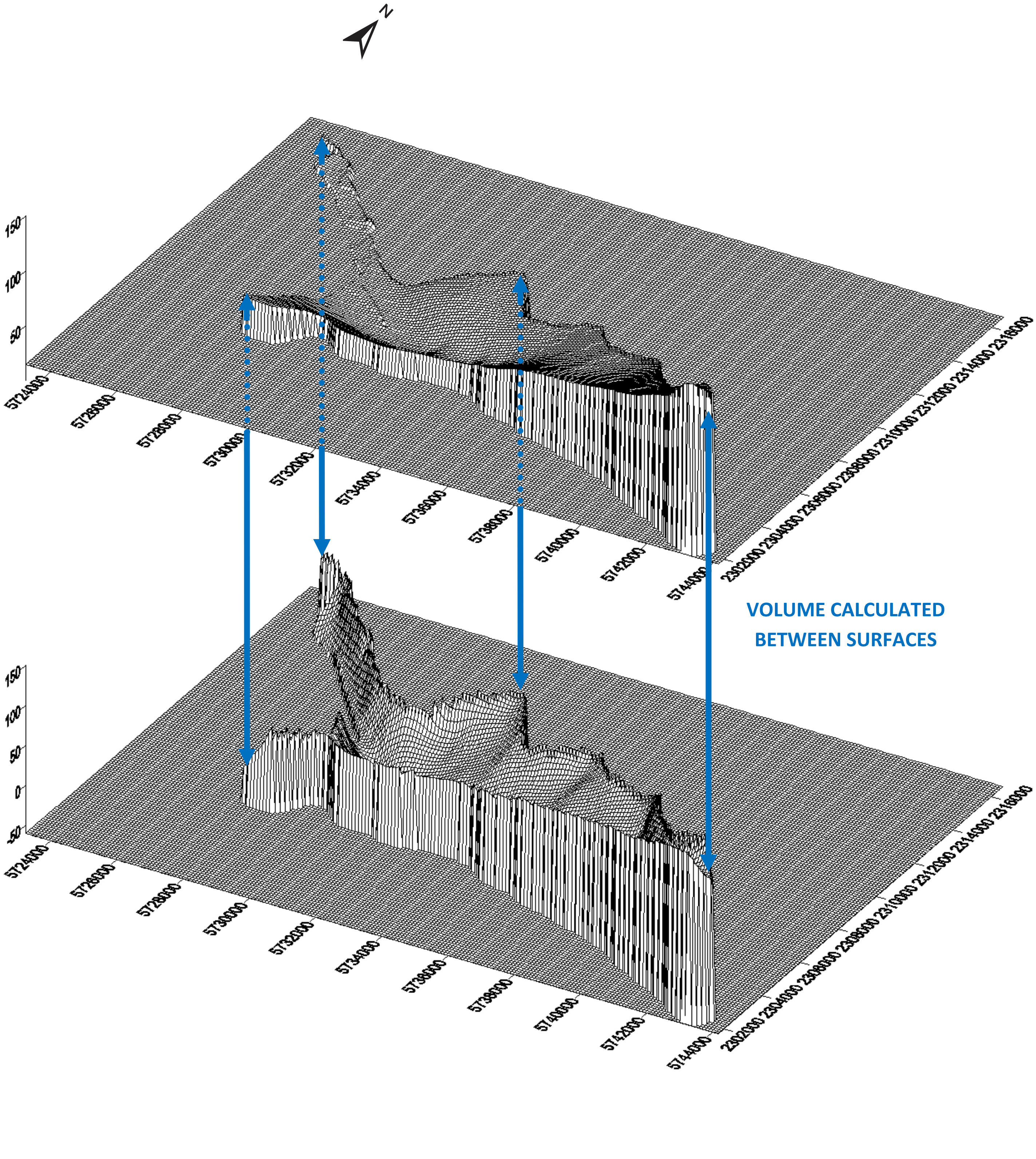
EXAMPLE STORAGE CALCULATIONS FOR EASTERN VALLEY FRINGE AREA

STEP 1: GRID AND TRIM BASE OF PERMEABLE SEDIMENT CONTOURS AND WATER LEVEL CONTOURS



EXAMPLE STORAGE CALCULATIONS FOR EASTERN VALLEY FRINGE AREA

STEP 2: MATCH UPPER AND LOWER SURFACE GRIDS



STEP3: VOLUME COMPUTATION

Grid Volume Computations

Thu Nov 16 15:32:09 2017

Upper Surface

Grid File Name:
C:\@Projects\LosOsosFringe\WorkingSurfer\BlankedSurfaces\KrigedSurface_GWE_EasternValley08_Blanked08.grd

Grid Size:	150 rows x 210 columns
X Minimum:	5723250
X Maximum:	5744150
X Spacing:	100
Y Minimum:	2301710
Y Maximum:	2316610
Y Spacing:	100
Z Minimum:	14.936657945908
Z Maximum:	172.44288281547

Lower Surface

Grid File Name:
C:\@Projects\LosOsosFringe\WorkingSurfer\BlankedSurfaces\KrigedSurface_BOPSE_EasternValley11_Blanked08.grd

Grid Size:	150 rows x 210 columns
X Minimum:	5723250
X Maximum:	5744150
X Spacing:	100
Y Minimum:	2301710
Y Maximum:	2316610
Y Spacing:	100
Z Minimum:	-60.298092792754
Z Maximum:	156.27115710511

Volumes

Z Scale Factor:	1

Total Volumes by:

Trapezoidal Rule:	1899015891.9937
Simpson's Rule:	1899610023.1816
Simpson's 3/8 Rule:	1898190276.6837

STEP4: CALCULATE GROUNDWATER IN STORAGE

Cut & Fill Volumes

Positive Volume [Cut]:	1899015891.9937
Negative Volume [Fill]:	0
Net Volume [Cut-Fill]:	1899015891.9937

Areas

Planar Areas

Positive Planar Area [Cut]:	47960000
Negative Planar Area [Fill]:	0
Blanked Planar Area:	263450000
Total Planar Area:	311410000

Surface Areas

Positive Surface Area [Cut]:	48049867.734348
Negative Surface Area [Fill]:	0

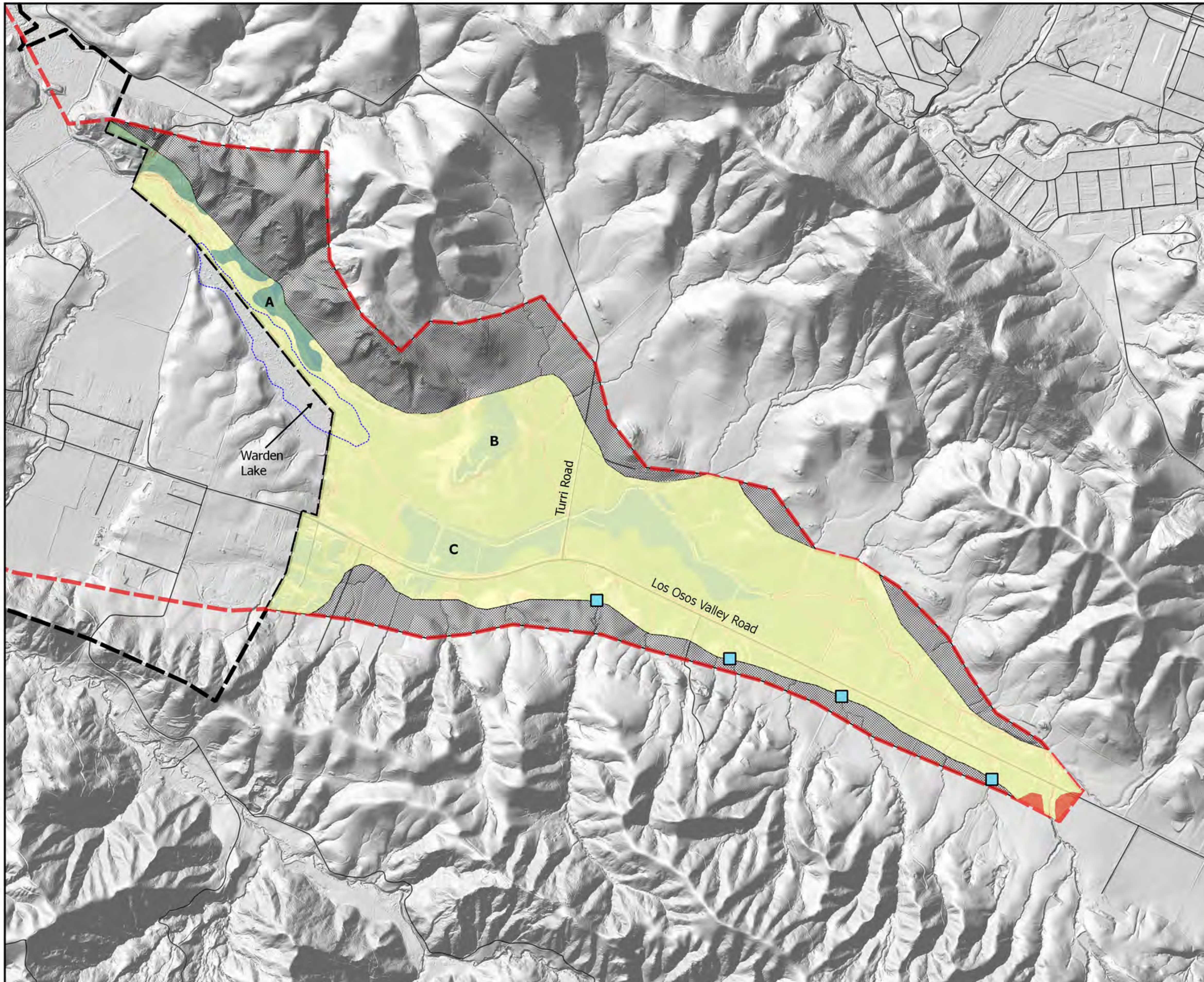
STORAGE CALCULATION

Storage = Positive Volume * Specific Yield

$$V = 1{,}899{,}015{,}892\ ft^3 * (S_y = 0.12) * \frac{\text{ft}^3}{43{,}560\ \text{Acre−ft}} = \ 5{,}231\ \text{Acre-ft}$$

APPENDIX G

Recharge Potential and Depth to Water Maps
Eastern Valley Fringe Area



Explanation

Recharge Potential (Smaller = Better)

