North San Benito County Groundwater Sustainability Plan Draft: Hydrogeologic Conceptual Model and Groundwater Conditions

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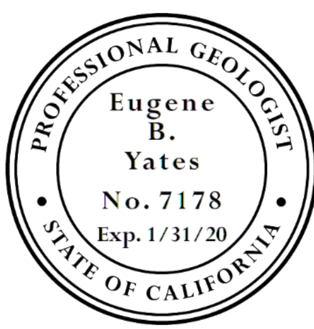

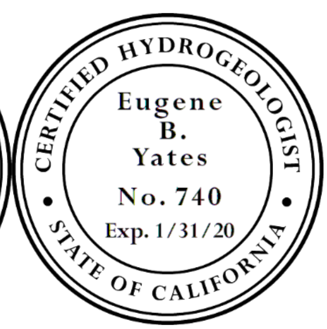

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3. HYDROGEOLOGICAL CONCEPTUAL MODEL

This chapter describes the hydrogeologic conceptual model of the North San Benito Basin, including the Basin boundaries, geologic formations and structures, and principal aquifer units. The chapter also addresses the interaction between groundwater and surface water and discusses groundwater recharge and discharge areas. The Hydrogeologic Conceptual Model presented in this chapter is a summary of relevant and important aspects of the Basin hydrogeology that influence groundwater sustainability. While the Chapter 1 Introduction and Chapter 2 Plan Area establish the institutional framework for sustainable management, this chapter, along with Chapter 4 Groundwater Conditions and Chapter 5 Water Budget, sets the physical framework.

The hydrogeologic conceptual model and basin conditions serves to document the technical aspects of the basin's hydrogeology to create a foundation. Later sections including the water budget and sustainability criteria will refer to and rely on the technical material contained here.

3.1. PHYSICAL SETTING AND TOPOGRAPHY

The North San Benito Subbasin (Basin) of the Gilroy-Hollister Groundwater Basin (DWR 2019a) covers approximately 200 square miles situated between and including portions of the Diablo Range to the east and the Gabilan Range to the west. It is adjoined on the north by the Llagas Subbasin (Llagas Basin), which is the northern extension of the Gilroy-Hollister Basin in Santa Clara County.

Figure 3-1 illustrates the topography of the Basin and surrounding uplands. The Basin is a series of connected north-northwest trending structural trough valleys; these contain unconsolidated to slightly consolidated sediments with primary porosity that store and transmit significant quantities of groundwater. These formations occur not just beneath the valley floor areas but also underlie some adjacent upland areas. Consequently, the Basin boundaries are defined mostly by geology and faults, not by topography. The northern boundary with Llagas Basin is institutional, defined by the county line; like the northernmost North San Benito Basin, the Llagas Basin underlies a relatively flat valley and consists of unconsolidated alluvial sediments. Almost all extraction and use of groundwater occur in the valley floor areas, both in the Basin and adjacent Llagas Basin.

The northern, main portion of the Basin (including urban areas and important farmland) is broad and flat and includes the San Juan and Hollister valleys and the Bolsa area (see **Figure 3-1**). The Llagas Subbasin north of the Basin continues another 15 miles northwest in Santa Clara County and include the cities of Gilroy and Morgan Hill. The San Juan Valley is separated from the Bolsa by the Lomerias Muertas and Flint Hills, which are an upward fold of older continental semi-consolidated to consolidated deposits that rises as much as 1,100 feet above the valley floor areas.

The semi-consolidated to consolidated materials also make up the hills along the southern edges of the San Juan and Hollister Valleys. The southern Basin is mostly hilly but includes the Tres Pinos Creek and Paicines valleys associated with Tres Pinos Creek and the San Benito River.

Ground surface elevations range from approximately 200 feet above mean sea level (msl) at the northern boundary to approximately 2,400 feet above msl in the southern uplands, as shown by 200-foot contours on **Figure 3-1**.

