Public Draft

San Luis Obispo Valley Basin Characterization and Monitoring Well Installation

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Prepared for

San Luis Obispo County Flood Control and Water Conservation District

Prepared by

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Contents

Tables

Figures

Appendices

Executive Summary

This report documents the basin characterization study (Study) for the San Luis Obispo Valley Groundwater Basin (Basin; Department of Water Resources (DWR) Basin 3-09). All available published reports, private well reports, well completion reports, geologic logs, and other data were reviewed to generate a comprehensive compilation of the current understanding of the hydrogeologic setting of the Basin. This information is intended to provide the basis of knowledge for future planning and management activities performed under the requirements of California's Sustainable Groundwater Management Act (SGMA), including the development of a hydrogeologic conceptual model, construction of a numerical groundwater model, and development of a groundwater sustainability plan (GSP).

The Basin covers approximately 20 square miles in central San Luis Obispo County (County). The Basin extents are defined as the contact of water-bearing sediments with the non-water-bearing formations of the Santa Lucia Range to the northeast, and the San Luis Range and the Edna Fault Zone to the southwest. It is commonly divided into two sub-areas: the San Luis Valley and the Edna Valley. The San Luis Valley is the area in approximately the northwestern half of the Basin; it includes the City of San Luis Obispo (City), and the primary land use is municipal and industrial. Most water supply in the San Luis Valley is from both in-basin groundwater sources and imported surface water sources (Whale Rock Reservoir, Salinas Reservoir, and Nacimiento Reservoir). The Edna Valley occupies the southeastern half of the Basin. The primary land use is agriculture, with wine grapes as the dominant crop type. Groundwater is the sole source of water supply in the Edna Valley.

The report provides a summary of the geologic setting of the Basin. The water-bearing geologic formations that comprise the Basin are the Recent Alluvium, Paso Robles Formation, and Pismo Formation. The non-water-bearing geologic formations that comprise the Basin boundaries are the Franciscan Assemblage, Obispo Formation and associated volcanics, and Monterey Formation. Eleven geologic cross sections are presented in this report that characterize the geologic understanding of the Basin. In the San Luis Valley, Recent Alluvium is observed at the surface through the entire area, and sits atop Paso Robles Formation sediments. Total sediment thickness in the San Luis Valley varies, but is less than 200 feet. In the Edna Valley, Recent Alluvium is observed only along current stream courses and floodplains. The Paso Robles Formation crops out in most of the Edna Valley, and it sits atop the marine sediments of the Pismo Formation. Total sediment thickness in the Edna Valley is considerably greater than in the San Luis Valley, with the deepest zone more than 500 feet thick.

The report provides a summary of the hydrogeologic setting of the Basin. Although there are three distinct geologic formations recognized as water-bearing sediments, there are no laterally extensive impermeable strata acting as hydrogeologic barriers to flow separating the formations. As a result, it is understood that the primary formations in each Basin sub-area function as single hydrogeologic units. Previous estimates for water budget components of recharge, storage, and pumping, are provided, as well as previous estimates of long-term sustainable yield for the Basin (Table ES-1). The area south and west of Buckley Road near the San Luis Obispo County Regional Airport (airport) appears to be a hydrologically unique area in the Basin where stream infiltration is the dominant recharge mechanism, and percolation of areally distributed precipitation-based recharge is less significant.

Table ES-1. Summary of Previous Basin Water Budget Component Estimates (acre-feet)

	DWR (1958)	Boyle (1991)	DWR (1997 Draft) 1
Recharge	2,250	3,650	4,560
Groundwater in Storage	67,000	69,900	46,700 – 55,800
Groundwater Pumpage	1,900	5,690 – 7,810	4,380 – 7,640
Sustainable Yield	2,000	5,900	6,000-7,000
1) The 1997 DWR Report was only issued in Draft form.			

Groundwater elevation contour maps from 1954 and 1990 depict similar flow patterns, with groundwater flowing from the Edna Valley toward the San Luis Valley and leaving the Basin through the San Luis Creek alluvium. Long-term groundwater level hydrographs in the Basin indicate that water levels in San Luis Valley display no long-term trends of declining water levels. In the Edna Valley, the data indicate declines in groundwater elevations during the past 20 years in response to increased agricultural pumping. Surface water/groundwater interaction in the Basin is conceptually understood as seasonal surface water flow supplying recharge to the underlying aquifers; it is unclear if this interaction persists through the rainy season, or if groundwater levels may rise to the point that the aquifer is supplying flow to the creeks.

A comprehensive set of hydrogeologic parameters (transmissivity, from constant-rate pumping tests of wells; and specific capacity, from short-term pumping tests) is collected from available data, including 48 wells with constant-rate test information, and 29 wells with specific capacity test information. There is good spatial coverage of these data throughout the Basin, and these data will be the basis for hydrogeologic parameter estimation for any future groundwater modeling efforts associated with the development of the GSP. This data is discussed in greater detail in Section 5 of this report.

The California Statewide Groundwater Elevation Monitoring (CASGEM) program's groundwater network, for which the San Luis Obispo County Flood Control and Water Conservation District (District) has accepted responsibility for Basin-wide reporting, has one well in the Basin, located along the southwest periphery of the Edna Valley. San Luis Obispo County performs semiannual water level measurements in the spring and fall on 14 wells in the Basin. This report discusses data gaps and presents recommendations for expanding the monitoring. Two new monitoring wells were designed, and one new dedicated monitoring well was installed in the Basin as part of this Study. Hydrogeologic data collection programs are discussed in more detail in Section 6 of this report.

A subsidence study was performed as part of this Study. Subsidence has been observed in the Basin along Los Osos Valley Road west of Highway 101. Subsidence in the area of Auto Mall Parkway is associated with compaction of organic sediments resulting from lowered groundwater levels from groundwater extraction in the vicinity. Subsidence also has observed in the Lake Laguna area; lowered groundwater levels in this area are likely due to natural drought cycles since the start of residential development.= Within the Basin, the subsidence study designated areas with three categories that relate to the potential for future subsidence. Areas with organic soils prone to compaction are assigned the highest potential. The area along Los Osos Valley Road, and the area immediately west of Highway 101 near Tank Farm Road are assigned the highest potential. Subsidence is discussed in more detail in Section 7 of this report.

Enhanced recharge projects will be one of the management strategies considered during the development of a GSP. This Study presents and discusses two recent studies that use existing geographic information system (GIS) data to identify areas with intrinsic recharge potential. One study focused on potential projects for enhancement of both water supply and ecological conditions conducive to fish habitat, and so is largely confined to consideration of areas of stream alluvium. A second study evaluates the potential for using fallow agricultural land as temporary recharge basins. Both studies identified areas within the Basin that are favorable to further consideration for this type of project.

Some of the new findings from work efforts completed as part of this characterization Study are:

- New well logs from wells installed since the last Basin-wide analysis was performed indicate that the deepest portion of the Edna Valley sub-area water bearing formations is more than 100 feet deeper than previously documented, now measured at a depth of over 500 feet.
- Field work performed for this Study in the area south and west of the airport along Buckley Road suggests that the aquifer system in that area is distinct in the Basin in that the dominant recharge mechanism is infiltration of stream seepage, while precipitation-based recharge appears to be less significant. This represents a refinement of the conceptual model.
- Evaluation of long-term water level hydrographs throughout the Basin indicates two distinct trends in groundwater use and associated water levels. In the San Luis Valley sub-area, water levels respond to seasonal weather patterns and longer-term drought cycles, but are essentially stable. In the Edna Valley sub-area, intensive agricultural development during the past 20 years has resulted in water level declines in some wells of approximately 100 feet since approximately 2000.
- Efforts have commenced to expand the District's voluntary groundwater monitoring network. One new dedicated monitoring well was installed as part of this Study, and specifications for a second well have been prepared for future installation. The District will continue discussions to potentially incorporate some of the City's wells into the monitoring program, if amenable to the City. Other stakeholders have indicated that they may allow their wells to be monitored. These newly added wells and potential new wells would address data gaps in the County's monitoring network in the Basin.
- A subsidence assessment performed by Yeh & Associates assigns three categories of subsidence risk. Results indicate most of the Basin is not likely to experience significant subsidence under existing water use and land use patterns. Areas along Los Osos Valley Road experienced subsidence in the 1990s because of compaction of organic soils (i.e., peat) associated with

lowered groundwater levels. This area and others with known organic soils remain the highest risk areas for subsidence.

- A comprehensive set of data for transmissivity and specific capacity was collected. Transmissivity estimates derived from constant-rate tests were collected for 47 wells. Specific capacity data were collected for an additional 29 wells. The data are well-distributed spatially throughout the Basin. Wells screened in the Alluvium and Paso Robles Formation have transmissivities ranging from about 5,000 to 158,000 gallons per day per foot (gpd/ft), and averaging over 42,000 gpd/ft.. Wells screened in Paso Robles and Pismo Formations have transmissivities ranging from less than 1,000 to about 40,000 gpd/ft, and average about 10,000 gpd/ft. These data are discussed in greater detail in Section 5 of this report.

1. Introduction

This DRAFT Study documents the work performed by GSI Water Solutions, Inc. (GSI), and Yeh & Associates on behalf of the San Luis Obispo County Flood Control and Water Conservation District (District) for the San Luis Obispo Valley Groundwater Basin (Basin) Characterization and Monitoring Well Installation Project (Study). The County of San Luis Obispo (County) and the City of San Luis Obispo are the Groundwater Sustainability Agencies (GSA), authorized and mandated under California's Sustainable Groundwater Management Act (SGMA). The County received grant funding to develop this Study, in order to produce foundational information needed for the GSAs' future development of a groundwater sustainability plan (GSP) for the Basin.

1.1 Purpose of the Study

The purpose of this Study is to perform a characterization of the Basin, and to install one monitoring well to enhance the groundwater monitoring network in the Basin that currently is maintained by the County. A characterization of hydrogeologic data in the Basin is a necessary component of future Basin planning activities of the GSAs in the Basin.

A comprehensive analysis and characterization of the Basin is key to understanding its geology and hydrogeology, and will provide the GSAs with the foundational information necessary to aid in the management of this critical resource. This Basin characterization provides the basis of knowledge necessary to develop elements required under SGMA, such as a conceptual hydrogeologic conceptual model, a water budget, and a GSP

The Basin (Basin Number 3-09) has been designated as a medium priority basin not subject to conditions of critical overdraft under the 2014 Final Basin Prioritization by the California Department of Water Resources (DWR). Medium priority basins that are not in critical overdraft are scheduled to submit a GSP to DWR by January 31, 2022.

1.2 Previous Hydrogeologic Studies

The Basin (or areas within it) has been the subject of a number of previous geologic and hydrogeologic studies. Some studies included the Basin as part of a larger study area (e.g., the County or larger areas of the Central Coast), while other studies focused on the Basin (or areas within it) specifically. In addition, there are current ongoing data collection efforts being carried out in the Basin. Several of the most significant previous studies and ongoing data collection programs are identified and summarized in the following sections.

1.2.1. Government Agency Reports

- ***U.S. Bureau of Reclamation (USBR)***
  USBR produced a 1955 Reconnaissance Report that provided descriptions of geologic units and discussion of the occurrence of groundwater throughout the County (USBR, 1955). The report focuses primarily on the potential for expanding irrigated agriculture in the study area.