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19

Factors:

Slope
Soil Type
Surface Geology

Adjudicated Plan Area

Bulletin 118 Basin Boundary- Los Osos Valley Groundwater Basin

Unsaturated Areas within Bulletin 118 Boundary

Preferred Recharge Sites

Basemap: Topographic Hillshade, 2011 Pacific Gas and Electric Diablo Canyon Power Plant (DCPP) LiDAR: Los Osos, CA Central Coast

0 2000 4000 ft

NORTH

Figure G1 - Recharge Potential Site Suitability Analysis Eastern Valley Fringe Area

Los Osos Valley Groundwater Basin Fringe Areas Characterization

County of San Luis Obispo

Cleath-Harris Geologists

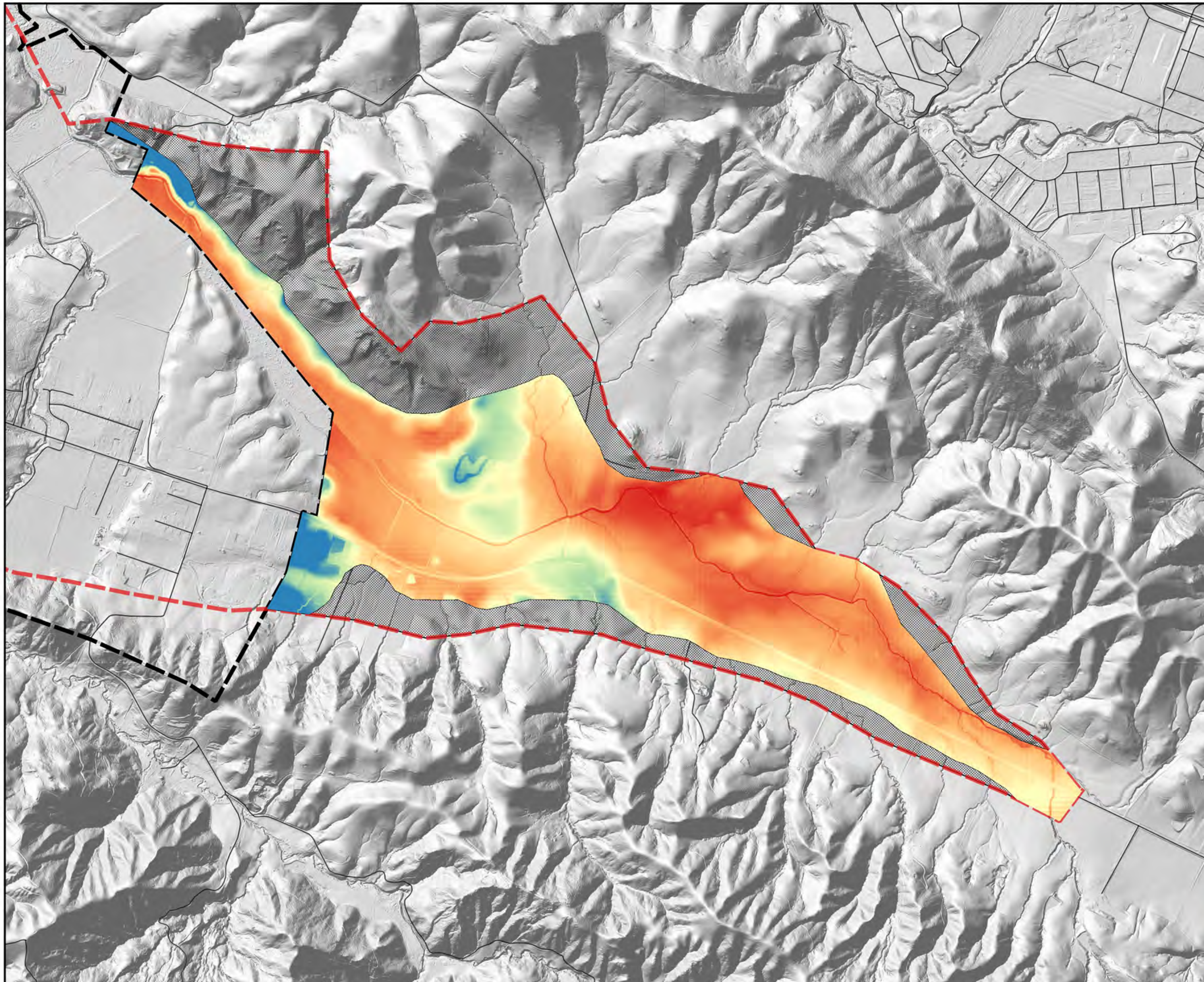
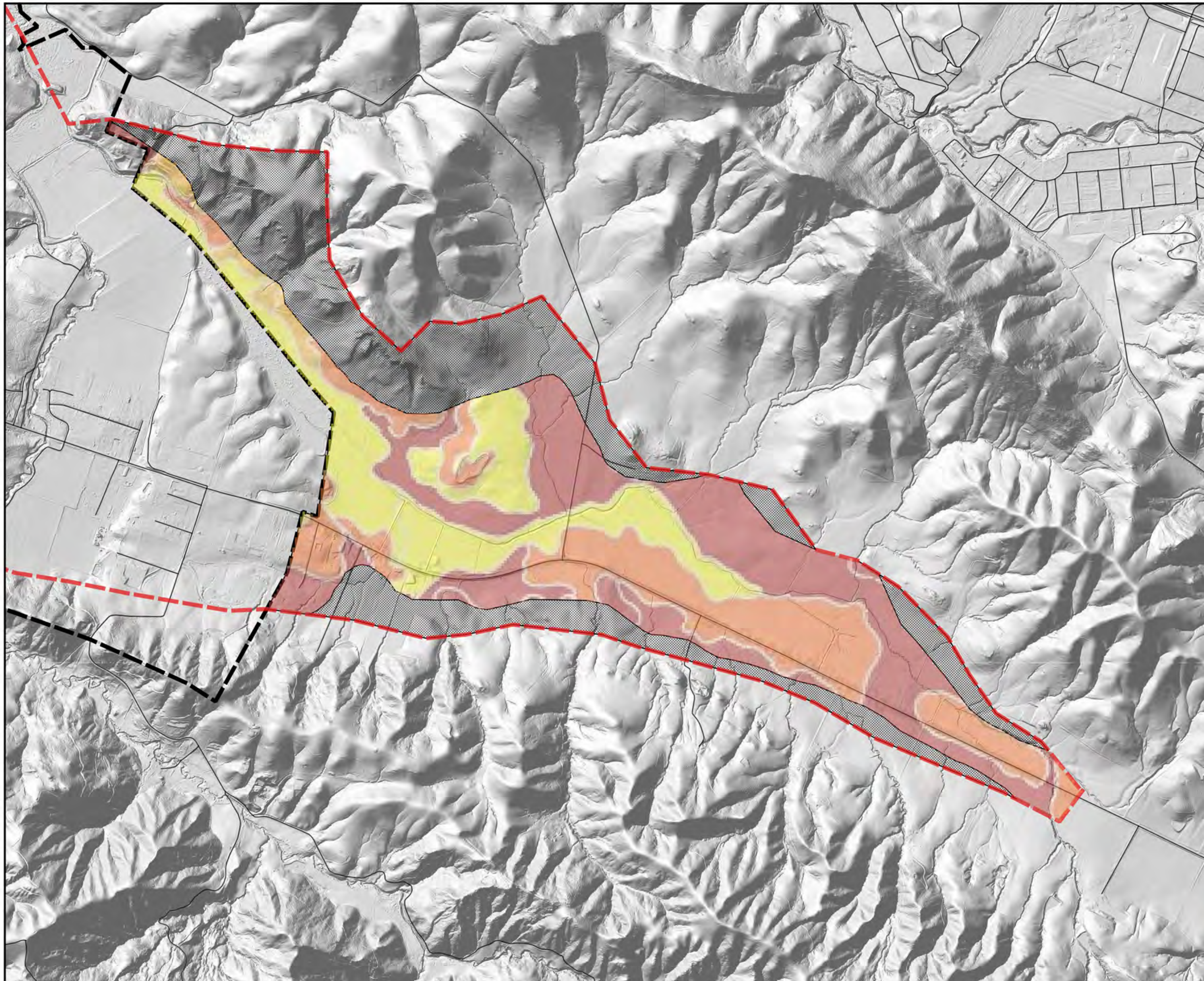


Figure G2 - Depth to Groundwater Site Suitability Analysis - Eastern Valley Fringe Area

Los Osos Valley Groundwater Basin Fringe Areas Characterization

County of San Luis Obispo

Cleath-Harris Geologists



Explanation

Soil Agricultural Groundwater Banking Index Rating Class

- Excellent
- Good
- Moderately Good
- Moderately Poor
- Poor
- Very Poor

- Adjudicated Plan Area
- Bulletin 118 Basin Boundary-
  Los Osos Valley Groundwater Basin
- Unsaturated Areas
  within Bulletin 118 Boundary

Basemap: Hillshade, 2011 Pacific Gas and Electric Diablo Canyon Power Plant (DCPP) LiDAR: Los Osos, CA Central Coast

0 2000 4000 ft

NORTH

Figure G3 - Recharge Potential-Modifed Soil Agricultural Groundwater Banking Index - Eastern Valley Fringe Area