3.2. SURFACE WATER FEATURES

Figure 3-2 shows surface water features including rivers, streams, springs, seeps, lakes, ponds, and reservoirs plus the Santa Clara and Hollister conduits. The sub-watershed boundaries that drain into and through the Basin are shown on **Figure 3-3**.

As shown, the Basin covers a portion of the Pajaro River watershed. Main tributaries to the Pajaro River include the San Benito River, Tres Pinos Creek, Santa Ana Creek, Arroyo Dos Picachos, Pacheco Creek, and Tequisquita Slough. Llagas and Uvas creeks flow into the Pajaro River from the north in Santa Clara County. The San Benito River, Tres Pinos Creek, Pacheco Creek, and Tequisquita Slough are dry much of the year, flowing mainly during wet winter conditions.

3.3. SOILS

Characteristics of soils are important factors in natural and managed groundwater infiltration (recharge) and are therefore an important component of a hydrogeologic system. Soil hydrologic group data from the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) (NRCS 2018) are shown on **Figure 3-4**. The soil hydrologic group is an assessment of soil infiltration rates determined by the water transmitting properties of the soil, which include hydraulic conductivity and percentage of clays in the soil, relative to sands and gravels. The groups are defined as:

- Group A – High Infiltration Rate: water is transmitted freely through the soil; soils typically less than 10 percent clay and more than 90 percent sand or gravel.
- Group B – Moderate Infiltration Rate: water transmission through the soil is unimpeded; soils typically have between 10 and 20 percent clay and 50 to 90 percent sand
- Group C – Slow Infiltration Rate: water transmission through the soil is somewhat restricted; soils typically have between 20 and 40 percent clay and less than 50 percent sand
- Group D – Very Slow Infiltration Rate: water movement through the soil is restricted or very restricted; soils typically have greater than 40 percent clay, less than 50 percent sand

The hydrologic group of the soil generally correlates with the potential for infiltration of water to the subsurface. However, there is not necessarily a correlation between the soils at the ground surface and the underlying geology or hydrogeology.

3.4. GEOLOGIC SETTING

The Basin lies within the Coast Ranges of California, a series of elongated ranges and valleys with a predominantly northwesterly trend. The Basin is structurally complex. The substantial depth of the Basin and the current topography of the land surface has resulted in part from folding of the geologic deposits. For example, the high hills that separate the Bolsa from the San Juan Valley are associated with the Sargent anticline (upward fold).

The topography is formed by folding and faulting of basement rocks in the area, leaving low-lying valleys that have been infilled with sediments. Basin fill material consists of unconsolidated to poorly consolidated alluvium of Tertiary and Quaternary age. The Quaternary alluvial deposits compose the valley floors and are the dominant geologic units in the Basin. The Basin also encompasses large areas of elevated hills composed of continental deposits. The surficial geology of the Basin and surrounding areas is shown on **Figure 3-5** (CGS 2002).

The geologic materials that compose the Basin fill are primarily unnamed non-marine sediments of Pliocene age or younger (less than 5 million years old). The recent geologic mapping of the area (CGS 2002) references these deposits simply by age (e.g., Puc, see **Figure 3-5**). These formations are exposed at the land surface in the hills surrounding the valleys. In the eastern and southeastern parts of Hollister Valley, semi-consolidated deposits outcrop in the hills (e.g., Puc and Pus, see **Figure 3-5**) and are encountered in the subsurface that yield little groundwater and are commonly referred to as the San Benito Gravels of Lawson 1895.