- ***California Department of Water Resources (DWR)***
  Three reports covering all or portions of the Basin were prepared by DWR. The first report (1958) covers all basins in the County. The second report (1964) covers San Luis Obispo and Santa Barbara Counties. The draft third report (1997) focuses on the San Luis Obispo Valley Basin, but was never finalized for official publication.

  - A 1958 report, “San Luis Obispo County Investigation” (DWR, 1958), discusses the water resources in the County and includes information about geology, hydrology, and hydrogeology. The report includes discussion of precipitation records, streamflow measurements, runoff calculations, depth-to-groundwater measurements, and selected water quality chemical data.

  - A 1964 report, “San Luis Obispo and Santa Barbara Counties Land and Water Use Survey, 1959” (DWR, 1964), focuses primarily on the development of surface water and groundwater resources for existing land use in the two-county area during the 1959 water year. Changes in land use patterns between 1949 and 1959 are discussed. The report concludes that water supply for the area of investigation may run short by 1980.

  - A 1997 draft report, “San Luis-Edna Groundwater Basin Study, Draft Report” (DWR, 1997), was prepared, but never finalized for official publication. The objective of this report was to provide the County with information on the hydrogeologic characteristics and dependable yield of the aquifers in the Basin. This report includes discussion of the geology of the Basin and descriptions of the water-bearing formations. It provides seven geologic cross sections of the Basin and includes discussion of the development of a groundwater model for the Basin modeled water level contours throughout the Basin. The report provides estimates for major water budget components for the Basin as a whole, as well as separate estimates for the Edna and San Luis Subbasins. It estimates “long-term dependable yield” for the San Luis Subbasin at 2,000 to 2,500 acre-feet per year (AFY), and for the Edna Subbasin at 4,000 to 4,500 AFY.

1.2.2. Consultants Reports

There are numerous reports from various consulting firms for private clients that were available for review during the preparation of this Study. This section briefly describes some of the most relevant reports made available.

A 1991 report by Boyle Engineering (Ground Water Basin Evaluation) was prepared for the City. The report is comparable in scope to DWR (1997). The objective of the 1991 report was to define the basin boundary and associated hydrology, assess the movement of groundwater within the Basin, and assess the City's groundwater development program. Long-term water level hydrographs are presented, and water level declines during drought are discussed. Water level elevation contour maps are presented for the spring of 1986 and 1990. The report discusses pumpage and water level declines in City wells, and estimates production rates, specific capacity, and transmissivity for City wells. Various water budget components are estimated, and will be discussed later in this report. The 1991 report recommends groundwater management strategies including increased data collection and monitoring, beneficial use or recharge of the City's wastewater effluent, and maximizing the City's groundwater extractions during periods of high streamflow.

A July 2000 report by TEAM Engineering evaluated groundwater pumping by the City in the 1990s in conjunction with reservoir operations from Whale Rock Reservoir and Salinas Reservoir. The report presents long-term hydrographs of City wells, and notes that City groundwater pumpage from 1990-1992 was 1,500 to 1,900 AFY in response to drought, but declined to 160 to 550 AFY after the drought ended. It notes that one reason for the reduction of City groundwater pumping is in response to nitrate contamination.

GSI reviewed numerous focused consulting reports during the collection of aquifer test data for wells in the Basin. Although these reports are not specifically cited in the text of this report, they were the basis of much of the data presented regarding hydrogeologic parameters, and as such are included in the References section of this report.

1.2.3. Geologic Maps

The most extensive geologic mapping performed along the Central Coast is the series of maps prepared by Thomas Dibblee. Dibblee mapped much of the area of San Luis Obispo and Santa Barbara Counties while working for the U.S. Geological Survey (USGS) and Atlantic Richfield Company. The maps that cover the Basin are published in 7 ½ -minute quadrangle maps at a scale of 1:24,000. The four Dibblee maps that cover the Basin are the geologic maps of the San Luis Obispo quadrangle (Dibblee, 2004a), the Lopez Mountain quadrangle (Dibblee, 2004b), the Pismo Beach quadrangle (Dibblee, 2006a), and the Arroyo Grande NE quadrangle (Dibblee, 2006b).

C.A. Hall also published several maps that cover the Basin. The Hall maps are presented in 15-minute quadrangles, at a scale of 1:48,000. The Hall maps that cover the Basin are the map of the Arroyo Grande 15-minute quadrangle and the map of the San Luis Obispo-San Simeon Region. In the Basin area, the Hall maps are not significantly different than the Dibblee maps. One observed difference between the Hall and Dibblee maps in the Basin is that some of the elevated alluvial terraces along the fringes of the

San Luis Valley are mapped as Paso Robles formation in Hall, and as Older Alluvium in Dibblee. Another difference is that the Hall maps include a small fault, named the Madonna Fault, in the northern extent of the Basin near the City that is not mapped by Dibblee. These are not substantive differences, and have no significant impact on this Study.

A series of preliminary geologic maps of the Basin area, mapped by M.O. Wiegers, were published by the California Geological Society (CGS) and are available to the public. The area of these maps are coincident with the Dibblee San Luis Obispo (2010), Pismo Beach (2011), and Arroyo Grande NE (2013) quadrangles. This series of maps does not identify the Paso Robles Formation by name, but refers to it with other Quaternary deposits. The Paso Robles Formation is referred to as Qvoaf, an abbreviation for Quaternary very old alluvial fanglomerate. For the purposes of this Study, there is no significant difference between these maps and the Dibblee maps.

The Pacific Gas and Electric Company (PGE) performed extensive geologic mapping on the coast of the County between Montana de Oro State Park and Avila Beach, in conjunction with the construction and operation of the Diablo Canyon Nuclear Power Plant. Although some of the mapping extends into the northwest extent of the Basin, the focus of the mapping effort is in the bedrock mountainous areas where the power plant was constructed. Therefore, most of the PGE geologic mapping is not relevant to this Study.

2. Basin Description

This section of the report discusses physical aspects of the Basin exclusive of specific geologic factors, which are discussed in the next section.

2.1 Physical Setting

The Basin is oriented in a northwest-southeast direction, and is composed of unconsolidated or loosely consolidated sedimentary deposits. It is approximately 14 miles long and 1.5 miles wide. It covers a surface area of about 12,700 acres (19.9 square miles). The Basin is bounded on the northeast by the relatively impermeable bedrock formations of the Santa Lucia Range, and on the southwest by the formations of the San Luis Range and the Edna fault system. The bottom of the Basin is defined by the contact of permeable sediments with the impermeable bedrock Miocene-aged and Franciscan Assemblage rocks (DWR 2003). A terrain map displaying the Basin boundaries is presented in Figure 1, which also displays the watershed areas of the San Luis Obispo Creek and Pismo Creek drainages. An aerial photo of the Basin area is presented in Figure 2. The Basin is commonly referenced as being composed of two distinct valleys, with the San Luis Valley in the northwest and the Edna Valley in the southeast.

The San Luis Valley comprises approximately the northwestern half of the Basin. It is the area of the Basin drained by San Luis Obispo Creek and its tributaries (Prefumo Creek and Stenner Creek west of Highway 101, Davenport Creek and smaller tributaries east of Highway 101). Surface drainage in San Luis Valley drains out of the Basin flowing to the south along the course of San Luis Obispo Creek toward the coast in the Avila Beach area, approximately along the course of Highway 101. The San Luis Valley includes part of the City and California Polytechnic University (Cal Poly) jurisdictional boundaries, while the remainder of the valley is unincorporated land. Land use in the City is primarily municipal, residential, and industrial. The area in the northwest part of the Basin, along Los Osos Valley Road, has significant areas of irrigated agriculture, primarily row crops.

The Edna Valley comprises approximately the southeastern half of the basin. The primary creeks that drain the Basin are the east and west branches of Corral de Piedras Creek; the Corral de Piedras Creek tributaries join to form Pismo Creek, draining south out of the Edna Valley into Price Canyon. Smaller unnamed tributaries drain south from the Basin in the extreme southeastern part of Edna Valley, ultimately joining Pismo Creek (Figures 1 and 2). The Edna Valley includes unincorporated lands, including lands associated various private water purveyors. The primary land use in the Edna Valley is agriculture. During the past two decades, wine grapes have become the most significant crop type in the Edna Valley.

The physical definition of the Basin boundary is the occurrence of unconsolidated or loosely consolidated sediments down to the contact with the basement rock of the Miocene-aged formations and Franciscan Assemblage. Figure 3 presents a topographic map of the bedrock surface defining the bottom boundary of the Basin. There is a topographic high point in the underlying bedrock elevation between the San Luis and Edna sub-basins. The watershed divide and the bedrock divide are not coincident.

Figure 4 presents contours of total sediment thickness of the water-bearing materials; the inset figure displays the thickness of sediments in a longitudinal cross section. It is apparent from Figure 4 that the sediments of the Edna Valley have significantly greater thickness than those of the San Luis Valley. The longitudinal profile of the Basin from the northwest on the left of the figure to the southeast on the right indicates the watershed divide present in the vicinity of Biddle Ranch Road, indicated on Figures 3 and 4. Precipitation that falls west of that divide ultimately flows to Davenport and San Luis Obispo Creeks, and precipitation that falls east of that divide flows to Corral de Piedras Creek or the other small tributaries, ultimately flowing to Pismo Creek south of the Basin.

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2.2 Precipitation

The primary weather patterns for the Basin derive from seasonal patterns of atmospheric conditions that originate over the Pacific Ocean and move inland. As storm fronts move in from the coast, rainfall in the area falls more heavily in the mountains, and the Basin itself receives less rainfall because of a muted rain shadow effect. Average annual precipitation ranges from approximately 18 inches throughout most of the Basin to about 22 inches in relatively higher elevation areas near the City and Cal Poly (Figure 5). Figure 6 presents the time series of annual precipitation for the period of record from 1871 to 2016 at the Cal Poly weather station. The average rainfall at this location is 21.87 inches, with a standard deviation of 8.71 inches. The historical maximum is 49.99 inches, which occurred in 1884. The historical minimum is 4.56 inches, which occurred in 2013.

2.3 Basin Water Purveyors

This section of the report briefly describes the major water suppliers in the Basin that use groundwater for supply. Each provider's service area is displayed on Figures 1 and 2. There are also numerous small water systems which are not included and listed in this study.

2.3.1. City of San Luis Obispo

The City, which reported a population of approximately 45,000 in the 2010 census, spans much of the northwest portion of the Basin. The City, through its Utilities Department provides water supply for most of the population. The City's water supply sources include both in-basin groundwater supplies, and imported surface water supplies, including Whale Rock Reservoir, Salinas Reservoir, Nacimiento Reservoir, recycled water, and groundwater.

The City began using groundwater as a source of supply in 1988. During a drought period in the late 1980s/early 1990s, groundwater was a significant portion of the City's water supply. However, since that time, the City has acquired additional surface water supplies and has diversified water sources, and thereby reduced use of groundwater. The City stopped pumping groundwater to its potable distribution system in April 2015 because of regulations that required costly treatment at the wellheads before the water could be used. However, the City's wells remain in operable stand-by condition, should the City need to use groundwater in the future.

2.3.2. Golden State Water Company – Edna

Golden State Water Company serves approximately 2,000 people in its service area in the Edna Valley sub-area, just southeast of the City (Figures 1 and 2). The water source is exclusively groundwater, from two wells in the service area.