Los Osos Valley Groundwater Basin Fringe Areas Characterization

County of San Luis Obispo

Cleath-Harris Geologists

APPENDIX H

2017 Water level Hydrographs

Hydrograph

Cemetery Mesa Lower Aquifer (Zone E) at Boundary with Fringe Area

FIGURE H-1

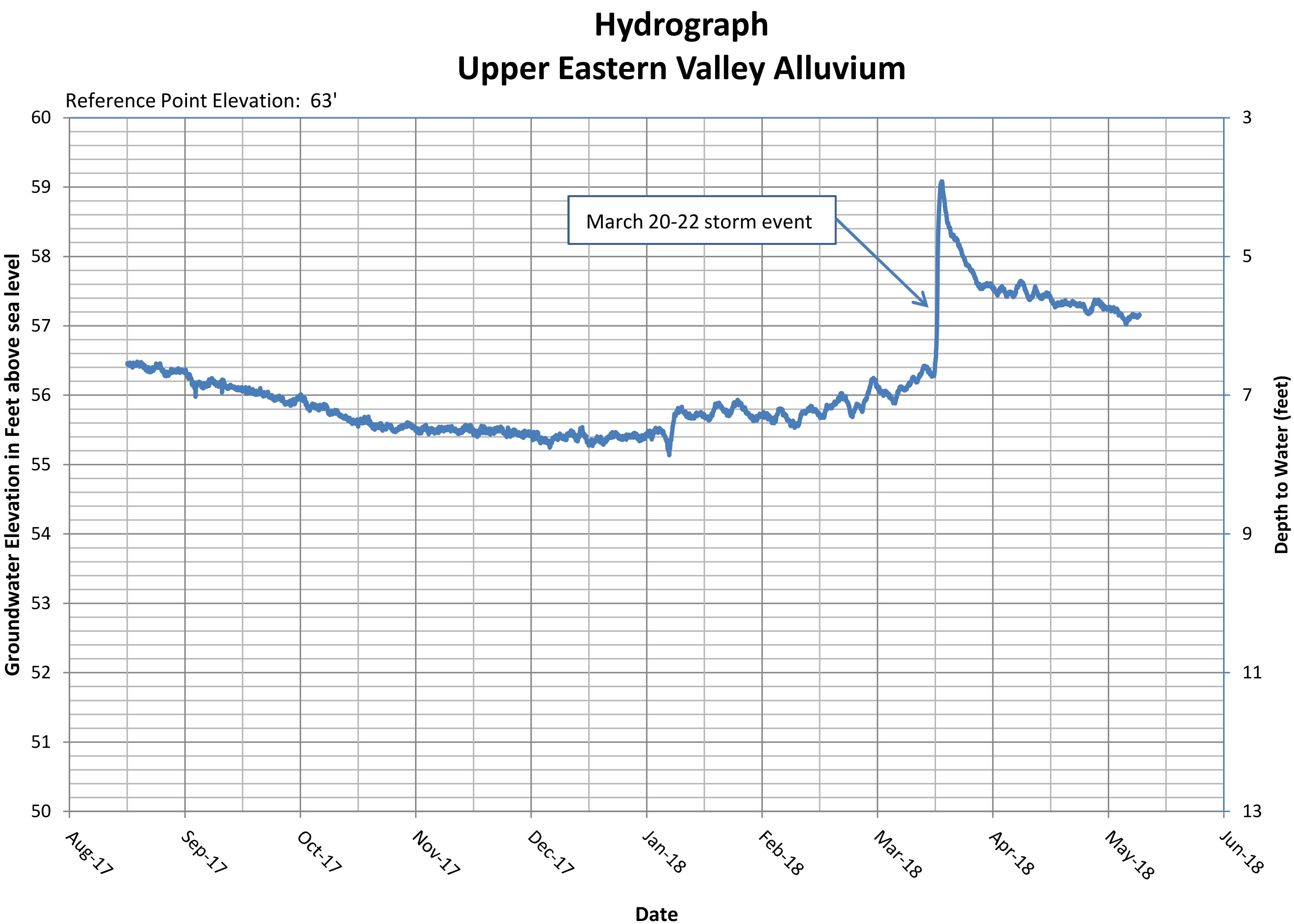
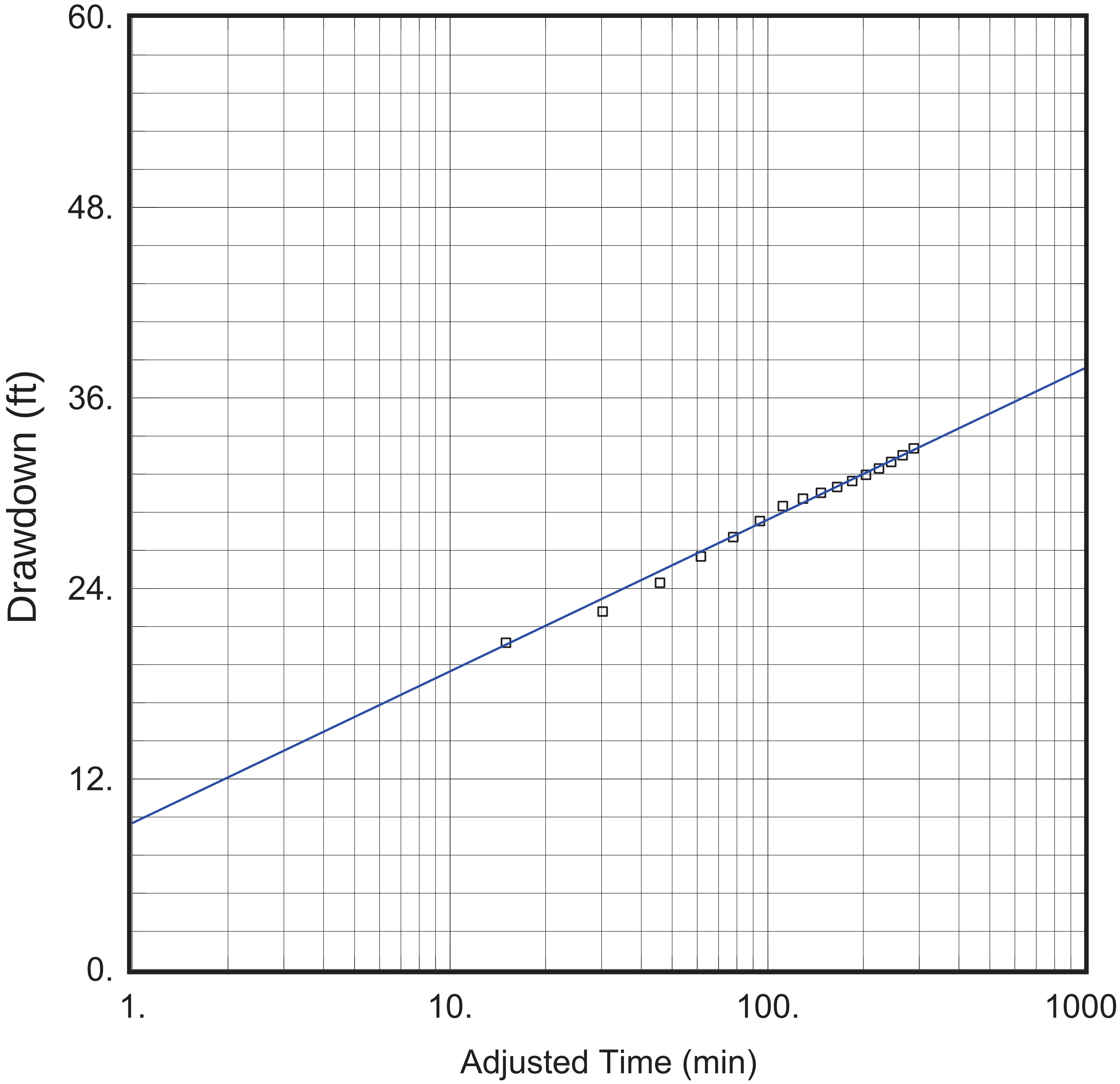

Hydrograph
Upper Eastern Valley Alluvium
Reference Point Elevation: 63'
March 20-22 storm event
Groundwater Elevation in Feet above sea level
Depth to Water (feet)
Date
60
59
58
57
56
55
54
53
52
51
50
3
5
7
9
11
13
Aug-17
Sep-17
Oct-17
Nov-17
Dec-17
Jan-18
Feb-18
Mar-18
Apr-18
May-18
Jun-18

FIGURE H-2

APPENDIX I

Aquifer Test Results

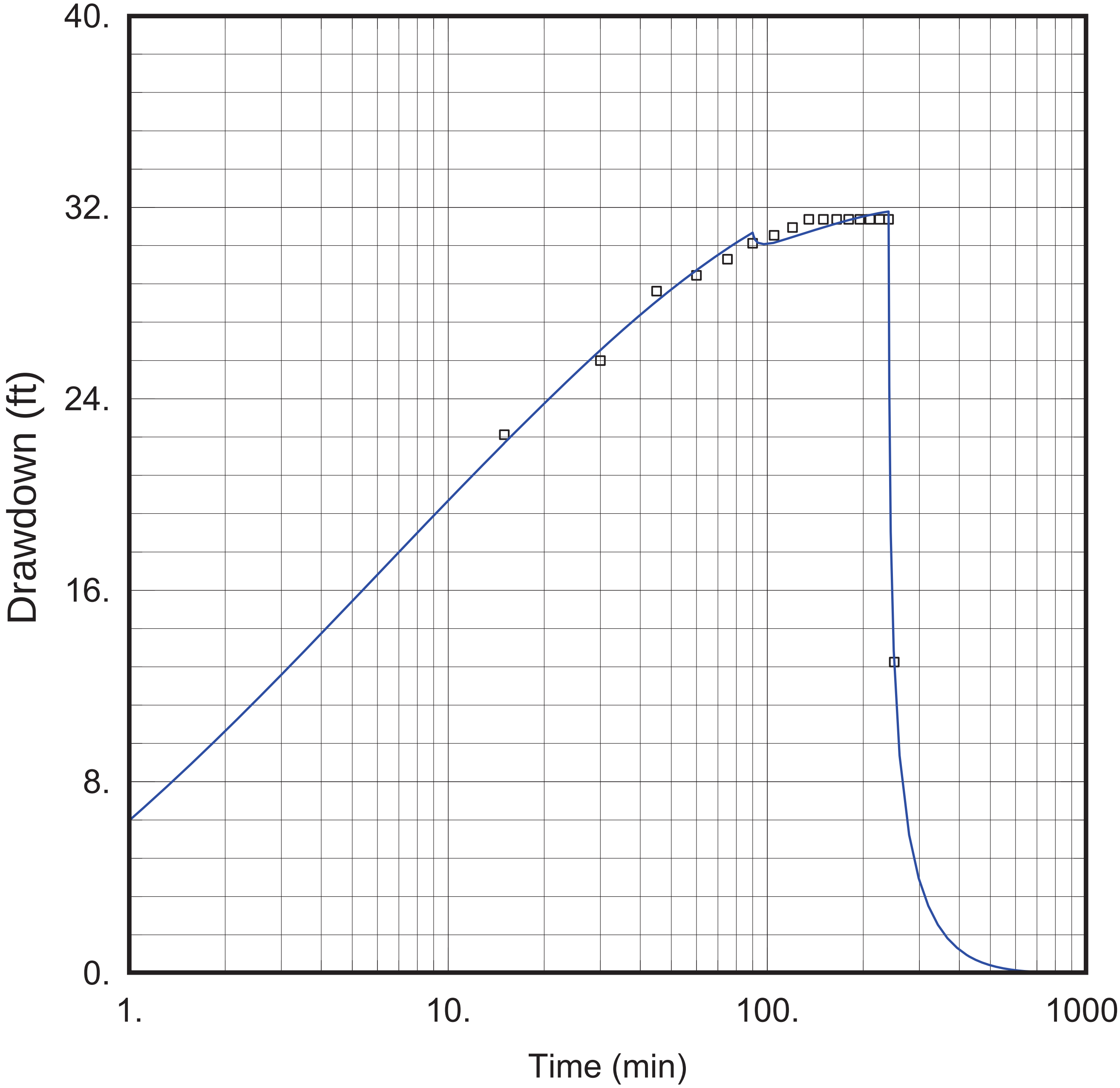
Lower Eastern Valley Alluvial Aquifer



Average Flow Rate (gpm)	110
Transmissivity (gpd/ft)	2,760
Saturated Thickness (ft)	70
Solution Used	Cooper-Jacob
□ Data point	graphed solution