Numerous investigators have recognized the difficulty in describing the subsurface stratigraphy of the alluvial valleys, due, in part, to sparse lithologic log data and a lack of distinctive textures and composition among the sedimentary units (Clark 1924, Kilburn 1972, Faye 1974 and 1976, and LSCE 1991). The most recent surficial geologic mapping of the Basin and surrounding area shows the Basin to include Holocene, Pleistocene, Plio-Pleistocene, and Pliocene continental deposits. These include relatively young alluvium (Q) stream gravel (Qg), basin deposits (Qb), older alluvium (Qo), and continental (QT) materials as well as mapped units of the Pliocene unnamed continental mudstone (Puc) and sandstone (Pus). Previous investigations and reports on the Basin have referred to these Pliocene deposits (Puc and Pus) as the Purisima Formation (Clark 1924, Kilburn 1972, Jenkins 1973, Faye 1974, Faye 1976, Kapple 1979, LSCE 1991 and 2015, Todd 1994a, 1994b, 2013, 2014, and 2015, JSA 1998, Yates and Zhang 2001, and DWR 2019a). However, the most recent surficial geologic mapping (CGS 2002) does not include the Purisima in or around the Basin (CGS does include the Purisima in other areas covered by this geologic map). Hereafter, the material mapped as Puc and Pus will be referred to as the Purisima Formation unless otherwise noted.

The surficial geology of the area surrounding the basin includes a number of named formations deposited between the Jurassic and Miocene (approximately 200 million to 5 million years old). These include the Mio-Pliocene Etchegoin Formation; the Miocene Quien Sabe Volcanics basaltic flows, breccias, intrusive andesites, and intrusive basalts; the Oligocene Vaqueros Sandstone; Eocene-Oligocene San Juan Bautista Formation; Eocene Unnamed Sedimentary rocks, Kreyenhagen Formation, Los Muertos Formation, and Tres Pinos Sandstone; Paleocene-Eocene Sedimentary rocks; Upper Cretaceous sedimentary rocks; Cretaceous Panoche Formation and multiple member of the Franciscan Complex; and Jurassic Coast Range Ophiolite Gabbro and the Hornblende Gabbro of Logan quarry. These geologic formations represent a wide variety of consolidated sedimentary, volcanic, and metamorphic rocks with low primary porosity, forming the lateral and vertical boundaries of the Basin.

3.5. Faults

The geology and hydrogeology of the Basin is complicated by intensive faulting and deformation along faults, most notably the Calaveras and San Andreas fault zones (LSCE 1991). As shown in **Figure 3-5**, the Calaveras Fault bisects the Hollister Valley from north to south and offsets the hills west of the Hollister Airport. It also has created San Felipe Lake, a sag pond at the north end of the valley (**Figure 3-2**). Geologic mapping (**Figure 3-5)** indicates that the Calaveras fault consists of several parallel splinters throughout the length of the Basin. The San Andreas Fault crosses a portion of San Juan Valley but is generally west of the western boundary of the Basin.

Other faults related to the San Andreas/Calaveras system have shaped the eastern side of the Basin. Some of these faults have been mapped only in the outcropping bedrock, and fault traces across the valley floor are uncertain. These include the Ausaymas Fault (sometimes referred to as the Quien Sabe), Tres Pinos Fault, and the unnamed fault traces associated with the Lomerias Muertas and Flint Hills.

3.6. Aquifers

The geologic materials underlying the Basin do not fall neatly into two categories of permeability, such as bedrock and basin fill. Some upland areas (such as the Lomerias Muertas, Flint Hills, and hills in the upper Tres Pinos Creek and San Benito River drainages) are simply upward folds of the same formations that represent aquifers in the valley areas. These upland areas store and transmit some groundwater to the valley portions; in brief, the Basin includes valley areas composed of Holocene and late Pleistocene alluvial deposits with relatively high permeability and upland areas with mainly Pliocene-Pleistocene continental deposits of moderate permeability. The Flint Hills and most of the southern portion of the Basin also encompass elevated areas of relatively low permeability Pliocene continental deposits, which yield less groundwater.

The valley-fill units were deposited in alluvial fan and fluvial environments from a variety of source rocks and directions. These deposits interfinger in the subsurface, making the differentiation of discrete aquifer packages difficult on a regional basis. This also results in variable aquifer properties across the Basin, even within the generally higher permeability valley fill alluvium (LSCE 1991, Faye 1974, and Todd 2013).