2.3.3. Edna Valley Growers Mutual Water Company (MWC)

This MWC (Figures 1 and 2) incorporated in April 2015. It provides a framework for a consortium of local growers and agricultural interests to coordinate strategies for providing water supply to the various agricultural enterprises located within its boundaries. The parcels included within this MWC are non-contiguous, and partially overlap the areas of both Golden State Water Company to the west, and Edna Ranch MWC to the east.

2.3.4. Edna Ranch Mutual Water Company

The Edna Ranch MWC-East (Figures 1 and 2) was founded in 2010, primarily to provide a water supply to a residential development in the southeast portion of the Basin. This MWC serves approximately 60 people. The water source is exclusively groundwater, supplied from three wells located in the MWC service area in the Edna Valley.

2.3.5. Varian Ranch Mutual Water Company

This MWC incorporated in 1987, and serves approximately 120 people in a residential development in the southeastern extent of the Basin. The water supply is exclusively groundwater, supplied from two wells in the Edna Valley.

3. Geologic Setting

This section of the report discusses the geologic setting of the Basin, physical properties of the significant geologic formations and lithologic data sources, and presents geologic cross sections throughout the Basin.

3.1. Geologic Formations and Water-Bearing Properties

For the purpose of this Study, the rocks in the Basin vicinity may be considered as two basic groups. The consolidated rocks range in age and composition from (1) Jurassic-aged serpentine and marine sediments to (2) Tertiary-aged marine depositions. Compared to the saturated sediments that comprise the Basin aquifers, the consolidated bedrock formations are not considered to be water-bearing. Although bedding plane and/or structural fractures in these rocks may yield small amounts of water to wells, they do not represent a significant portion of the pumping in the area. In fact, the delineation of the Basin boundaries is defined both laterally and vertically by the contacts of the Basin sedimentary formations with the consolidated bedrock formations.

From a hydrogeologic standpoint, the most important strata in the Basin are the sedimentary basin fill deposits that define the vertical and lateral extents of the Basin. These include recent and older deposits of terrestrial sourced sediments, underlain in some areas by older marine sedimentary units.

Figure 7 displays a stratigraphic column of the significant local geologic units. Figure 8 presents a geologic map of the Basin vicinity (assembled from a mosaic of the Dibblee maps from the San Luis Obispo, Pismo Beach, Lopez Mountain, and Arroyo Grande NE quadrangles) showing where the various formations crop out at the surface. Fault data displayed in Figure 8 were acquired via the USGS Earthquake Hazards Program. The Quaternary fault and fold database from which the shapefiles are derived was published in 2006 and cites a wide variety of published sources. Fault traces within the shapefile represent surficial deformation caused by earthquakes during the Quaternary Period (the last 1.6 million years).

Figure 8 also displays the Basin boundaries defined in DWR Bulletin 118. Inspection of Figure 8 indicates that the existing GIS shape files for the Basin boundary do not appear to match up with the mapped extent of the water-bearing formations. This is likely an artifact of previous mapping being performed at a larger statewide scale. This Study suggests a potential adjustment of the Basin boundaries that honors the contacts displayed in the geologic maps (Dibblee 2004a, 2004b, 2006a, 2006b) as shown on Figure 8, and will be discussed in more detail later in this report.

The water-bearing sedimentary formations and the non-water-bearing bedrock formations are briefly described below.

3.1.1 Water-Bearing Series

- ***Recent Alluvium***

  The Recent Alluvium is the mapped geologic unit composed of unconsolidated sediments of gravel, sand, silt, and clay, deposited by fluvial processes along the courses of San Luis Obispo Creek, Davenport Creek, East and West Corral de Piedras Creeks, and their tributaries. Lenses of sand and gravel are the productive strata within the Recent Alluvium. These strata have no significant lateral continuity across large areas of subsurface within the Basin. Thickness of Recent Alluvium may range from just a few feet to more than 50 feet. Well pumping rates may range from less than 10 gallons per minute (gpm) to more than 100 gpm. However, wells screened exclusively in Recent Alluvium are generally less productive than wells that screen significant thicknesses of the Paso Robles and/or Pismo Formations.

- ***Paso Robles Formation***
  The Paso Robles Formation underlies the Recent Alluvium throughout most of the Basin, and overlies the Pismo Formation where present. It is composed of poorly sorted, unconsolidated to mildly consolidated sandstone, siltstone, and claystone, with thin beds of volcanic tuff in some areas. The Paso Robles Formation was deposited in a terrestrial setting on a mildly sloping floodplain that has been faulted, uplifted, and eroded since deposition. The Paso Robles Formation is exposed at the surface through much of the Edna Valley, except in areas where existing streams have deposited Recent Alluvium on top of it. It is not readily distinguishable from alluvium in geophysical well logs, or in driller's logs documented on well completion reports. Locally, the Paso Robles Formation is sometimes, but not always, distinguished as being yellow in color, with sticky clay. Well Completion Reports with these types of descriptions generally were identified as Paso Robles Formation for the purpose of cross sections. However, it was sometimes difficult to distinguish between Recent Alluvium and Paso Robles Formation in driller's descriptions, and professional judgment and broader context within the Basin were often used when defining the contact between these two units. Wells completed in both the Recent Alluvium and Paso Robles Formation have reported yields from less than 100 to over 500 gpm.

- ***Pismo Formation***
  The oldest geologic water-bearing unit with significance to the hydrogeology of the Basin is the Pismo Formation. The Pismo Formation is a Pliocene-aged sequence of marine deposited sedimentary units composed of claystone, siltstone, sandstone, and conglomerate. There are five recognized members of the Pismo Formation (Figure 7). While all are part of the Pismo Formation, the distinct members reflect different depositional environments, and the variations in geology may affect the hydrogeologic characteristics of the strata. From the bottom (oldest) up, these are:

    - **The Edna Member**, which lies unconformably atop the Monterey Formation, and is locally bituminous (hydrocarbon-bearing)
    - **The Miguelito Member**, primarily composed of thinly bedded grey or brown siltstones and claystones
    - **The Gregg Member**, usually described as a medium-grained sandstone
    - **The Bellview Member**, composed of interbedded fine grained sandstones and claystones

- **The Squire Member**, generally described as a medium- to coarse-grained fossiliferous sandstone of white to grey sands

Previous reports have identified the significant thicknesses of sand at depth beneath the Paso Robles Formation in the Edna Valley as the Squire Member of the Pismo Formation. However, it is not clear whether these are accurately assigned as Squire. Other members of the Pismo Formation may be part of the sequence, and there is some ambiguity as to the actual member assignment. Even in adjacent quadrangle geologic maps by Dibblee, there is ambiguity in the geologic nomenclature. In the adjacent maps of the Pismo Beach and the Arroyo Grande NE quadrangles, a continuous exposure of this unit across the boundary between the two maps is referred to as Pismo Formation in one map, and Squire Sandstone in the other. Therefore, it is probably more accurate to generally refer to these units as the Pismo Formation, and not try to specifically identify the member designations. This convention will be followed for the remainder of this report.

The Pismo Formation is extensive below the Paso Robles Formation in the Edna Valley. Thicknesses of Pismo Formation up to 400 feet are reported or observed in well completion reports and in the cross sections. The presence of sea shells in the lithologic descriptions of well completion reports is clearly diagnostic of the Pismo Formation because of its marine origin. Many of the well completion reports in the Edna Valley document water-bearing blue and green sands beneath the Paso Robles Formation, and these are considered to be largely diagnostic of the Pismo Formation as well. Wells that are completed in both the Paso Robles and Pismo Formations are reported to yield from less than 100 gpm to approximately 700 gpm.

3.1.2 Non-Water-Bearing Series

- ***Monterey Formation***

The Monterey Formation is a thinly bedded siliceous shale, with layers of chert in some locations. In other areas of the County outside of the Basin, the Monterey Formation is the source of significant oil production. There are no active oil wells within the Basin boundaries, although an active oil field is present just south of the Edna Valley in the mountains south of the Basin and west of Price Canyon. While fractures in consolidated rock may yield small quantities of water to wells, the Monterey Formation is not considered to be an aquifer for the purposes of this Study.

- ***Obispo Formation***

The Obispo Formation and associated Tertiary volcanics are composed of materials associated with volcanic activity along tectonic plate margins approximately 20 to 25 million years ago. The Obispo Formation is composed of ash and other material expelled during volcanic eruptions. The “Nine Sisters” series of peaks separating the Los Osos and Chorro Valleys are volcanic plugs, composed of volcanic rock, which lithified at the core of volcanoes that became inactive with time. Although fractures in consolidated volcanic rock may yield small quantities of water to wells, the Obispo Formation is not considered to be an aquifer for the purposes of this Study.

- ***Franciscan Assemblage***
  The Franciscan Assemblage contains the oldest rocks in the Basin area, ranging in age from late Jurassic through Cretaceous (150 to 66 million years ago). The rocks include a heterogeneous collection of basalts, which have been altered through high-pressure metamorphosis associated with subduction of the oceanic crust beneath the North American Plate before the creation of the San Andreas Fault. The current assemblage includes ophiolites, which weather to serpentinites and are common in the San Luis and Santa Lucia Ranges. The rocks are frequently reddish green in color. Although fractures may yield small quantities of water to wells, the Franciscan Assemblage is not considered to be an aquifer for the purposes of this Study.

3.2. Geologic Structure

The primary geologic structures of significance to the hydrogeology of the Basin are the Edna Fault Zone and the adjacent Los Osos Fault Zone, which together form the southwestern boundary of the Basin through the uplift of the Franciscan and Monterey strata southwest of the faults. The Edna Fault is identified as a normal fault, extending from southeast of the Edna Valley to the vicinity of the town of Edna (Figure 8). There are some disconnected and unnamed fault splays mapped in the area south of the airport. The Los Osos Fault Zone is mapped along the southwest edge of the Los Osos Valley. Movement along the Edna and Los Osos Valley Fault Zones has brought the water-bearing sediments of the Basin into contact with the non-water-bearing bedrock formations of the San Luis Range. The Edna Fault also cuts sediments of the Pismo Formation. No available water level or other data indicate that the faults have any significant effect on the movement or quality of groundwater in the Basin.

3.3. Geologic History

The rocks of the Franciscan Assemblage are believed to have been formed from subduction of the oceanic Farallon tectonic plate beneath the continental crust of the North American Plate in the late Jurassic and Cretaceous Periods, approximately 1,144 to 66 million years ago. During this plate subduction, oceanic sediments atop the Farallon Plate were "scraped off" and added to the leading edge of the North American Plate (Chipping, 1987). Widespread folding, faulting, and metamorphism occurred during this process. These sediments comprise the Franciscan Assemblage, which are one of the primary strata forming the Coast Ranges in present day California. An unconformity exists between the Cretaceous rocks of the Franciscan Assemblage and the earliest Tertiary strata.

The volcanics of the Obispo Formation and associated intrusive volcanic rocks were formed in the Tertiary Period, approximately 16 to 25 million years ago. This volcanic activity was likely associated with the subduction activity previously described.

The Monterey Formation formed during the Miocene Age, about 5 to 16 million years ago. The Monterey is a collection of sediments formed on the sea floor, with both marine and terrestrial source material. The bulk of the Coast Ranges likely was submerged beneath the ocean during the Monterey deposition.