FIGURE I-1: PUMPING TEST RESULTS

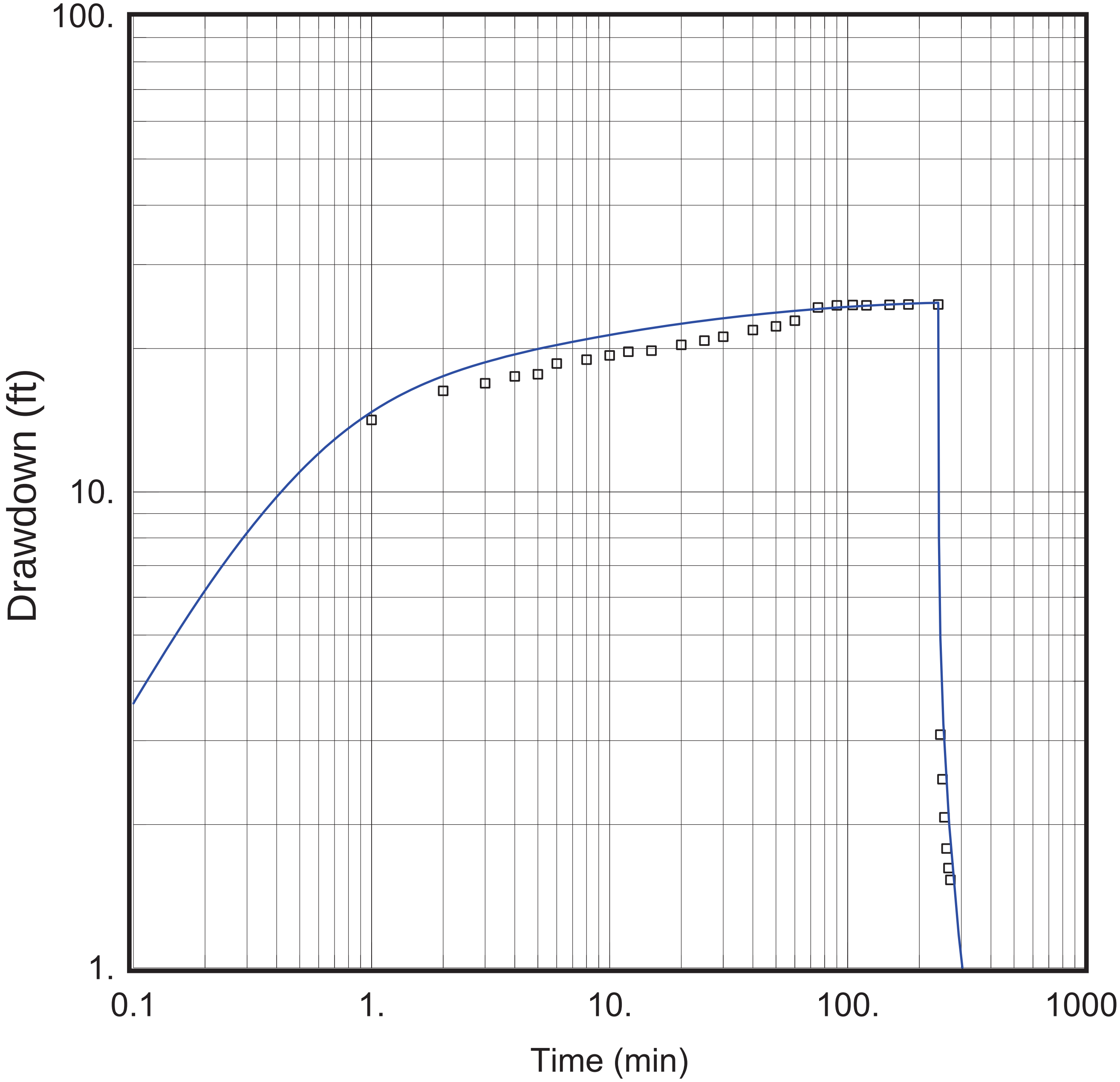
Lower Eastern Valley Alluvial Aquifer



Average Flow Rate (gpm)	117
Transmissivity (gpd/ft)	2,070
Saturated Thickness (ft)	70
Solution Used	Hantush
□ Data point	graphed solution

FIGURE I-2:
PUMPING TEST
RESULTS

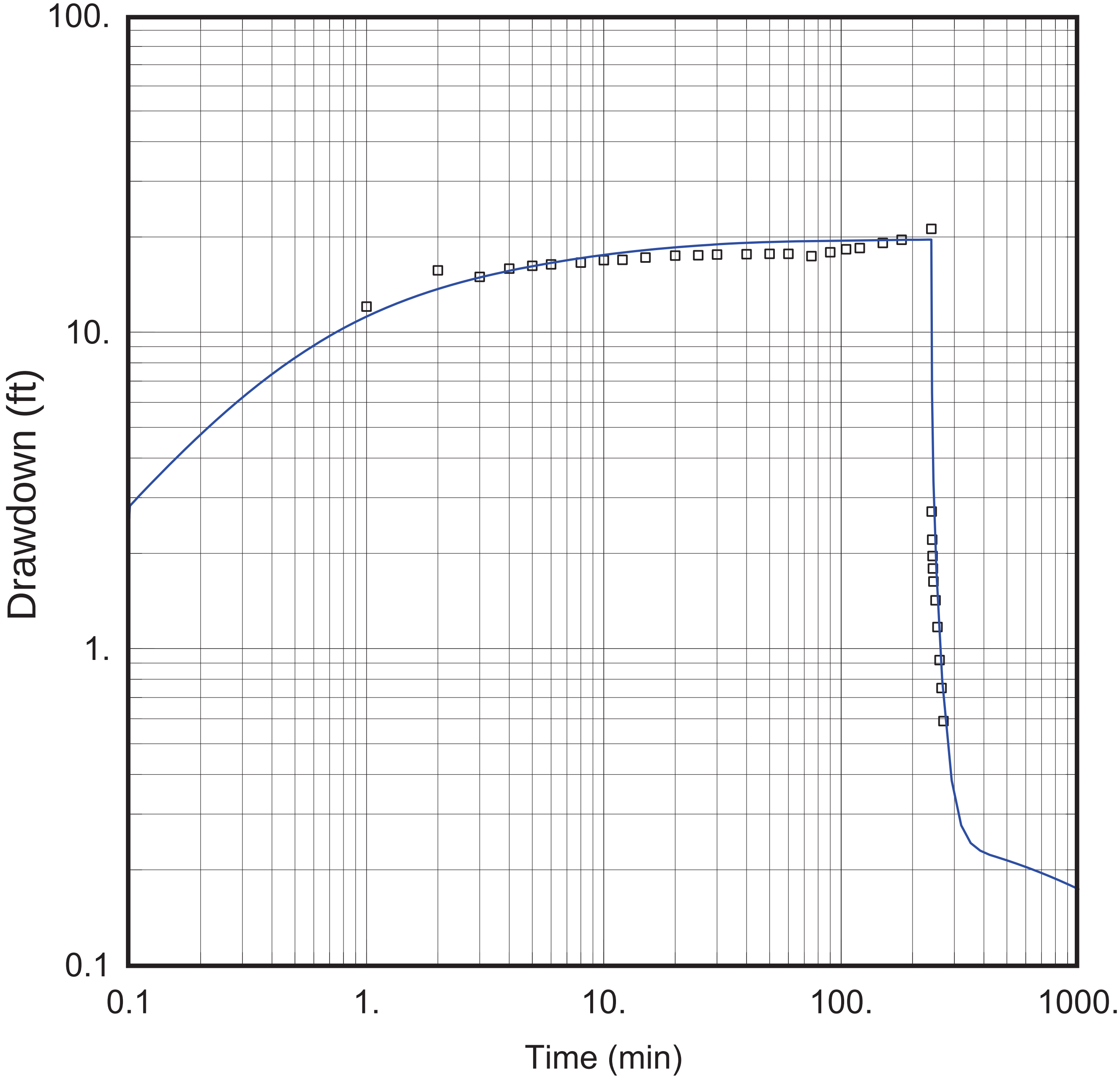
Upper Eastern Valley
Alluvial Aquifer



Average Flow Rate (gpm)	49
Transmissivity (gpd/ft)	2,640
Saturated Thickness (ft)	27
Solution Used	Moench
□ Data point	graphed solution