3.6.1. Principal Aquifers

The Holocene alluvial sedimentary sequences represent the principal aquifers; their distribution is shown on **Figure 3-5**. As shown, the principal aquifers underlie the Hollister and San Juan valleys and the Bolsa. These unconsolidated alluvial deposits consist mainly of clay, silt, sand, and gravel ranging in age from Tertiary to Holocene. The Purisima and other Pliocene deposits are presumed to be present at depth beneath the alluvial deposits. However, distinguishing these older semi-consolidated materials from younger alluvial materials in borings or geophysical logs is difficult and no there is no geologic interpretation that is known and widely accepted. The oldest of the principal aquifers lie unconformably on consolidated bedrock of Jurassic, Cretaceous and early Tertiary age (Kilburn 1972 and Todd 2013). These unconformable contacts generally occur below the depth of groundwater wells in the Basin and accordingly, definitive information or mapping of the Basin bottom is lacking. This is discussed in more detail below.

Groundwater in the principal aquifers generally occurs in both unconfined and confined conditions. Surficial clay deposits, especially in the Bolsa area and Hollister and San Juan Valleys, create non-continuous confining layers. In the northern Hollister Valley and San Juan Valley, artesian conditions locally result in flowing wells and nuisance shallow groundwater that requires near-surface drains.

3.6.2. Secondary Aquifers

As indicated above, the Pleistocene and Pliocene age Purisima Formation and other continental (non-marine) deposits are also important aquifers within the Basin. These secondary aquifers are composed of clay, silt, sand, and gravel (LSCE 1991, Yates and Zhang 2001, and Todd 2013 and 2015). They are a thick sequence of clay, silt, sand and gravel mapped in the southern portion of the Basin as unnamed Pliocene continental mudstone (Puc) and sandstone (Pus). In some areas of the Basin, these semi-consolidated rocks have been divided into three unnamed units, from oldest to youngest: unit 1, unit 2, and an undifferentiated unit (Kilburn 1972, DWR 2019a).

3.6.3. Physical Properties of Aquifers

Summary descriptions of the aquifer formation are provided below. Few reliable aquifer parameter measurements are available from wells within the Basin, accordingly, assessment of aquifer parameters has been undertaken in association with numerical model construction and calibration. The available aquifer parameter information and distribution within the Basin are described in the numerical model documentation report included in **Appendix G**.

Holocene Alluvium, principal aquifer:
The alluvium consists of unconsolidated lenticular beds of gravel, sand, silt, and clay deposited by streams as flood plain, alluvial-fan, slope-wash, and terrace deposits (Kilburn 1972). Saturated deposits are moderately to extremely permeable. The thickness generally ranges from 0 to 300 feet (JSA 1998).

Purisima Formation, secondary aquifer:
The Purisima Formation and other Pliocene continental deposits, while lithologically similar to the overlying alluvium, are generally more consolidated and less permeable (JSA 1998). The Purisima Formation ranges from the surface in some areas to several thousand feet deep; in the Bolsa it is believed to directly overlie consolidated basement rocks of Jurassic age (Kilburn 1972).

Unit 1 and Unit 2, secondary aquifer:
Unit 1 crops out and is believed to form the low hills at the north end of Santa Ana Valley and to underlie unit 2. Unit 1 is approximately 1,200 feet thick. The log of well 12S/5E-23A3 indicates the top of the unit at a depth of 420 feet at this location (Kilburn 1972). Unit 1 is made up of clay, sand and gravel with individual beds not more than five to ten feet thick. Unit 2 consists of three or four thick sand sequences separated by thinner clay intervals. Units 1 and 2 are not known to occur west of the Calaveras fault.

Undifferentiated Unit, secondary aquifer:
Kilburn (1972) describes the undifferentiated unit as including one or more of the following units: alluvium, older alluvium, San Benito Gravels, and alluvial-fan material that may occur in the subsurface along the front of the Diablo Range. This unit is believed to overlap and rest unconformably on an older erosion surface formed on units 1 and 2.