In the Basin area, the Monterey Formation was folded and tilted before the deposition of the Pismo Formation above it. The Pismo Formation also was deposited in a marine environment. As the successive members of the Pismo Formation were being deposited, the sea floor was gradually rising. By the time of the Squire Member deposition, shallow water fossils indicate a surf zone environment. This evidence of local uplift may be coincident with the beginning of the Coast Range Orogeny, the mountain-building episode that created the present Coast Ranges, and continues to the present day.

Sediments from the newly forming mountains spread to the east and south of the Santa Lucia Mountains, north of the present day Basin. Coalescing alluvial fans resulted in the deposition of the Paso Robles Formation on top of the exposed Franciscan Assemblage and Monterey Formation during the early Pleistocene Epoch, about 2 million years ago. Following deposition, the San Luis Valley was uplifted; subsequent erosion and deposition associated with recent fluvial processes resulted in substantial erosion of the Paso Robles Formation and deposition of Recent Alluvium above it. Although the Edna Valley experienced similar uplift, the smaller watershed area resulted in less extensive erosion and deposition than observed in the San Luis Valley. Thus, the Paso Robles Formation is still observed at the surface in the Edna Valley, although it is highly dissected on the northern slopes of the Basin.

3.4. Lithologic Data

All readily available lithologic data were obtained for the preparation of this report. Sources of data included Well Completion Reports on file with the County and DWR, boring logs documented in published government reports or private consultant reports, geophysical boring logs, and various other sources. In all, 343 data points with lithologic information were collected for use in the preparation of cross sections for this report. Lithologic data were assigned spatial coordinates based on available mapping, and descriptions of geologic materials were recorded in a database for reference in future SGMA management activities. Lithologic data point locations are presented in Figure 9.

3.5. Cross Sections

Eleven cross sections were prepared for this report; three (A1-A2, A2-A3, A3-A4) are oriented along the longitudinal axis of the Basin and eight (B-B’ through I-I’) are oriented across the Basin, perpendicular to the longitudinal axis (Figure 9). All lithologic data was reviewed during the selection of the cross section line locations. The cross sections display lithology, interpretations of geologic contacts based on available data, screened intervals, and interpreted and mapped faults. If the geologic interpretation was not clear from the points on the cross section lines, nearby data from other locations was reviewed to provide broader geologic context. Each geologic cross section is discussed in the following paragraphs.

Because the longitudinal axis of the Basin is much longer than the cross basin section lines, the longitudinal axis was divided into three separate cross sections for the sake of clarity and presentation of detail.

- **Cross Section A1-A2** (Figure 10) extends approximately 6.5 miles from the northwest extent of the Basin at its boundary with the Los Osos Basin to about 1 mile east of Highway 101. Land surface elevation is about 200 feet mean sea level (msl) at the northwest extent, and slopes gently downward to about 120 feet msl at the southeast extent. Recent Alluvium is exposed at the surface for the entire length of this cross section, ranging in thickness from less than 50 feet near the Los Osos Valley Basin boundary to about 80 feet near the center of the section. The Paso Robles Formation is relatively thin in the northeast where it has been significantly eroded by the alluvium, but thickens to approximately 70 feet in the southeastern part of the section. Marine sands of the Pismo Formation occur below the Paso Robles Formation in the southeastern part of the section, with a maximum thickness of about 50 feet. However, this lens of Pismo Formation appears to be isolated from thicker deposits of Pismo Formation in the Edna Valley, and does not extend to the southeast along this section line. Because this section line largely parallels the major fault zones of the Edna and Los Osos Valley faults, these faults are not apparent on these cross sections.

- **Cross Section A2-A3** (Figure 11) extends approximately 4 miles along the longitudinal Basin axis, starting near Tank Farm Road and cutting obliquely across Buckley Road in the northeast to just past Edna Road in the southwest. Land surface elevation is approximately 120 feet msl in the northwest and climbs to more than 270 feet msl in the southwest. Along the northwest half of the section line, alluvium is exposed at the surface, with an approximate thickness of 40 to 50 feet. The alluvium is primarily underlain by the Paso Robles Formation with thicknesses ranging from approximately 40 to 80 feet. Just southeast of the airport, the Paso Robles Formation is exposed at the surface, beginning at the point where there is a noticeable rise in land surface elevation. The thickness of the Paso Robles Formation in this area is up to 120 feet. Pismo Formation sediments underlie the Paso Robles Formation in this area, with thickness of about 50 feet in the area of Davenport Creek. The Pismo Formation thickness starts to expand greatly along this section line to the southeast, with about 250 feet of Pismo sediments evident at the southeastern extent of the section line. The deepest well, located in the center of the section, lies at approximately the high point of the bedrock surface. This is commonly accepted as the dividing line between the San Luis Valley and the Edna Valley. Several of the borings in this section indicate wells are partially or completely screened in bedrock formations, indicating that the relatively thin saturated portions of the water-bearing sediments did not yield enough water for the purposes of the wells.

- **Cross section A3-A4** (Figure 12) extends about 6.5 miles along the Basin axis from approximately Biddle Ranch Road to the southeast extent of the Basin. Land surface elevation rises from about 250 feet msl on the northwest end of the section to more than 500 feet msl in the southeast. Relatively thin occurrences (40 feet or less) of Recent Alluvium associated with Corral de Piedras Creek and its tributaries are evident in some areas on the western half of this section. In the southeastern extent of the section, the Paso Robles Formation crops out at the surface where the land is beginning to rise to the northern mountains, and is dissected by small streams and valleys in this area. The Pismo Formation sediments reach their maximum thickness of more than 400 feet along the northwestern extent of this section; the thickness of the Pismo gradually thins to about 90 feet at the southwestern extent of the section.

- **Cross section B-B’** (Figure 13) extends about 1.5 miles across the Basin perpendicular to the Basin axis in the vicinity of Foothill Boulevard and Los Osos Valley Road. The section line has a land surface elevation of about 180 feet msl on the northern end, sloping downward to about 130 feet msl along the Basin’s long axis, and rising again to about 230 feet msl on the southern end. Recent Alluvium is exposed at the surface along this entire section, with thicknesses of about 20 to 30 feet. In the northern half of the section, alluvium is deposited directly on underlying basement rock. In the southern half of the section, the Paso Robles Formation underlies the alluvium with a maximum thickness of about 45 feet. The southern extent of the section crosses the Los Osos Fault Zone.

- **Cross Section C1-C1’** (Figure 14) extends from the northern lobes of the Basin boundary, which are formed from alluvium from Stenner and San Luis Obispo Creeks, and trends southward approximately 5.5 miles across the Basin from Cal Poly through the City, approximately along the path of Highway 101. Land surface elevation is about 350 feet at the northern end of the section line on some noticeable hilltops along the line, and slopes downward to an approximate altitude of 80 feet on the southern end. Because the southern end of this section line is located near where San Luis Obispo Creek exits the Basin and flows toward the coast, there is no elevation gain on the southern end of this section as is observed in B-B’ and the other cross-Basin sections. Most of the northern extent of this section has alluvium of about 20 to 40 feet of thickness deposited directly on underlying basement rock. Only in the southernmost 1½ miles of the section line, where it crosses the main body of the Basin, do other sediments underlie the alluvium. The Paso Robles Formation is about 90 feet thick here, and it is in turn underlain by about 60 feet of Pismo Formation sediments.
- **Cross Section C2-C2’** (Figure 15) extends about 1½ miles southward through the eastern lobe of the northern part of San Luis Valley. Alluvium is deposited directly on top of basement rock along this section. Alluvium thickness ranges from less than 10 feet to about 40 feet.
- **Cross Section D-D’** (Figure 16) extends about 2.5 miles southward from a prominent serpentine ridge in the north to the southern Basin boundary. Land surface elevation is about 160 feet on the northern end of the section, sloping down to about 110 feet in the Basin center, and rising to about 180 feet on the southern end. Recent Alluvium is exposed at the surface along most of this section, reaching a maximum thickness of about 80 feet. The alluvium is deposited directly on basement rock through the northern half of the section. In the southern half of the section, approximately 20 to 30 feet of Paso Robles Formation underlies the alluvium. Near the southern extent of the Basin, the section line crosses into the combined Edna-Los Osos Fault Zone, at which point the land surface elevation rises steeply and the Paso Robles Formation crops out at the surface due to the upthrown formations south of the faults.
- **Cross Section E-E’** (Figure 17) extends about 2½ miles across the Basin in the vicinity of the airport and the area south of Buckley Road. Land surface elevation ranges from about 170 feet on the northern end to 230 feet in the southern end. In the northern half of this section, Recent Alluvium and some pods of older alluvium are exposed at the surface. In the southern half, the Paso Robles Formation is exposed. Alluvial thickness in the northern half of the section ranges from about 20 to 70 feet, and is underlain by about 30 to 35 feet of Paso Robles Formation. In the southern half of the section, it crosses into the Edna-Los Osos Fault Zone, and the Paso Robles Formation is upthrown to the point that it is exposed at the surface. Paso Robles Formation

thickness ranges from 50 feet to about 100 feet. Sediments of the Pismo Formation underlie the Paso Robles Formation in this area, and are about 25 to 70 feet thick.

- **Cross Section F-F'** (Figure 18) extends about 2 miles north to south in the western extent of the Edna Valley area. The Paso Robles Formation is exposed at the surface along most of this section. One small pod of alluvium associated with Davenport Creek is evident in the center of the section. The Paso Robles Formation has a maximum thickness of about 175 feet in this section. It is underlain by about 50 to 60 feet of Pismo Formation sediments in the area north of the Edna Fault Zone. To the south, the section line extends into the Edna Fault Zone. South of the fault, the formations are upthrown, resulting in a small area of Pismo Formation sediments exposed at the surface.

- **Cross Section G-G'** (Figure 19) extends about 2 miles through the heart of the Edna Valley area. Land surface elevation ranges from about 300 feet on the north end to more than 350 feet on the south end. A thin veneer of alluvium, about 20 feet thick, that is associated with Corral de Piedras Creek and tributaries is exposed at the surface along much of this section. The Paso Robles Formation crops out in the north of the section, and underlies the alluvium with an average thickness of about 50 to 60 feet. The Pismo Formation displays its largest thickness along this section, with a maximum thickness of about 450 feet near where this section intersects with cross section A3-A4. The southern end of the section line crosses into the Edna Fault zone, and sediments are displaced such that the Pismo Formation sediments are exposed at the surface on the southern slopes of the Basin in this area.

- **Cross Section H-H'** (Figure 20) extends approximately 2½ miles through the Edna Valley. Land surface is approximately 350 feet on the northern end, sloping downward to about 230 feet near Corbett Canyon Road, then quickly rising to nearly 400 feet on the south end of the section on the upthrown side of the Edna Fault. The Paso Robles Formation is exposed at the surface for nearly the entire section. The section line crosses a small exposure of Recent Alluvium associated with Corral de Piedras Creek. In the northern half of the section, the Paso Robles Formation sediments are deposited directly on the basement rock formations, with a maximum thickness of about 80 feet. In the southern half of the section, the basement rock elevation plunges and the thickness of the Paso Robles Formation is about 150 to 230 feet. The Pismo Formation underlies the Paso Robles Formation sediments in the southern half of the section, with a maximum thickness of about 200 feet. In the Corbett Canyon area, the section crosses the Edna Fault; south of the fault the basement rock formations are thrust up to the surface, and represent the boundary of the Basin.