FIGURE I-3:
PUMPING TEST
RESULTS

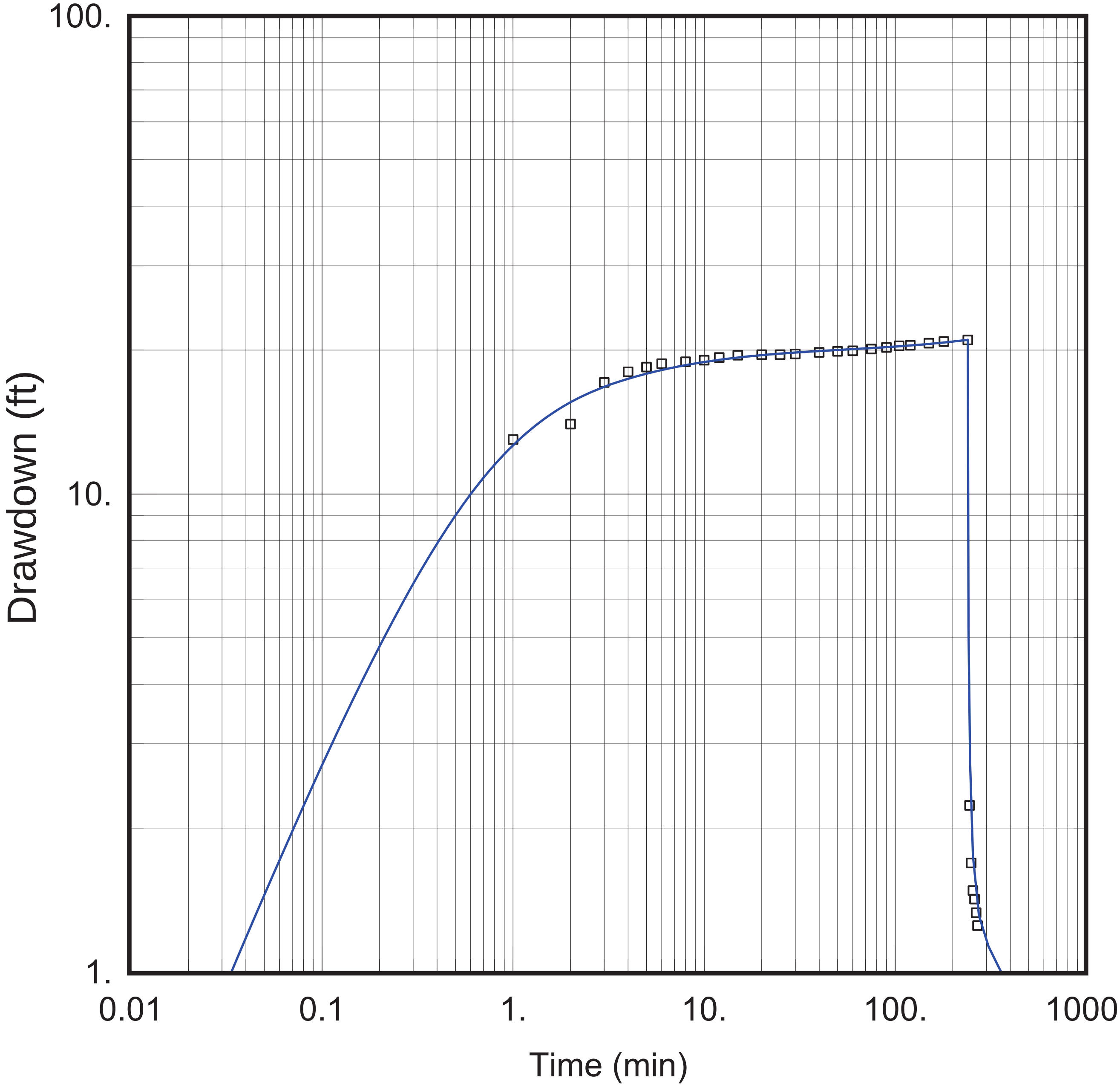
Upper Eastern Valley Alluvial Aquifer



Average Flow Rate (gpm)	50
Transmissivity (gpd/ft)	2,170
Saturated Thickness (ft)	27
Solution Used	Moench
□ Data point	graphed solution

FIGURE I-4: PUMPING TEST RESULTS

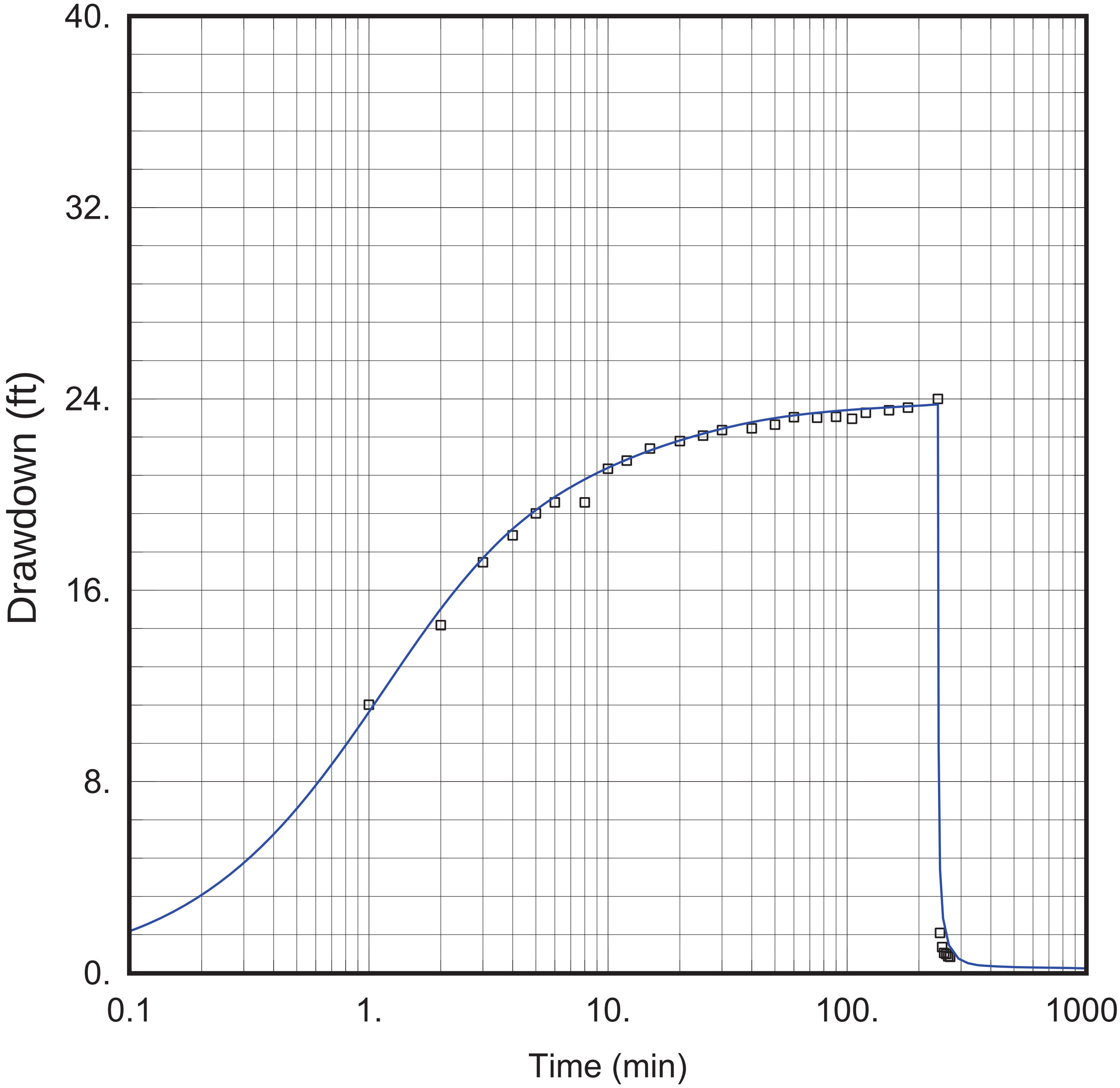
Upper Eastern Valley Alluvial Aquifer



Average Flow Rate (gpm)	42
Transmissivity (gpd/ft)	2,290
Saturated Thickness (ft)	28
Solution Used	Moench
◻ Data point	graphed solution

FIGURE I-5: PUMPING TEST RESULTS

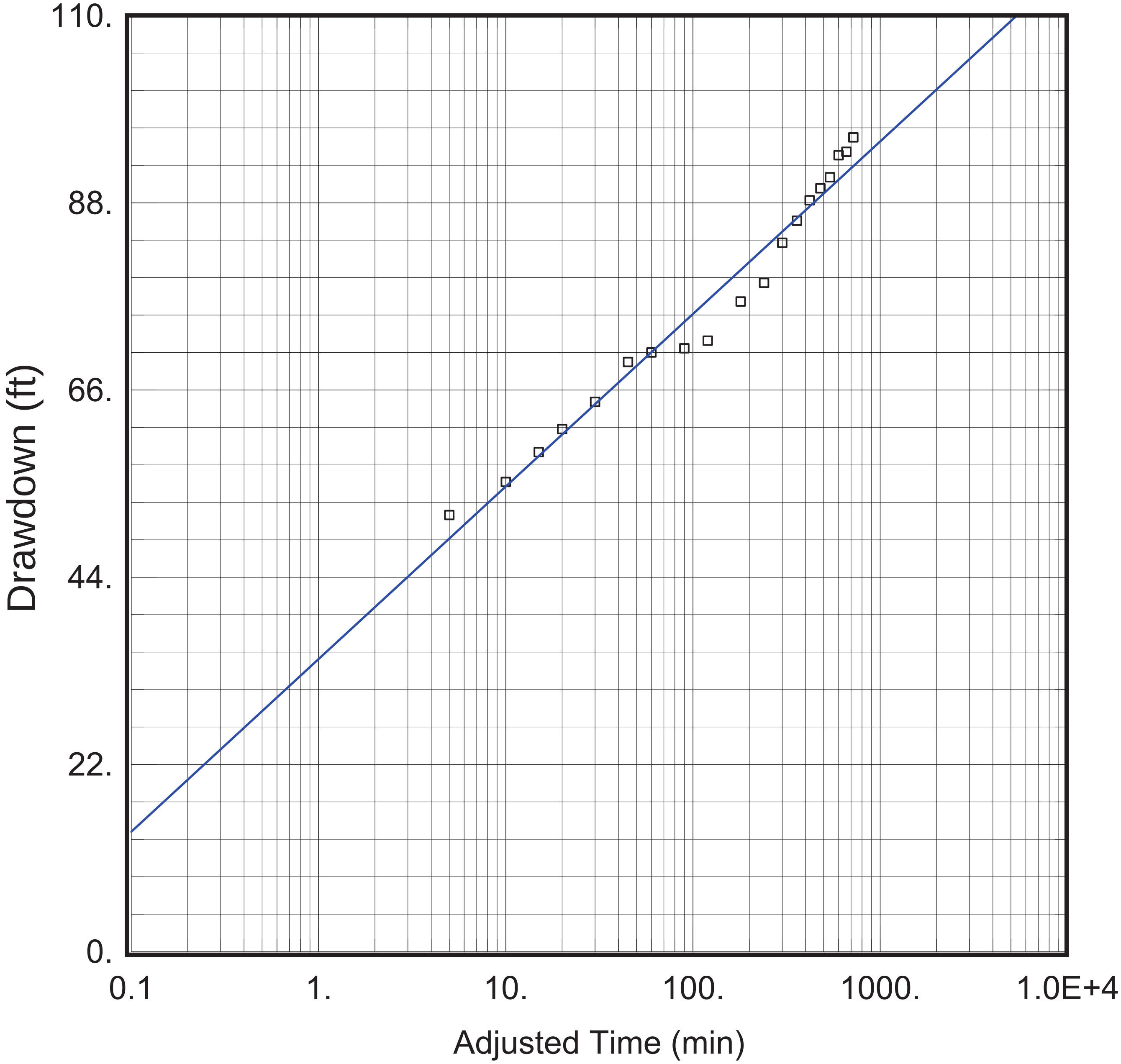
Upper Eastern Valley Alluvial Aquifer



Average Flow Rate (gpm)	25
Transmissivity (gpd/ft)	1,320
Saturated Thickness (ft)	31
Solution Used	Moench
□ Data point	graphed solution