3.7. STRUCTURES AFFECTING GROUNDWATER

The complex depositional and tectonic history of the Basin have resulted in numerous structures that potentially affect the flow and transmission of groundwater. The primary structures affecting groundwater are lower permeability aquifer materials and faults.

As described above, the presence of lower permeability aquifers and the contacts between these aquifers and overlying primary aquifers are difficult to discern because of their similar compositions. Accordingly, no distinct aquitards are known or have been mapped at depth and the surficial geologic mapping shown on **Figure 3-5** is the best representation of the presence of these materials in the Basin.

Faulting has been indicated to affect groundwater flow within the Basin in some locations and in some conditions (LSCE 1991 and Todd 2015). Evaluation of groundwater elevations across fault traces has shown that large groundwater gradients sometimes exist on portions of the Calaveras Fault in the north of the Basin (LSCE 1991 and Todd 2015). However, evaluation of current groundwater conditions in wells on both sides of the Calaveras Fault indicate that if the fault is a barrier, then it primarily affects flow when groundwater elevations are low. Groundwater model construction and calibration also indicated relatively large vertical gradients near uncertain traces of the Ausaymas/Quien Sabe and Tres Pinos Faults (Todd 2015). However, most of the paired wells with large vertical gradients are far apart and it is unclear if the observed gradients are the result of barriers associated with faulting, differences in lithology and well construction, or some other permeability changes.

3.8. Definable Basin Bottom

The depth to consolidated Tertiary units and other bedrock units beneath the alluvium and Plio-Pleistocene sediments is not well characterized. Kapple (1979) indicates that the Quaternary-age aquifers (including the unconsolidated basin fill, San Benito Gravels, and an undifferentiated sedimentary unit) range in thickness up to 1,300 feet in the Hollister Valley. Data from exploratory oil wells indicate that basin fill sediments extend as much as 4,000 feet below the ground surface near the center of the Basin, far beyond the depths of water supply wells (Kilburn 1972). Generalized cross sections prepared for a San Benito County Groundwater Study (LSCE 1991) that covered a portion of the Basin generally corroborate this interpretation with alluvium estimated to average about 700 feet thick in the Bolsa area and Hollister Valley.

In the northern San Juan Valley, the alluvium appears to be thinner than in the Bolsa and Hollister Valley areas and is estimated to be about 400 feet thick. Wells deeper than this in the northern San Juan Valley may be producing water from the underlying consolidated formations (Purisima and others as indicated above). The Purisima Formation is thought to reach thicknesses in the subsurface of more than 1,500 feet in the northern portion of the San Juan Valley (Kilburn 1972); although, most of the wells are less than 350 feet deep. No wells are known in the Flint Hills northeast of San Juan Valley; however, one well located on the west side of San Juan Valley is screened in the same continental mudstones formation that underlies the Flint Hills and is 300 feet deep.

The depth of the southern Basin is not well characterized. Several irrigation wells in the Paicines Valley penetrate alluvial deposits to depths ranging from 100 to 500 feet below ground surface (ft-bgs) (LSCE 1991). A review of driller’s logs in the area indicated an average alluvial depth of 400 feet (Todd 2013). The alluvial thickness in the Upper Tres Pinos Creek area is thought to be less than 100 feet (LSCE 1991); however, Pliocene or early Pleistocene continental sediments of moderate permeability underlie the remainder of the Upper Tres Pinos Creek Watershed. Based on a review of driller’s logs, the average well depth in this area is about 300 feet (Todd 2013).

LSCE (1991) reports that wells in the Tres Pinos Valley (then defined as a separate basin) encounter alluvial deposits ranging from 135 to 630 ft-bgs. DWR (2019a) reports that the alluvial material is generally less than 100 feet thick. A review of the few driller’s logs in the area (Todd 2013) indicates an average depth to bedrock of 360 feet.