- **Cross Section I-I'** (Figure 21) crosses the southern extent of the Edna Valley. The northern part of the section lies along the lower slopes of the Santa Lucia Range, and displays Paso Robles Formation sediments deposited on top of bedrock formations. A small pod of Recent Alluvium associated with Corral de Piedras Creek is displayed. Along the center of the Edna Valley, the Paso Robles Formation thickness is about 200 feet, and is underlain by about 100 feet of Pismo

Formation sediments. The section crosses the Edna Fault Zone, which shows Pismo Formation sediments upthrown to land surface on the south side of one fault splay, and bedrock of the Monterey Formation upthrown to land surface elevation south of a second fault splay.

4. Hydrogeologic Setting

This section of the report discusses the Basin's hydrogeologic setting, including previous estimates of various water budget components, previous sustainable yield estimates, groundwater flow patterns, transient long-term water level trends, and a brief discussion of groundwater quality.

4.1. Hydrogeologic Units

Section 3 of this report details the presence of three distinct geologic formations in the Basin that are considered aquifers and yield significant quantities of groundwater to wells: Recent Alluvium, Paso Robles Formation, and Pismo Formation. Although geologic age and depositional environment clearly define these as separate formations, this distinction does not extend to defining the formations as specific and unique hydrogeologic units.

Although there are significant intervals of clay evident in boring logs throughout the Basin, the clay lenses are not consistent across large areas. There is no evidence of a regionally or laterally extensive impermeable strata that isolates the formations from one another vertically. As a result, it appears that in the San Luis Valley, the Recent Alluvium and the Paso Robles Formation function as a single hydrogeologic unit. It does not appear that any wells in the San Luis Valley are screened exclusively in either the Recent Alluvium or the Paso Robles Formation. Similarly, in the Edna Valley, there is no laterally extensive impermeable strata separating the Paso Robles and Pismo Formations. Frequently, the sand of one formation is in contact with the sands of the other formation. Therefore, it appears that in the Edna Valley, the Paso Robles Formation and the Pismo Formation function as a single hydrogeologic unit. An installation of paired monitoring wells, with each screened exclusively in one formation, would be necessary to define any significant vertical gradient or hydrogeologic separation between the two formations.

4.2. Overview of Water Budget

As previously described, the Basin is composed of a collection of unconsolidated to loosely consolidated sediments, bounded by bedrock formations laterally and vertically. A water budget is simply an accounting of all the hydrologic inflows and outflows to the Basin. Before groundwater development in the area, groundwater was recharged to the aquifer system (i.e., inflows) via areal infiltration of rainfall across the Basin, seepage losses to underlying aquifers from seasonal streamflow, and, to some extent, mountain front recharge along the Basin margins, as rainfall on the mountain slopes travels via overland flow to the Basin surface. Pre-development outflows from the Basin occurred via evapotranspiration of shallow groundwater, and through outflow from the Basin through alluvial sediments at the locations where San Luis Obispo Creek and Pismo Creek leave the Basin.

Since groundwater development became prevalent in the 20th century, the components of the water budget have changed from the pre-development system. Removal of groundwater via pumping has become the dominant outflow component of the water budget. In addition, secondary recharge occurs through deep percolation of applied irrigation water, and additional stream seepage resulting from release of treated wastewater to Stenner Creek.

The following report sections summarize water budget component estimates reported in previous studies. An updated estimate of past, current, and future water budgets will be generated in the GSP, as per Section 10727.2(a)(3) of the Water Code.

4.3. Recharge

As previously discussed, the primary mechanisms for recharge in the Basin occur via areal infiltration of rainfall, percolation of seasonal streamflow from the alluvial sediments to underlying formations, deep percolation of applied irrigation water, and mountain front recharge. Mountain front recharge has not been specifically discussed or quantified in previous studies, and is general conceptually lumped in with recharge from precipitation.

DWR (1958) estimated that average recharge to the Basin was 2,250 AFY. Working with data from a longer period of record, Boyle (1991) estimated total recharge to the Basin from 1978-1990 was 3,650 AFY (1,510 acre-feet from irrigation percolation, 1,450 acre-feet from rainfall, 430 acre-feet from stream seepage losses, 300 acre-feet from reclaimed wastewater). In its draft report, DWR (1997), using a groundwater model approach, estimated recharge from precipitation, agriculture return flows, and incidental urban recharge, at an average value of 4,560 acre-feet, ranging from 2,300 AFY in a drought year to 9,590 AFY in a wet year. It should be noted that DWR (1997) only estimates aquifer recharge from stream seepage during dry years. These estimates are presented in Table 1.

Table 1. Summary of Previous Basin Water Budget Component Estimates (acre-feet)

	DWR (1958)	Boyle (1991)	DWR (1997 Draft)
Recharge	2,250	3,650	4,560
Groundwater in Storage	67,000	69,900	46,700 – 55,800
Groundwater Pumpage	1,900	5,690 – 7,810	4,380 – 7,640
Sustainable Yield	2,000	5,900	6,000-7,000

Although recharge from streamflow is estimated as a relatively small component of total recharge in previous studies, it should be noted that this is from a Basin-wide perspective. There appear to be areas in the Basin where recharge is dominated by stream seepage. During field work associated with this project, several wells were evaluated in the area near Buckley Road, south and west of the airport. No public water service is available in this area, so the homes use private wells for domestic supply. However, the wells in this area usually are not located on the properties that they supply, but rather they are clustered near the creek beds in the area; water from the wells is conveyed via pipeline to storage tanks proximate to the homes they supply. Anecdotal information indicates that well drilling in locations that are not along the creek beds result in either dry holes or wells with limited pumping rates (less than 10 gpm). By contrast, the wells located along the creeks are capable of pumping at significantly higher rates (30 gpm to more than 100 gpm). These data appear to support the observation that the aquifer in this area is being primarily supplied by recharge from the seasonally flowing creeks. It is not clear why recharge from percolation of rainfall is limited in this area; there may be a small impermeable horizon in the Paso Robles Formation in this area that inhibits vertical groundwater flow.

Most of the wells in the area near Buckley Road are on the order of 100 feet deep, which is too deep to be screened only in the local alluvium. During the seasonal winter rains when the creeks are flowing, water levels are at approximately the same level as the water in the creek. During the dry season, water levels decrease to about 15 to 20 feet below land surface. The alluvium appears to recharge the underlying Paso Robles Formation. As one moves laterally away from the creek beds, well yields decrease, and the incidence of dry holes increases, indicating that precipitation-based recharge is barely adequate to supply recharge to a pumping well. But wells along the creek, which experience significant stream-based recharge, continued to pump even through the significant recent drought of 2011-2016.

4.4. Groundwater Storage

Groundwater storage within the Basin is a transient parameter, changing with seasonal and long-term fluctuations in groundwater surface elevations. However, estimates of the average quantity of groundwater in storage can be calculated using Basin surface area, average water levels, average specific yield or storativity, and saturated thickness.

DWR (1958) estimated saturated storage capacity for the Basin to be 67,000 acre-feet.

Boyle (1991) estimated total groundwater storage in the San Luis sub-basin at 23,900 acre-feet, and in the Edna sub-basin at 46,000 acre-feet, for a total of 69,900 acre-feet. This is comparable to DWR's estimated saturated storage capacity (DWR, 1958).

In its draft report, DWR (1997) estimated ranges in storage for the period of record 1970-1993. Storage estimates for the San Luis sub-basin ranged from about 14,700 to 17,800 acre-feet, and estimates for the Edna sub-basin ranged from about 32,000 to 38,000 acre-feet, resulting in total basin storage estimates of 46,700 to 55,800 acre-feet, somewhat less than estimates from DWR (1958) and Boyle (1991).

A summary of these storage estimates is presented in Table 1.

4.5. Groundwater Pumping

Patterns and quantities of groundwater use in the Basin have varied depending on the period of record. The City did not begin groundwater development until the late 1980s. In the 1990s, the City relied on significant groundwater use, particularly in times of drought. Today, by contrast, the City's potable water wells are used only for emergency standby. Agricultural use in the Edna Valley has changed in recent decades in response to market drivers, with the total irrigated acreage expanding significantly, and the crop types changing; currently, wine grapes are the dominant product. Estimates of groundwater pumpage in the Basin are sporadic. Agricultural wells have not been metered in the past, and methods to estimate agricultural pumpage indirectly may vary. However, the published estimates are presented in Table 1 and are briefly discussed below.

DWR (1958), in the same table that presents the safe seasonal yield estimate of 2,000 AFY, estimates that 1,900 acre-feet of groundwater production were developed at that time. No details on this estimate are evident in the report text.

Boyle (1991) reports an estimate of agricultural groundwater pumpage of 5,200 AFY, based on evaluation of irrigated acreage of various crop types, unit water use for each crop type, and irrigation efficiency. It is noteworthy that there is no reported irrigated vineyard acreage reported for the study period: 1978-1990. Municipal and industrial pumpage is estimated to average 600-800 AFY during that period, but was reported to be as high as 2,600 AFY during the drought year of 1990. Resultant total groundwater pumpage estimates for the Basin range from 5,690 to 7,810 AFY.

In its draft report, DWR (1997) presents some estimates for groundwater pumpage in the Basin. For years ranging from 1970 to 1995, groundwater pumpage estimates for all water user groups from the San Luis Valley range from 1,900 to 3,300 AFY, with the maximum estimate in the drought year of 1990. Pumpage estimates from the Edna Valley range from 2,330 to 4,340 AFY. Resultant total groundwater pumpage estimates for the Basin range from 4,380 to 7,640 AFY.

4.6. Sustainable Yield

The concept of sustainable yield, long term yield, or safe yield is a hydrogeologic construction that has undergone changes throughout the decades, as public and legal perceptions and understanding of hydrologic systems have evolved. In general, it is defined as the amount of water that can be withdrawn without producing an undesired effect. However, in California, the term “safe yield” has a rigid definition associated with the court case Los Angeles v. San Fernando, so that term is largely avoided nowadays in favor of “sustainable yield”. The DWR Groundwater Sustainability Plan (GSP) Annotated Outline makes specific reference to “sustainable yield”. These terms are considered to be largely identical for the purposes of this Study. However, in all future management activities performed under SGMA requirements, the terminology of sustainable yield will be used.

DWR (1958) estimated the sustainable yield of the Basin to be 2,000 AFY.

Boyle (1991) estimated the sustainable yield of the Basin to be 5,900 AFY.

DWR (1997) estimated the long-term sustainable yield for the Basin at 6,000 to 7,000 AFY (2,000 to 2,500 AFY in the San Luis sub-basin, and 4,000 to 4,500 AFY in the Edna sub-basin).

A summary of these yield estimates is presented in Table 1.

4.7. Surface Water/Groundwater Interaction

Surface water/groundwater interactions represent a small, but significant, portion of the water budget of an aquifer system. In the Basin, these interactions occur primarily at streams and lakes. No significant springs are known in the Basin.

Laguna Lake is the only lake in the Basin. The downstream outlet of the lake is dammed to artificially impound water to maintain water elevation in the lake to preserve and enhance the wildlife habitat and recreational purposes. The water in the lake is partially supplied by seasonal flow in Prefumo Creek, which flows into Laguna Lake. However, even when Prefumo Creek does not flow for significant periods of time, Laguna Lake remains at least partially full. This appears to indicate that in addition to surface water inflow, the water in the lake is at least partially supplied by subsurface groundwater flow.