FIGURE I-6: PUMPING TEST RESULTS

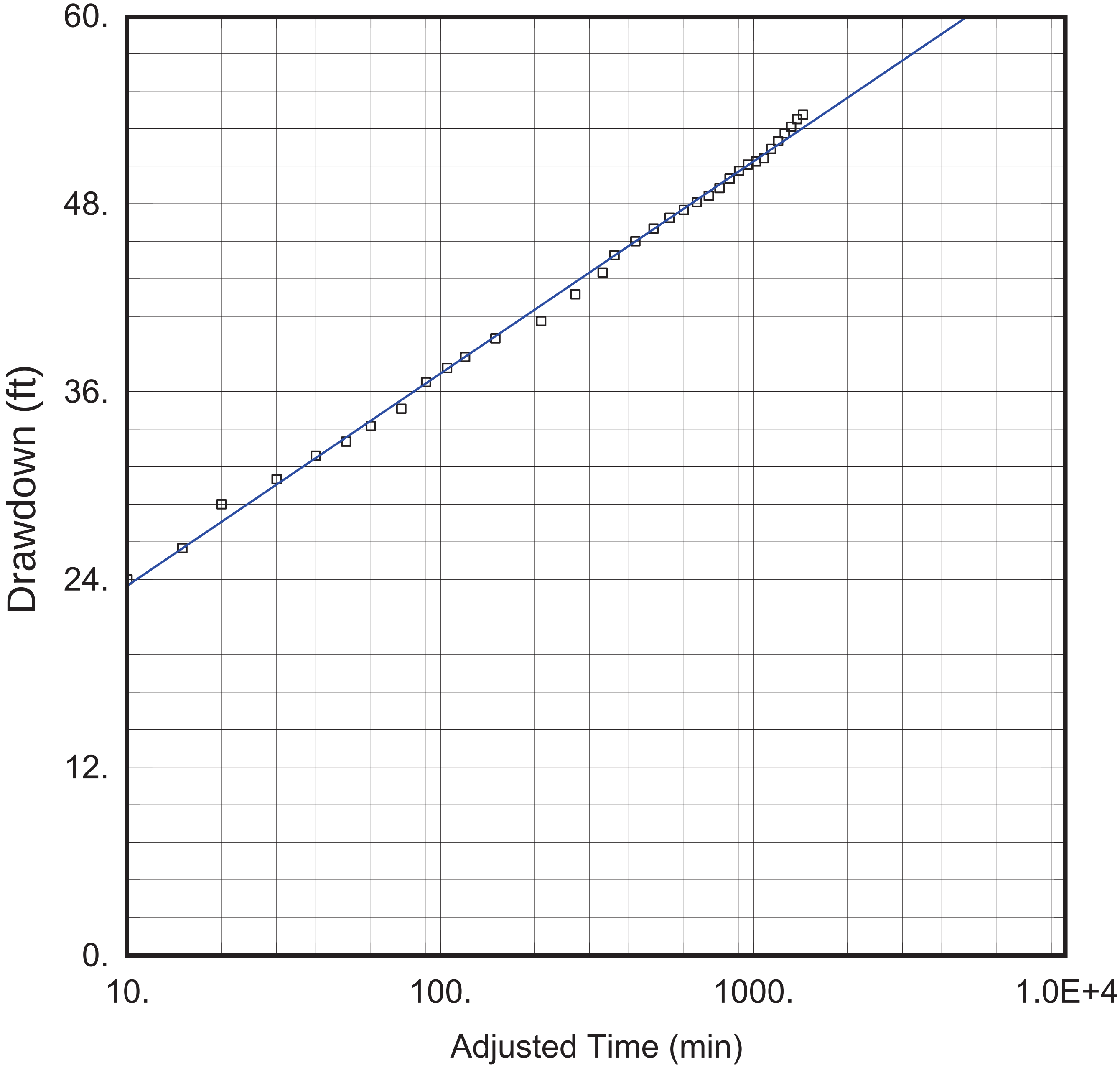
Bedrock Aquifer



Average Flow Rate (gpm)	300
Transmissivity (gpd/ft)	3,900
Saturated Thickness (ft)	100
Solution Used	Cooper-Jacob
▫ Data point	graphed solution

FIGURE I-7:
PUMPING TEST
RESULTS

Bedrock Aquifer



Average Flow Rate (gpm)	150
Transmissivity (gpd/ft)	2,920
Saturated Thickness (ft)	320
Solution Used	Cooper-Jacob
□ Data point	graphed solution

FIGURE I-8:
PUMPING TEST
RESULTS

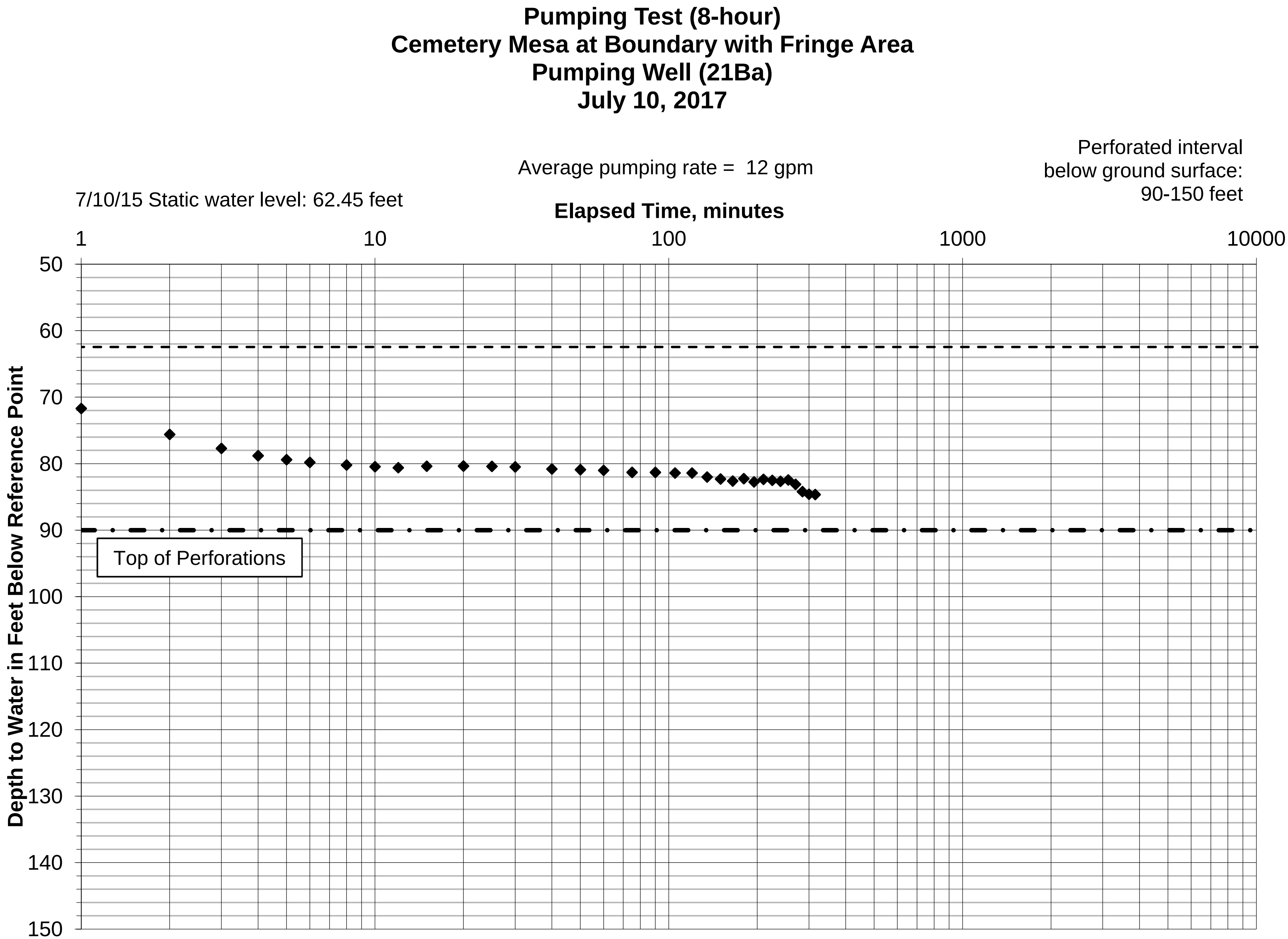
Table 1
30S/11E-21Ba (405182) - Pumping Well
Pumping Test (8-hour)
Cleath-Harris Geologists