3.9. CROSS SECTIONS

Four hydrogeologic cross sections were constructed to characterize the thickness and distribution of aquifer sediments and to delineate the hydrostratigraphy within the Basin (**Figure 3-6**). The goals of constructing cross sections were to identify hydrogeologic structures affecting groundwater and to confirm aquifer descriptions presented above. Construction of the cross sections focused on conditions relevant to hydrostratigraphic layering in the Basin. The assessment was designed to use and combine existing information in the ArcHydro Groundwater (Strassberg et al. 2011) data format that supports application of geographic evaluation tools within a Geographic Information System (GIS) platform. The information assessed in this evaluation included:

- Surficial geology
- Faulting
- Lithologic borehole logs
- Well construction logs
- Previously completed local hydrogeologic conceptualizations.

This information was collected and translated into a unified GIS compatible database structure for cross section construction and geographic evaluation. This approach allows any hydrostratigraphic structures relevant to groundwater flow in the Basin to be easily translated from GIS for use in other formats.

3.9.1. Available Data and Information

Existing datasets and information were collected from all available sources. These sources included the following:

- Surficial geology in GIS coverage format (CGS 2002)
- Fault locations and orientations (CGS 2002)
- Fault subsurface expressions (Wallace 1990)
- Lithologic and well construction logs from SBCWD
- Drillers Log files from DWR
- National Elevation Dataset (NED) ground surface digital elevation model data for San Mateo and Santa Clara Counties (USGS 2018)

These data and information sources resulted in a dataset of over 2,400 locatable wells and boreholes within and near the Basin. Of these, lithologic and construction records were digitized for 374 wells and boreholes (**Figure 3-6**). These location, lithologic, and well construction records were combined into a unified dataset covering the Basin and surrounding areas. The unified dataset is composed of a series of related tables in a geodatabase that follows the data storage conventions of ArcHydro Groundwater. Construction of the unified database required combination of well location, lithologic, and well construction data from multiple data sources. These data sources often contained different information types. At each stage of the database construction process, care was taken to include all data from each data source. In addition, many records were included in multiple data sources, and often the records from two or more data sources had differences in locations or information for wells. Duplicate well locations or records were combined into single records preserving all information from each individual data source.

Multiple faults cross portions of the Basin, as discussed above. To portray these faults on cross sections, it was necessary to estimate orientations and approximate dip angles. Wallace (1990) includes approximate information regarding the subsurface expressions of the Calaveras and San Andreas Faults within the area of the Basin. Wallace estimates that the Calaveras generally dips 80 degrees to the east and the San Andreas dips 70 degrees to the west.

3.9.2. Cross Section Construction

The four cross section transect locations shown on **Figure 3-6** were selected based on available data to provide lithologic coverage throughout the Basin. These cross sections cross and extend slightly beyond Basin boundaries and are designated as A to A’ through D to D’, as indicated on **Figure 3-6**.

The datasets incorporated into the database discussed above were used to populate the cross sections for use in hydrostratigraphic correlation. These data were applied to the sections using the ArcHydro Groundwater extension to ESRI’s ArcGIS Desktop software. ArcHydro Groundwater includes tools for plotting surficial geology, faults, lithologic, construction, and elevation surfaces from a two-dimensional map to two-dimensional cross sections. The wells with lithologic and construction information in the vicinity of the cross sections are shown on **Figure 3-6**. Each cross section was populated with the following datasets:

- Ground surface elevations from the county NED files
- Surficial geology
- Faults
- Well and borehole lithology and well construction from all wells within 1,000 feet of each cross section, except cross section A to A’ where the few wells present were projected over larger distances.

These data were plotted to the cross sections using the ArcHydro Groundwater toolset and then used to interpret and correlate hydrostratigraphy. Lithologic data were used to interpret sand and gravel aquifer units throughout the Basin. Sands and gravels were lumped together in the interpretation. In locations where multiple lithologic logs were present on a cross section, preference was given to the closest logs. Mapped surface geology (CGS 2002) and subsurface conditions around the faults were used to interpret the locations and relationships of older materials to one another and alluvium.