Groundwater interaction with streams in the Basin is not well quantified, but it is recognized as an important component of recharge in the water budget. Where the water table is above the streambed and slopes toward the stream, the stream receives groundwater flow from the aquifer; this is known as a gaining reach (i.e., the stream gains flow as it moves through the reach). Where the water table is beneath the streambed and slopes away from the stream, the stream loses water to the aquifer; this is known as a losing reach. During seasonal dry flow conditions, it is clear that groundwater elevation is deeper than the streambed. Therefore, it is generally understood that San Luis Obispo Creek discharges to the underlying aquifer, at least in the first part of the wet-weather flow season. If there is constant seasonal surface water flow, it is possible that groundwater elevations may rise to the point that they are higher than the stream elevation, and the creek may become a seasonally gaining stream. But there are no data to corroborate this. It may remain a losing stream throughout most or all years.

The amount of flow in surface water/groundwater interaction is difficult to quantify. Boyle (1991) assumed that 10 percent of the measured surface water flow coming into the Basin in San Luis Obispo Creek, Stenner Creek, and San Luis Obispo Creek was recharged to the aquifer, and used an average rate of 430 AFY. In its draft report, DWR (1997) reports model-generated estimates ranging from streams gaining 2,700 AFY from the aquifer, to streams losing 680 AFY to the aquifer.

The County, through its Water Resources Division coordination with Zone 9 and the City, maintains a network of five stream gauges in the San Luis Valley of the Basin to record quantities of flow throughout the year. The gauges were constructed in November 2001, and have periods of record from that year to the present. Continuous data monitoring is recorded.

There are some actions that the GSAs could take to increase the understanding of the nature of surface water/groundwater interaction in the Basin. One possibility is the installation of shallow groundwater monitoring wells paired with the stream gauge stations. This would provide relative elevation data between streamflow and groundwater to better characterize the direction of flow between the streambed and the aquifer. Another possibility is to analyze the daily stream data from the stream gauges discussed above for base flow separation. This could provide greater understanding of the quantity of flow as water moves downstream. A third possibility is a synoptic low flow study, in which a series of streamflow discharge measurements is performed on a subject stream on the same day, so that changes in flow can be documented simultaneously at different areas of the stream, therefore quantifying the amount of flow gain or loss along the reach. The GSAs will consider what is necessary and feasible in order to fill these and other data gaps, during development of a GSP.

4.8. Groundwater Flow Direction

Groundwater flow in the Basin is predominantly from the Edna Valley northwestward toward the San Luis Obispo Creek alluvium, at which point the flow direction leaves the Basin along the stream course. Groundwater in the northwestern areas of the Basin near the City boundary and Los Osos Valley Road flows southeastward toward the San Luis Obispo Creek alluvium. There are also local areas of flow leaving the Basin along the Corral de Piedras Creek and alluvium of other smaller tributaries, in the southeastern portion of the Basin.

DWR (1958) published a series of maps depicting groundwater elevation maps for the various parts of its study area, including groundwater elevations in the Basin for Fall 1954 (Figure 22). This map displays dominant groundwater flow direction from higher elevations in the Edna Valley (over 280 ft msl) to lower elevations (less than 110 feet msl) where San Luis Obispo Creek exits the Basin.

Boyle (1991) presents water level elevation contour maps for the spring of 1986 and 1990, based on water level data collected in the field. A recreation of the Boyle water level contours for spring of 1990 is presented in Figure 23 and displays a pattern of groundwater flow in the Basin very similar to that exhibited in the DWR map. Contours for the spring of 1986 are not presented in this report, but 1986 represents wetter conditions than the 1990 map, and it is noted in Boyle (1991) that there is a difference of approximately 10 feet of elevation between the two maps, representing the variation in water levels that may be observed between wet and dry weather cycles.

In its draft report, DWR (1997) used a computer groundwater model developed for its study to generate a series of modeled water level maps representing wet, dry, and average conditions. The model results are not re-presented in this Study, but the maps display the same general flow patterns as the DWR (1958) and Boyle (1991) maps based on field data. Water level elevations in what DWR defines as the San Luis sub-basin in wet years were approximately 10 to 20 feet higher than in dry years. In what DWR defines as the Edna sub-basin, the difference in groundwater elevations between wet and dry years was approximately 20 to 30 feet.

Recent groundwater level data collected as a part of the District’s voluntary monitoring network have not been used to generate representative water level contour maps.

4.9. Hydrographs

The San Luis Valley and the Edna Valley are characterized by different patterns of groundwater use. In the San Luis Valley, groundwater use has been dominated by municipal and industrial use. In the Edna Valley, groundwater use is dominated by agricultural use. During the past 15 to 20 years, vineyards have supplanted other crops as the dominant agricultural use. Available water level data were reviewed, and data from wells with the longest period of record are presented here. (These wells do not necessarily correspond with the County’s current monitoring network.)

Figure 24 presents long-term groundwater elevation hydrographs for ten wells throughout the Basin. Two different patterns are evident in Figure 24. The hydrographs for the wells in the San Luis Valley indicate that water levels in these wells, although somewhat variable in response to seasonal weather and use fluctuations and longer-term drought cycles, are essentially stable. There are no long-term trends indicating steadily declining water levels in this area. By contrast, several wells in the Edna Valley display steadily declining water levels during the past 15 to 20 years. Two wells in close proximity along the northern edge of Edna Valley display much greater volatility in response to seasonal fluctuations than the San Luis Valley, but do not display a long-term decline of water levels.

4.10. Water Quality

Boyle (1991) reported that water quality data from 20 wells in the valley alluvium was comparable to the water quality of the surface water that flows into the Basin from the upstream watershed areas. Samples from most wells that tapped the alluvium yielded groundwater characterized as excellent to poor quality magnesium bicarbonate water. One well near the town of Edna produced excellent quality calcium bicarbonate water. Most of the groundwater samples collected from the Basin yielded water that was classified as very hard, with total hardness as calcium carbonate ($CaCO_3$) in excess of 201 parts per million (ppm).

Basin-wide water quality data were acquired through the Groundwater Ambient Monitoring and Assessment (GAMA) Program, a comprehensive groundwater quality monitoring program created by the State Water Resources Control Board. Water quality data within the GAMA database is organized by a variety of different datasets, including environmental monitoring wells, public water system wells, U.S. Geological Survey National Water Information Systems, among others. For this study, water quality data sets from the following organizations were used:

- Department of Drinking Water (DDW)
- Department of Pesticide Regulation (DPR)
- Department of Water Resources (DWR)
- U.S. Geological Survey (USGS)

A download of available data for the Basin was performed. Chemical data for 82 wells were obtained. A brief summary of the some relevant data is presented below.

Total Dissolved Solids (TDS) is a common analysis to determine general suitability of water quality for human consumption. A TDS concentration of 500 milligrams per liter (mg/L) is the secondary standard for drinking water in the US. A TDS of greater than 1,000 mg/L is generally considered brackish water. In the GAMA data downloaded for this project, 250 samples in the Basin reported analyses for TDS, with results ranging from 220 mg/L to 2,800 mg/L, with an average of 768 mg/L.

Chloride is another water quality parameter often cited to indicate the relative salinity of water. The secondary standard for chloride in drinking water is 300 mg/L. In the GAMA data downloaded for this project, 263 samples in the Basin reported analyses for chloride, with results ranging from 22.9 mg/L to 2,200 mg/L, with an average of 181 mg/L.

Nitrates are commonly found in groundwater in agricultural areas. The Maximum Contaminant Level (MCL) for nitrate in drinking water in 10 mg/L. In the GAMA data downloaded for this project, there have been 341 groundwater samples analyzed for nitrate (some of these are multiple samples from a single well). Of these analyses, 76 exceeded the MCL for nitrate.

5. Hydraulic Parameters

The relative productivity of an aquifer can be measured via transmissivity, hydraulic conductivity, specific capacity, and specific yield. The most robust method of measuring transmissivity is using a long-term (frequently 24 hours or more) constant-rate pumping test. Water level drawdown data collected during this test can be analyzed and used to calculate transmissivity. Hydraulic conductivity is a unit parameter obtained by dividing transmissivity by the aquifer thickness. Specific capacity is a simple measure of flow rate (gpm) divided by drawdown (feet), routinely measured by well service contractors during well maintenance and reported in units of gpm per foot of drawdown (gpm/ft). Specific capacity measurements may be affected by well construction details, and, therefore, are not only related to aquifer characteristics. Nevertheless, commonly accepted empirical relationships allow estimates of transmissivity to be made from specific capacity measurements. Specific yield is a parameter applicable only to unconfined sediments, and reflects the amount of groundwater storage that will drain under gravity from an unsaturated unit.

Data describing transmissivity, hydraulic conductivity, and specific capacity from water wells throughout the Basin were compiled. The hydraulic parameters discussed in this section were obtained from these general types of sources:

- Previous studies or reports with regional or formation-specific estimates that do not include source data or time-drawdown data
- Previous pumping tests provided by local landowners, consultants, and stakeholders with time-drawdown data
- Service reports or invoices from well service contractors provided by stakeholders
- Pumping tests conducted on private wells specifically for this Study

The data obtained from these various sources are described in the following sections. All available reports and documents that were made available through data requests, report reviews, etc., were reviewed for technical information, and included in this summary if the data were judged to be sufficient.

Figure 25 displays the spatial distribution of all data that were reviewed during the preparation of this report. Aquifer test data are distinguished from specific capacity data. Inspection of Figure 25 indicates a good spatial coverage of transmissivity estimates, with reasonable data density throughout the Basin.

Wells screened in the Alluvium and Paso Robles Formation have transmissivities ranging from about 5,000 to 158,000 gallons per day per foot (gpd/ft), and averaging over 42,000 gpd/ft.. Wells screened in Paso Robles and Pismo Formations have transmissivities ranging from less than 1,000 to about 40,000 gpd/ft, and average about 10,000 gpd/ft. These data are discussed in greater detail in Section 5 of this report.

Table 2 presents a compilation of all transmissivity data compiled during the preparation of this report. Table 3 presents a compilation of the specific capacity data. This information will be necessary in the technical work supporting preparation of the GSP for the Basin, particularly if a groundwater model is developed.

5.1. Previous Published Reports

DWR (1958) reports a range of irrigation well pumping rates from 300 to 600 gpm, and a range of specific capacity values of 15 to 20 gpm/ft for the Basin. There is no clear definition whether these values reflect data for Recent Alluvium or whether they include data for deeper units, such as the Paso Robles Formation and the Pismo Formation. The following "rule of thumb" empirical relationship is commonly accepted to estimate transmissivity from specific capacity values:

$T\ (gpd/ft) = SC\ (gpm/ft) * (1{,}500 – 2{,}000)$, *where*

T = *Transmissivity (gpd/ft)*

SC = *Specific Capacity (gpm/ft)*

1500 – 2000 = Empirical factor, (1,500 used for unconfined, 2,000 for confined aquifer)

Using this relationship, DWR's (1958) reported values correspond to transmissivity estimates ranging from 22,500 to 40,000 gallons per day per foot (gpd/ft).