Day	Time	Elapsed Time	Depth to Water	Drawdown	Recorded Pumping Rate
Mo./Day/Yr	hr:min	minutes	feet	feet	gallons per minute
7/10/17	9:33	0	62.45	0.00	Start
	9:34	1	71.7	9.25	14
	9:35	2	75.6	13.15	
	9:36	3	77.7	15.25	
	9:37	4	78.8	16.35	12
	9:38	5	79.4	16.95	
	9:39	6	79.8	17.35	
	9:41	8	80.2	17.75	
	9:43	10	80.45	18.00	
	9:45	12	80.6	18.15	10
	9:48	15	80.38	17.93	
	9:53	20	80.35	17.90	12
	9:58	25	80.4	17.95	12
	10:03	30	80.48	18.03	
	10:13	40	80.8	18.35	12
	10:23	50	80.9	18.45	12
	10:33	60	81	18.55	12
	10:48	75	81.3	18.85	
	11:03	90	81.3	18.85	12
	11:18	105	81.4	18.95	12
	11:33	120	81.4	18.95	12
	11:48	135	82	19.55	12
	12:03	150	82.3	19.85	12
	12:18	165	82.6	20.15	12
	12:33	180	82.25	19.80	
	12:48	195	82.74	20.29	12
	13:03	210	82.35	19.90	12
	13:18	225	82.5	20.05	12
	13:33	240	82.65	20.20	12
	13:48	255	82.45	20.00	12
	14:03	270	83.1	20.65	12
	14:18	285	84.2	21.75	12
	14:33	300	84.59	22.20	12
	14:48	315	84.64	22.25	12

Avg PumpRate ***12***

Pumping Well (21Ba)
Recovery Test (60-min manual)

Day	Time	Elapsed Time	Depth to Water	Elapsed Time	Recovery Time Ratio
Mo./Day/Yr	hr:min	minutes	feet	minutes	
		Since pumping started	s	Since pumping stopped	t/t(0)
7/10/17	17:40	487	74.44	1	487.0
	17:42	489	69.76	2	244.5
	17:43	490	68.44	3	163.3
	17:44	491	67.89	4	122.8
	17:45	492	67.24	5	98.4
	17:46	493	66.89	6	82.2
	17:48	495	66.49	8	61.9
	17:50	497	66.26	10	49.7
	17:52	499	66.09	12	41.6
	17:55	502	65.96	15	33.5
	18:00	507	65.78	20	25.4
	18:05	512	65.59	25	20.5
	18:10	517	65.56	30	17.2
	18:20	527	65.39	40	13.2
	18:30	537	65.24	50	10.7
	18:40	547	65.14	60	9.1



Pumping Test (8-hour)
Cemetery Mesa at Boundary with Fringe Area
Pumping Well (21Ba)
July 10, 2017
Average pumping rate = 12 gpm
Perforated interval below ground surface: 90-150 feet
7/10/15 Static water level: 62.45 feet
Elapsed Time, minutes
1
10
100
1000
10000
Depth to Water in Feet Below Reference Point
50
60
70
80
90
100
110
120
130
140
150
Top of Perforations

FIGURE I-9

Recovery Test
Cemetery Mesa at Boundary with Fringe Area
Pumping Well (21Ba)
July 10, 2017

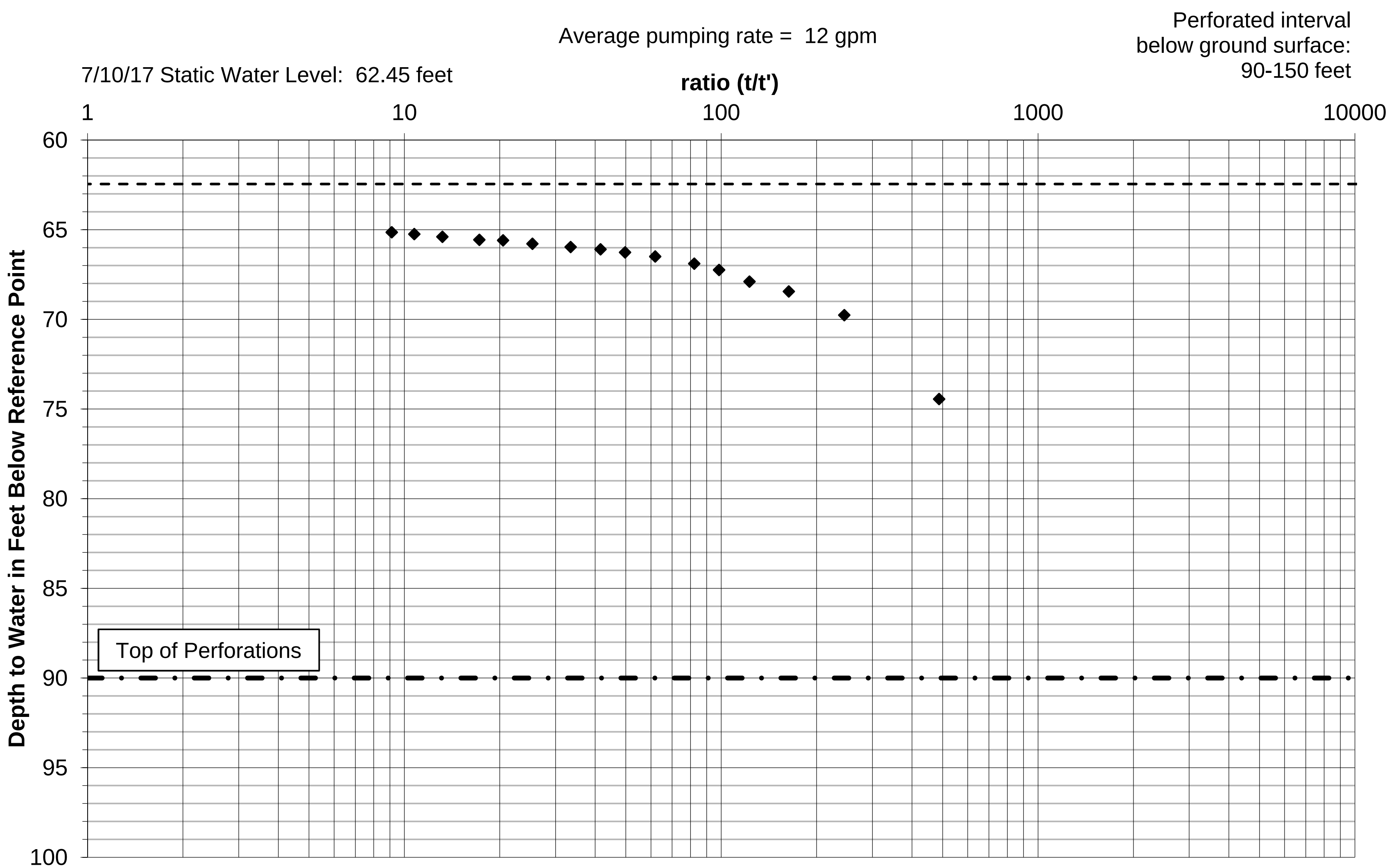


FIGURE I-10

Table 2
Observation Well 21Bb
Pumping Test (8-hour)
Cleath-Harris Geologists

Day	Time	Elapsed Time	Depth to Water	Drawdown
Mo./Day/Yr	hr:min	minutes	feet	feet
7/10/17	9:33	0	60.85	0.00
	9:34	1		
	9:35	2		
	9:36	3	60.83	-0.02
	9:37	4		
	9:38	5		
	9:39	6		
	9:41	8		
	9:43	10	60.9	0.05
	9:45	12		
	9:48	15	60.95	0.10
	9:53	20	61	0.15
	9:58	25		
	10:03	30	61.11	0.26
	10:13	40	61.23	0.38
	10:23	50	61.34	0.49
	10:33	60		
	10:48	75	61.64	0.79
	11:03	90	61.81	0.96
	11:18	105	61.97	1.12
	11:33	120	62.11	1.26
	11:48	135	62.28	1.43
	12:03	150	62.44	1.59
	12:18	165		
	12:33	180	62.68	1.83
	12:48	195	62.8	1.95
	13:03	210	62.89	2.04
	13:18	225	62.98	2.13
	13:33	240	63.1	2.25
	13:48	255	63.21	2.36
	14:03	270	63.32	2.47
	14:18	285	63.41	2.56
	14:33	300	63.58	2.73
	14:48	315	63.75	2.90
	15:03	330		
	15:18	345	63.92	3.07
	15:33	360	64.07	3.22
	15:48	375	64.16	3.31
	16:03	390	64.26	3.41
	16:18	405	64.37	3.52
	16:33	420	64.46	3.61
	16:48	435	64.55	3.70
	17:03	450	64.61	3.76
	17:18	465	64.7	3.85
	17:33	480	64.76	3.91

Pumping Test (8-hour)
Cemetery Mesa at Boundary with Eastern Valley Fringe Area
Observation 21Bb
July 10, 2017