The resulting cross sections are shown individually with well construction, hydrostratigraphy, faulting, and bedrock on **Figures 3-7** through **3-10**. Areas with no well or lithologic data are blank and the transition is indicated by a dashed line. Cross section A to

A’ is the longitudinal profile down the length of the Basin; it is noteworthy in showing the significant topographic change from south to north and rugged character of Basin upland areas. This longitudinal profile is semi-parallel to the Calaveras Fault and intersects the Calaveras Fault zone. The other transverse cross sections illustrate the stratigraphy below the Basin’s main valleys insofar as data are available.

3.9.3. Hydrostratigraphic Evaluation

The cross sections are consistent with and support the conceptual model described above. These sections show that most of the Basin is composed of a mix of interbedded silts and clays (fine grained materials) and sands and gravels (coarse grained materials) in discontinuous lenticular deposits. In general, a higher percentage of sand and gravel occurs near the San Benito River and Tres Pinos Creek, as would be expected. The cross sections also show that distinguishing the primary alluvial aquifer from the same type of materials in the older underlying aquifers is infeasible with available information. Additionally, the cross sections show that most water wells do not extend deep enough to document the full thickness of the water bearing materials that make up the aquifers of the Basin.

3.10. Recharge and Discharge Areas

Groundwater recharge occurs over the entire surface of the Basin, in varying intensities. It can be conceptualized as consisting of three components based on their footprints: areas, lines and points. These categories and their locations are shown in **Figure 3-11**. Dispersed recharge over broad areas derives from deep percolation of rainfall and applied irrigation water beneath the root zone of plants. Estimates of this areal flux are quantified in Chapter 5, Water Budget, for hundreds of polygon areas representing different combinations of soil, water and vegetation. Land use plays a significant role in the recharge flux, and the figure shows three categories of land use that generally have different magnitudes of recharge: non-irrigated natural vegetation (low), urban areas (medium) and irrigated cropland (high).

Percolation from streams is a major source of recharge to the Basin, and streams are shown as linear features on the map. Percolation from small streams in upland areas is estimated in the water balance analysis from a rainfall-runoff-recharge model, and percolation from larger streams in valley floor areas is estimated using the groundwater model.

Percolation from ponds can be represented as points at the scale of the entire Basin. SBCWD has conducted managed aquifer recharge at the Union Road Pond near the San Benito River and the Frog Pond near Arroyo de Las Viboras. Percolation ponds also include wastewater treatment plant disposal ponds. The recharge map shows the locations of six wastewater percolation ponds serving San Juan Bautista, Hollister, the Ridgemark development and Tres Pinos.

Finally, subsurface inflow to the Basin probably occurs at various locations around its perimeter. The water balance section describes how this flux was estimated by applying the rainfall-runoff-recharge model to tributary watershed areas and how it was assumed to be distributed along the Basin perimeter in the groundwater model.

Groundwater recharge can be increased through management actions and projects, termed Managed Aquifer Recharge (MAR). As described in the Plan Area (Section 2.1.4), SBCWD has a long history of percolating surface water to augment recharge, mostly in or near stream channels. MAR activities are likely to be continued and enhanced in the future; potential projects will be addressed in GSP Section 8, Management Actions and Projects.

With regard to discharge, wells are by far the largest discharges from the Basin, and they are abundant in the urban and agricultural areas shown on the recharge map. Natural outflow from the Basin consists of groundwater discharge into creeks and rivers. The primary exit points are groundwater seepage into the lower ends of the Pajaro and San Benito Rivers as they approach the northwestern end of the basin and enter the bedrock canyon leading to the coast. Locations of gaining reaches of streams are mapped and discussed in Section 4.11, Interconnection of Surface Water and Groundwater.

3.11. Primary Groundwater Uses

The primary groundwater uses in the Basin include municipal, agricultural, rural residential, small community water, and small commercial purposes. Municipal and agricultural demand in the Zone 6 portion of the Basin is met by a combination of imported water from the Central Valley Project (CVP) and groundwater. Outside Zone 6, water demand for all uses comes entirely from groundwater. Groundwater production for all users comes largely from the principal aquifer in the central and northern portions of the Basin. In upland areas and smaller valleys of the Basin, production comes from the principal and secondary aquifers.