Boyle (1991) evaluated five constant-rate aquifer tests for City wells, all in the San Luis Valley, and reported transmissivity values ranging from 11,200 to 71,000 gpd/ft, with an average of 41,240 gpd/ft.

DWR (1997) did not discuss any pumping test results or transmissivity estimates derived from field tests. However, in its draft report, DWR (1997) did discuss the range of hydraulic conductivity values used in the preparation of its groundwater model. In general, with its approach, lower hydraulic conductivity values reflect greater percentages of clay in the subsurface. DWR reported using a range of hydraulic conductivity values in the San Luis sub-basin ranging from 3 feet per day (ft/day) to 50 ft/day, with an average of less than 15 ft/day. In the Edna sub-basin, DWR reported using a range from 3 to more than 30 ft/day, with an average of about 6 ft/day.

5.2. Previous Pumping Test Data

Information on previous pumping tests and specific capacity tests was obtained through requests to the water purveyors, private well owners, and stakeholders in the Basin. In some cases, these data were contained in a summary from private consulting reports. The previously derived pumping test data collected for this Study were reviewed and analyzed, and results are summarized in Table 2. Transmissivity data were obtained for 48 wells in the Basin, and specific capacity information was obtained for an additional 29 wells.

Table 2 presents all the pertinent information regarding the transmissivity testing for each well that was retrievable from the available information, including test data, pumping rate, static and pumping water levels, screened intervals, total depth, and formations screened. It was not always readily apparent which formations are screened from the available data, and sometimes well screens may span more than one formation. If there is uncertainty regarding this designation, it is indicated with a question mark in Table 2. Calculated transmissivity values range from less than 1,000 gpd/ft to a maximum of 158,400 gpd/ft.

5.3. Previous Specific Capacity Data

Table 3 presents all available information for the 29 specific capacity well tests identified. Table 3 includes a transmissivity estimate based on the empirical relationship between specific capacity and transmissivity that was discussed previously. Figure 27 presents a display of the spatial distribution of all specific capacity and constant-rate tests.

5.4. 2017 Pumping Tests

One of the project tasks performed for this Study was to conduct constant-rate aquifer pumping tests on privately owned wells in the Basin that had no existing transmissivity estimate. District staff initiated contact with several well owners based on information collected from stakeholders, public records, and observed data gaps. District staff and GSI staff made several trips to the field to evaluate the logistics for various privately owned wells to be tested. The following constraints had to be overcome to perform an aquifer test on a private well:

1. The tests needed to be scheduled so as not to interfere with the well owners' individual well operations, including a period of inactivity before the test, the pumping period, and a recovery period.
2. There needed to be adequate storage to handle the pumped water, or alternately, an appropriate place to dispose of the water.
3. There needed to be a way to measure flow rate or total flow volume over time.
4. Ideally, a valve would be present to provide control of the flow rate.

Details of the down-well plumbing on third-party wells often is not clearly understood. Thus, equipment placed down the well has the potential to become tangled on piping or plumbing. For this reason, the initial plan of using downhole electronic data loggers to measure water level changes was abandoned in favor of hand-held measurements. For a variety of reasons related to some of the other constraints, the original plan for 8-hour tests was scaled back to a 4 to 5-hour test with a 1 to 2-hour recovery period. Due to both the wealth of existing pumping test data, and constraints with accessing private wells, in the end five wells were identified for performing the tests. The following paragraphs subsections provide details and results of the tests.

5.4.1. Biddle Ranch Road Well

An irrigation well operated by a local vineyard, located between Biddle Ranch Road and Corral de Piedras Creek, was made available to the District for a pumping test. An initial attempt to perform the aquifer test was made on July 27, 2017. Various technical and logistical issues forced postponement of the test until July 31, 2017. The well is equipped with an instantaneous read flow meter, and a valve to restrict flow as necessary to maintain a constant flow rate. Pumped water was directed to a fallow field adjacent to the well, where it percolated into the subsurface. A 5-hour constant-rate test was performed, with the well pumping at approximately 60 gpm. After 5 hours of continuous pumping, the pump was shut off, and recovery data were recorded for two hours.

Semi-logarithmic plots of time versus drawdown for both the drawdown and recovery tests are included in Appendix C. Application of the Cooper-Jacob equation to the drawdown data indicates a transmissivity of 2,880 gpd/ft. Analysis of the recovery data indicate a transmissivity estimate of 4,525 gpd/ft.

5.4.2. Evans Road Well

A privately owned domestic well on Evans Road in the area south of Buckley Road was made available to the District for a pumping test. District and consulting personnel made a field trip to view several of the wells in this neighborhood. As discussed in Section 4.3, most of the wells in this vicinity are not located on the properties they supply, but are clustered along the local creek channels, with buried pipelines conveying the pumped water to storage tanks nearer the homes they serve.

The well is located along a small tributary of Davenport Creek. It is piped approximately 1,000 feet to a pair of storage tanks behind homes on the south side of Evans Road. The well has a total depth of 98 feet, with a screened section from 58 to 98 feet. The test was performed on August 8, 2017. The well was pumped for 4 hours, and allowed to recover for 2 hours. Measurements of depth-to-water were collected using a hand-held water level meter, and flow was measured by monitoring the change in accumulated volume in the two storage tanks during the pumping period.

Semi-logarithmic plots of time versus drawdown for both the drawdown and recovery tests are included in Appendix C. Application of the Cooper-Jacob equation to the drawdown data indicates a transmissivity of 3,605 gpd/ft. Analysis of the recovery data indicates a transmissivity estimate of 4,620 gpd/ft.

5.4.3. Buckley Road Well

A well located at a home on Buckley Road was made available to the District for a pumping test. Similar to the Evans Road well locations, the wells at this location are located along a tributary of Davenport Creek. The tested well is plumbed to an underground pipe network that discharges into a pond on the property. Consultant personnel constructed a discharge apparatus that allowed the constriction of flow to maintain a steady flow rate. Flow rate was measured by regularly filling a 55-gallon barrel from the discharge hose and recording the length of time required to fill it.

Problems occurred in this test because of the apparent lack of a check valve on the well column. In addition, there may be other laterals in the buried pipe network off of the main water pipeline from the well that may have been periodically filling and then backflushing into the well. This resulted in erratic water level readings, which can be seen on the time-drawdown graph for the test included in Appendix C. The drawdown readings were too unstable to use the traditional Cooper-Jacob analysis to calculate transmissivity. However, the maximum observed drawdown was used to calculate specific capacity for the well, which was 0.8 gpm/ft. Using the empirical relationship previously discussed, this corresponds to a transmissivity of approximately 1,600 gpd/ft, which is in the same order of magnitude as the transmissivity estimates from the other pumping tests.

5.4.4. Tiffany Ranch Road Well

An irrigation well operated by a local agricultural concern, located southwest of Orcutt Road and northwest of Tiffany Ranch Road, was made available to the District for a pumping test. The tested well is plumbed into a network of underground irrigation pipes, and discharges into a reservoir on the property. The well has a total depth of 500 feet with a screened section from 200 to 500 feet. The test was performed on November 21, 2017 at a constant flow rate of 265gpm. The well was pumped for 4 hours, and allowed to recover for over an hour. Measurements of depth-to-water were collected using a hand-held water level meter and flow rates were measured using a digital gauge installed by the owner at the well head.

Semi-logarithmic plots of time versus drawdown for both the drawdown and recovery tests are included in Appendix C. Application of the Cooper-Jacob equation to the drawdown data indicates a transmissivity of 6,360 gpd/ft. Analysis of the recovery data indicates a transmissivity estimate of 6,996 gpd/ft.

5.4.5. New District Groundwater Monitoring Well

During the week of December 4, 2017, Mazzi Drilling installed a dedicated groundwater monitoring well in Edna Valley along Orcutt Road. This is discussed in detail in Section 9 of this report. A brief pumping test is to be performed on this well, and will be documented in the Final version of this report.

6. Ongoing Hydrogeologic Data Collection Programs

6.1 California Statewide Groundwater Elevation Monitoring (CASGEM)

The CASGEM program was developed by DWR in 2009 based on amendments to the California Water Code. The law mandates that groundwater elevations in basins be regularly monitored to document seasonal and long-term trends in groundwater elevation. The District has taken on the role as the Monitoring Entity in specific parts of high and medium priority basins within the county, including all of the San Luis Obispo Valley Basin. In September 2014, the District published the CASGEM monitoring plan for high and medium priority groundwater basins in the County. It referenced a single CASGEM well in the Basin, located near the southern boundary of the Edna Valley (Figure 26). The target well density under the CASGEM program is one well per 10 square miles. Because the Basin area is about 20 square miles, an additional monitoring well is needed to meet CASGEM's data density objectives. This target well density is not adequate to generate potentiometric surface maps of groundwater elevations. The objective of the CASGEM wells is to document long-term trends in water levels, such as are discussed Section 4.9.

6.2 San Luis Obispo County Water Level Program

The District maintains a voluntary groundwater monitoring program, independent of and with far greater well density than the CASGEM program within the Basin. The District has a strict policy of limiting the release of well data collected as part of the District's monitoring program, in order to honor Existing Well Confidentiality Agreements that a number of participants of the voluntary program signed. Currently, the District has 14 active wells in its program (Figure 26). These wells are monitored for depth-to-groundwater in the spring and fall of each year. This program has been in place since approximately 1968, when Resolution No. 68-223 was adopted to define the policy role of the District. Some water level data extend back to the 1950s. Currently, maps of groundwater elevation are not prepared from the water level data collected because the data density is not adequate to generate representative maps.

Inspection of Figure 26 shows the presence of large data gaps in the Basin for which no monitoring well is present to collect water level data. As part of this Study, opportunities were investigated to expand the monitoring well network both through construction of new monitoring wells, and through identification of new private wells that might voluntarily be made available to the District for water level measurement.

As part of this Study, communication was initiated between the City and District to discuss the potential for some or all of the City's wells to be incorporated into the District's semiannual monitoring program. Because the City wells are on standby and are not operated regularly, they would be ideal candidates for incorporating into the monitoring network. Incorporation of these wells would go a long way toward addressing apparent data gaps for the San Luis Valley.

In addition, this Study included a task to identify two sites for potential new monitoring wells. Mapped data gaps, property ownership, hydrogeologic data, and other factors were evaluated in identifying potential locations. District and consulting personnel evaluated then conducted field visits of numerous sites before deciding on two recommended locations (Figure 26). Plans, specifications, and bid packages were prepared to solicit bids from area drilling companies to install these wells, dependent on available funding. Based on funding limitations, the County will install one new monitoring well as a part of this Study, but will retain the other proposed monitoring well site for consideration during the GSP development phase. This work is documented in greater detail in Section 9.

7. Subsidence

As part of this Study, the County sponsored an evaluation of subsidence potential within the Basin. The evaluation was performed by Yeh & Associates. The report that documents the subsidence study is included in Appendix D. A brief summary of the major findings of the subsidence study is presented here.

Subsidence has been documented in parts of the San Luis Valley. The most severe subsidence that is known to have occurred in the Basin was in the 1990s along the Los Osos Valley Road corridor. Subsidence occurred within young organic soil (i.e., peat) in response to extraction of groundwater within a relatively shallow aquifer and resulted in significant settlement of the ground surface. The settlement caused significant damage to businesses and homes in that area as local groundwater pumping dewatered the soft soil units beneath buildings and the surrounding area. Subsidence resulted in more than 1 foot of settlement of the ground surface in some locations that damaged buildings, blew out windows of a car dealership, and resulted in severe damage and reconstruction or retrofitting buildings.