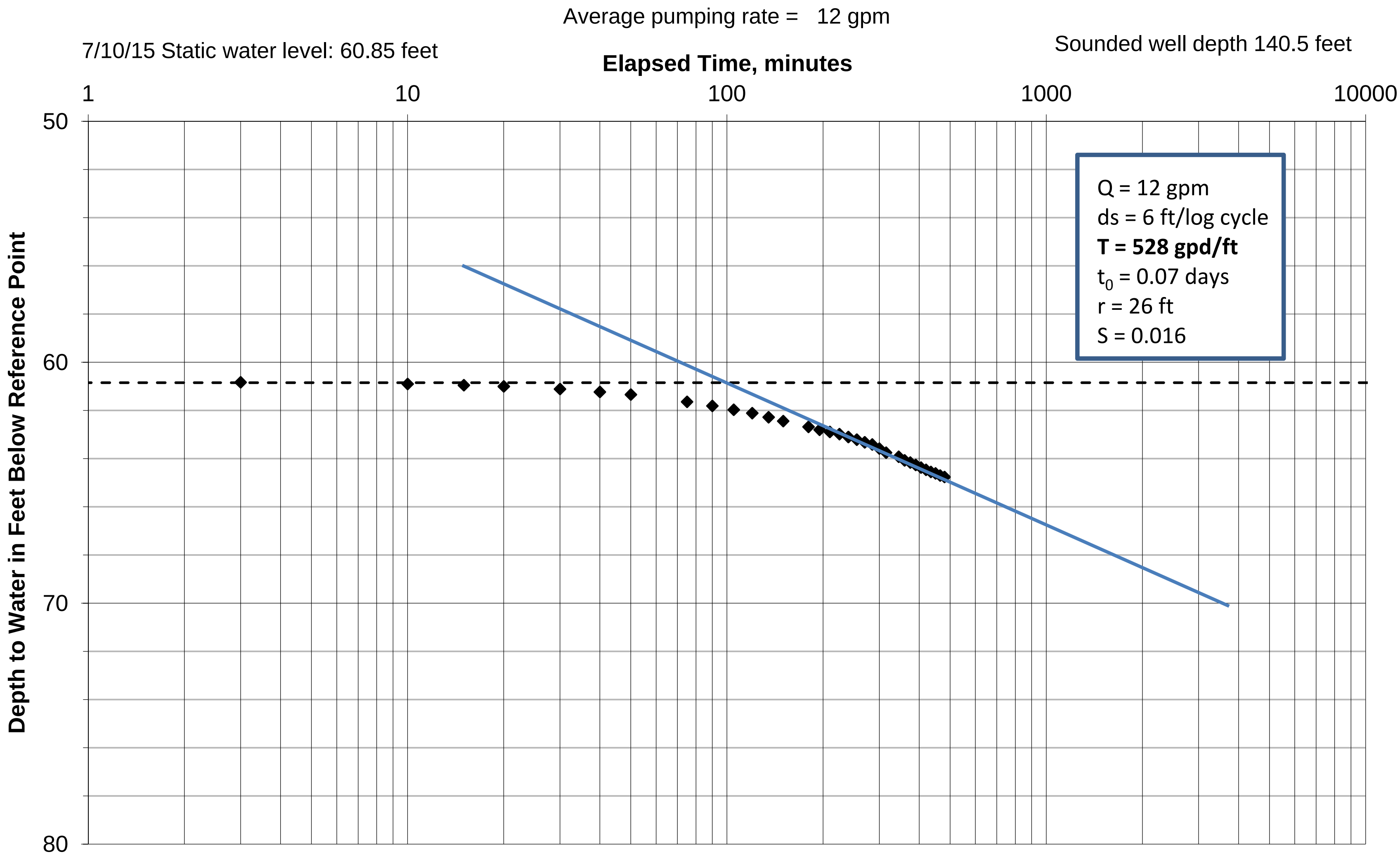


FIGURE I-11

Recovery Test
Cemetery Mesa near Fringe Area Boundary
Observation Well (21Bb)
(Transducer Data, 10 hours)
July 10, 2017

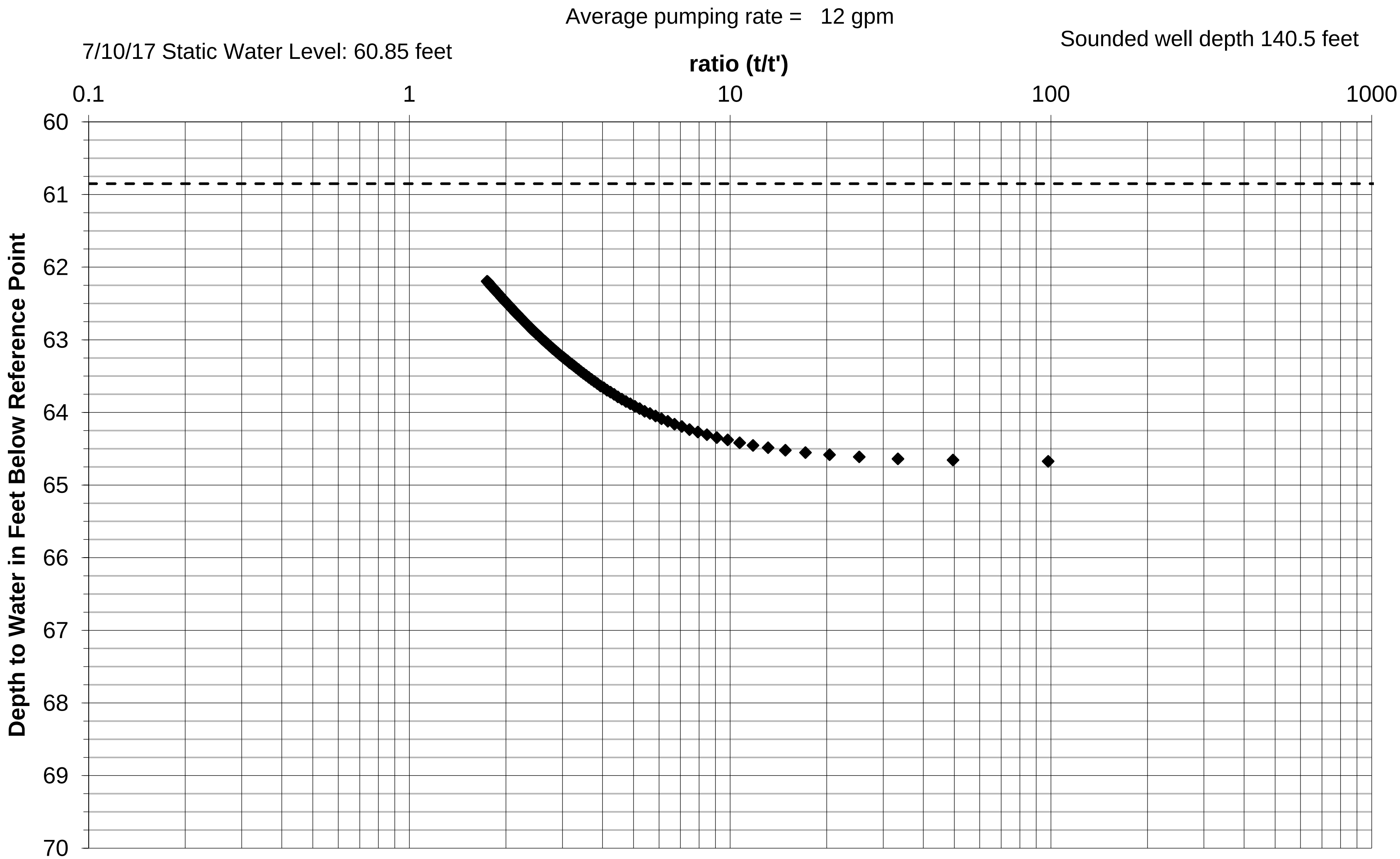


FIGURE I-12

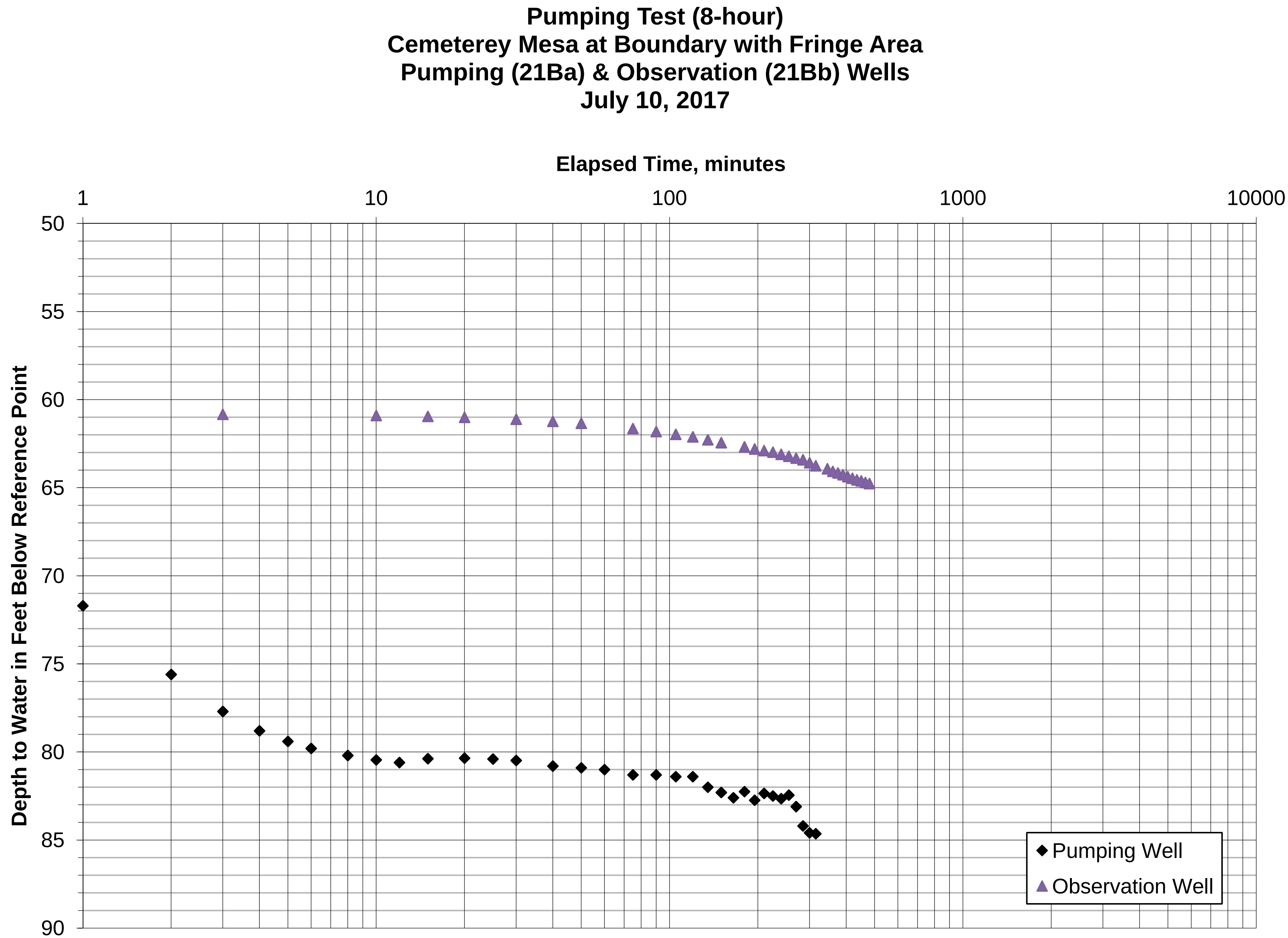

Pumping Test (8-hour)
Cemeterey Mesa at Boundary with Fringe Area
Pumping (21Ba) & Observation (21Bb) Wells
July 10, 2017
Elapsed Time, minutes
1
10
100
1000
10000
Depth to Water in Feet Below Reference Point
50
55
60
65
70
75
80
85
90
Pumping Well
Observation Well

FIGURE I-13