Another area of known subsidence is along the shores of Laguna Lake. Homes located along the shoreline have experienced settlement that has cracked foundations, patios, and window and door openings. Many homes in that area have been underpinned and retrofitted to address the settlement. While the history of subsidence near Laguna Lake is not specifically related to extraction of groundwater, lowering of the groundwater table in that area could result in further settlement and subsidence.

The historical manifestation of subsidence generally has been limited to a specific geographic area in the City and compressible soil types that were particularly vulnerable to large settlements in response to lowering of the local groundwater table. This history emphasizes the importance of considering subsurface conditions that may be associated with subsidence. Not all soil and rocks are vulnerable to the type of subsidence that occurred along Los Osos Valley Road. The potential for subsidence to occur, and the severity of the subsidence, is dependent on the geology, groundwater levels, and the properties of the soil and rock that may be dewatered in association with groundwater pumping.

The subsidence evaluation consisted of a review of published data and studies performed by local, state, and federal agencies, as well as a familiarity of local geology and soil. The following is a summary of the key findings.

DWR identifies the Basin as having a low subsidence potential. However, historical subsidence is known to have occurred in specific geographic areas of the Basin because of groundwater pumping. The Basin was evaluated on the basis of the extent of known and mapped geologic units within the Basin. The relative potential for subsidence was divided into three categories and delineated as shown in Figure 27.

- **Category 1.** Category 1 has the highest likelihood of future subsidence if subject to lowered groundwater levels in the future. Based on a review of public data and consultant reports, alluvium mapped in these areas contains young organic soil known in areas around Los Osos Valley Road, Laguna Lake, and low-lying wetland areas near Tank Farm Road. These areas are known to have experienced historical subsidence or to contain soft or organic soil, and were identified as having a potential for subsidence in relation to geology and groundwater pumping. These areas are identified as Category 1 in Figure 27, with star symbols marking approximate areas of known historical subsidence. Extraction of groundwater resources in these areas could cause further subsidence.

- **Category 2.** Low-lying topographic areas in the Basin that are mapped as young alluvial soil were identified as potentially containing soft or organic soil layers that may have a potential for subsidence in relation to groundwater pumping, but currently there is no historical or subsurface information to further evaluate those areas. Those areas are mostly located along Prefumo Creek and San Luis Obispo Creek and the main drainages through the west end of the Edna Valley near Price Canyon. These areas are identified as Category 2 in Figure 27. This screening criteria recognizes the unconsolidated nature typical of young alluvium that has been mapped in these areas potentially could subside because of compaction of the aquifer if groundwater levels were lowered.

- **Category 3.** Geographic areas in the Basin that were mapped as bedrock or older surficial sediments, and are not known to be underlain by young organic soil or young alluvium, were identified as Category 3 in Figure 27. These areas were evaluated and characterized as not having factors known to be susceptible to subsidence in relation to groundwater pumping. Generally, these are upland areas where bedrock is shallow or where bedrock is mapped at the ground surface, such as in the areas around the airport and Orcutt Road.

8. Potential for Enhanced Recharge Projects

Part of the ultimate process for developing a GSP will be to identify and implement management actions and strategies that bring a basin into sustainability. This could include development of projects that augment natural aquifer recharge through application of seasonally available surface water to recharge ponds (or possibly injection wells), or through other appropriate means. Two studies use available GIS data within the Basin to identify locations with higher likelihood of success for such projects (leveraging GIS data defining key factors such as topography, soil type, etc.). These are desktop studies and therefore are conceptual in nature, and any recharge project would need site-specific field characterization and feasibility study before implementation. Still, although they differ in scope and approach, the results of these studies provide a first effort at identifying areas that may have the intrinsic physical characteristics to implement a recharge project.

Stillwater Sciences (Stillwater), prepared for the Upper Salinas-Las Tablas Rural Conservation District (USLTRCD), published a grant funded study in September 2015 designed to improve data gaps in the County's Integrated Regional Water Management (IRWM) plan. The Percolation Zone Study of Pilot-Study Groundwater Basins in San Luis Obispo County, California identified areas with relatively high natural percolation potential that, through management actions, could enhance local groundwater supplies for human and ecological benefits to the aquatic environment for salmon habitat. The study used existing data in a GIS analysis to identify potentially favorable areas for enhanced recharge projects in the combined San Luis Obispo/Pismo Creek Watershed *(Note: the Santa Rosa Creek watershed along the coast also was evaluated, but is not relevant to this Study.)* GIS coverages for the following four factors were evaluated to determine areas that may be favorable for such projects:

- Topography
- Geology
- Soils
- Land cover

The results of the Stillwater-USLTRCD study are presented in Figure 28. (This figure corresponds to Figure 17 in Stillwater's Project Report.).The analysis indicated that approximately 2,220 acres in the Basin are categorized with high potential for intrinsic percolation, and 6,583 acres have medium potential. The largest area in the Basin that is classified with high recharge potential is the alluvium along East and

West Corral de Piedras Creeks in the Edna Valley. Although any such project would require a site-specific characterization, the Stillwater-USLTRCD study provides a desktop analysis that indicates a “first cut” at identifying potentially favorable areas.

The University of California (UC) at Davis and the UC Cooperative Extension published a study in 2015 that also uses existing GIS data to identify areas potentially favorable for enhanced groundwater recharge projects. However, the scopes and focus of the approaches are somewhat different. While the Stillwater study focused on local San Luis Obispo stream corridors and emphasized fish habitat conditions, the UC study is statewide in scope (including more than 17.5 million acres), is scientifically peer reviewed, and focuses on the possibilities of using fallow agricultural land as temporary percolation basins during periods when excess surface water is available. The UC study developed a methodology to determine a Soil Agricultural Groundwater Banking Index (SAGBI) to assign an index value to agricultural lands through the state. The SAGBI analysis incorporates the following five important agricultural factors into its analysis:

- Deep percolation
- Root zone residence time
- Topography
- Chemical limitations (salinity)
- Soil surface conditions.

Statewide, the SAGBI analysis found that 8 percent of the lands analyzed were categorized as “Excellent,” 10 percent as “Good,” and 10 percent as “Moderately Good.” In the Basin, the SAGBI analysis identified approximately 2,860 acres as having either “Moderately Good” or “Good” recharge potential. There were no “Excellent” classifications in the Basin. The results of the SAGBI analysis in the Basin are presented in Figure 29.

9. Monitoring Well Installation

This section will be completed in December-January after the planned installation of a new monitoring well along Orcutt Road in Edna Valley is completed. Drilling is scheduled for the week of December 4.

10. Conclusions and Recommendations

This report documents the basin characterization Study for the San Luis Obispo Valley Groundwater Basin (DWR Basin 3-09). All available published reports, private well reports, well completion reports, geologic logs, and other data were reviewed to generate a comprehensive compilation of the current understanding of the hydrogeologic setting of the San Luis Obispo Valley Basin. This information is intended to provide the basis of knowledge for the GSAs’ future planning and management activities as required by Sustainable Groundwater Management Act (SGMA), including the development of a Groundwater Sustainability Plan and related tools such as development of a hydrogeologic conceptual model and water budget.

All available lithologic data were reviewed and evaluated to generate 11 geologic cross sections throughout the Basin. Previous hydrologic reports about the Basin were reviewed, and all pertinent information regarding the hydrogeologic setting of the Basin is presented.

10.1 Conclusions

This Study yielded the following conclusions:

- In the San Luis Valley sub-area, the Recent Alluvium and the Paso Robles Formation function as a single hydrogeologic unit. In the Edna Valley sub-area, the Paso Robles Formation and the Pismo Formation function as a single hydrogeologic unit. No laterally extensive impermeable strata separate the formations vertically. The formations are in hydraulic communication.
- The water-bearing sediments of the Edna Valley are much thicker than the San Luis Valley. The maximum thickness of water-bearing sediments in the Edna Valley is greater than 500 feet, which is approximately 100 feet more than previously documented.
- The area south and west of the airport seems to be hydrologically distinct in the Basin in that recharge appears to be dominated by stream seepage during seasonal wet weather creek flows, while areally distributed precipitation-based recharge is less significant. This does not appear to be the case in the San Luis Valley and the Edna Valley.
- Water level elevation maps of the potentiometric surface of the water bearing sediments in the Basin from previous studies indicate groundwater flows to the northwest from the Edna Valley toward the San Luis Valley; therefore there appears to be hydrologic communication between the sub-areas. Long-term groundwater elevation hydrographs indicate that water levels in the San Luis Valley are largely stable, while much of the Edna Valley has experienced water level declines over the past 20 years.
- Data from 47 pumping tests and 29 specific capacity tests from locations broadly distributed though the Basin provide an excellent data base for hydrogeologic parameters to be used in future technical evaluations supporting the development of a GSP.
- Significant subsidence occurred in the San Luis Valley along Los Osos Valley Road in the 1990s, due to the compaction of dewatered organic soils when water levels declined due to groundwater pumping in the area. Areas where organic soils are known to occur have the greatest potential for subsidence if water levels decline in those area.
- The existing Basin boundary promulgated in DWR publications and GIS data has inaccuracies, likely due to previous mapping being completed at a different scale. GSAs could consider seeking a possible revision of the Bulletin 118 Basin boundary that is consistent with the Dibblee geologic maps of the Basin.

10.2 Recommendations

GSI makes the following recommendations for future hydrogeologic analysis in the Basin. Some recommendations address possibilities for improvement and expansion of the groundwater monitoring network while others address technical analyses that could be performed to further understand aspects of the Basin hydrogeologic system. And finally, some address administrative actions that may be pursued in coordination with other government agencies.

- Formalize an arrangement with the City to incorporate some or all of their wells into the District's voluntary groundwater monitoring program\.
- Consider installing shallow monitoring wells near some or all of the District-operated stream gages along San Luis Obispo Creek to better understand the dynamics of surface water/groundwater interaction and its significance to the water budget.
- In order to assess the hydrogeologic significance of individual geologic formations, install a pair of monitoring wells in close proximity with each well specifically screened in separate geologic units, or a nested monitoring well screened in different strata. For example, adjacent wells in the Edna Valley could be screened in the Paso Robles Formation and the Pismo Formation.
- Pursue future opportunities to install monitoring wells in the areas identified and discussed as data gaps in this Study.
- Consider instrumenting dedicated monitoring wells with automatic transducers for water level data collection.
- Generate water level maps from the data collected during the District's semi-annual water level data collection. Even if data are sparse, the process of generating the water level maps will help to identify preferred locations for future monitoring wells.
- Perform baseflow separation analysis on the daily data from the District stream gage network to better understand the surface/groundwater interaction.
- Perform a low flow study along San Luis Obispo Creek through the Basin to better understand gains/losses of the stream and stream/aquifer dynamics.
- Consider pursuing a basin boundary modification request through processes established by DWR to revise the Bulletin 118 Boundary to better correspond to published geologic mapping at a local scale.
- In the area south of Buckley Road, in order to better characterize water table conditions and the dynamics of recharge along the creeks in this area, install new monitoring wells, or identify existing well owners willing to participate in the District's voluntary monitoring program.

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