3.12. Data Gaps in the Hydrogeologic Conceptual Model

The hydrogeologic conceptual model has identified data gaps in available information, as follows:

- The bottom of the Basin is poorly defined throughout and no mapping of the elevation of the Basin bottom exists. Significant exploratory drilling beyond the typical depth of water wells in the Basin or extensive detailed geophysical work would be required to fill this data gap.
- The extent, thickness, and relationship between the principal and secondary aquifers has not been well delineated beyond surficial geologic mapping. As with the Basin bottom, filling this data gap would require significant exploratory drilling and/or geophysics.
- The effect of faults on groundwater flow—which varies both geographically and vertically—is not well documented. The available groundwater monitoring wells are not appropriately located or constructed for the purpose of performing detailed high-quality evaluations of the effects of faults throughout the Basin under a variety of groundwater conditions.

4. CURRENT AND HISTORICAL GROUNDWATER CONDITIONS

This chapter describes the current and historical groundwater conditions in the North San Benito Basin. SGMA requires definition of various study periods for current, historical, and projected future conditions. Current conditions, by SGMA definition, include those occurring after January 1, 2015 and accordingly, historical conditions occurred before that date. A historical period must include at least 10 years. For the North San Benito Basin, which has been actively monitored and managed for decades, the development and application of the numerical groundwater flow model has been central to SBCWD management. The study period for the numerical model begins in water year 1975 and extends through water year 2017. This period is representative and includes droughts and wet periods, with an average annual rainfall of 12.97 inches, comparable to the long-term average of 12.9 inches (1875 to 2017). Accordingly, groundwater conditions over time are described through 2017.

Groundwater conditions are described in terms of the six sustainability indicators identified in SGMA; these include:

- Groundwater elevations
- Groundwater storage
- Potential subsidence
- Groundwater quality
- Seawater intrusion (which is not likely to occur in this inland basin)
- Interconnected surface water and groundwater dependent ecosystems.

4.1. GROUNDWATER ELEVATIONS

4.1.1. Available Data

The evaluation of groundwater elevations in the Basin was conducted using groundwater elevation data obtained from several sources, including the DWR Water Data Library (which includes CASGEM data), San Benito County Water District (SBCWD), USGS, and Santa Clara Valley Water District (SCVWD). The Data Management System contains groundwater elevation data for 254 wells from 1924 to 2018. These wells are shown on **Figure 4-1**.

4.1.2. Groundwater Occurrence

As summarized in Chapter 3, groundwater is present in principal and secondary aquifers that generally are not distinguished in the Basin, because of sparse lithologic log data and a lack of distinctive textures and composition to differentiate the hydrostratigraphy. Groundwater in Basin aquifers occurs under unconfined to confined conditions, and areas with artesian flowing wells have been mapped; however, insufficient data are available to define vertical zones and to provide zone-specific groundwater elevation hydrographs and maps.

4.1.3. Groundwater Elevations and Trends

Hydrographs show groundwater elevation trends over time were prepared for all 254 wells with elevation data; these hydrographs then were reviewed to identify representative wells. The selection of representative wells was based a quantitative approach that considered hydrographs with long records characteristic of an area and distribution of wells across the Basin. In brief, all available groundwater elevation data were plotted as hydrographs and well locations were plotted on a basin-scale map. Each graph was rated (low-5, medium-10, and high-15) for the following criteria:

- Location – Wells were prioritized considering broad distribution across the Basin (including potential Management Areas), availability of other wells nearby, and location near active recharge or discharge areas.
- Ongoing/Recent monitoring – Wells were selected that are part of the active monitoring network or have recent data.
- Historical – Wells were evaluated with consideration of length of monitoring record. Wells with data before 1977 were given a high rating; wells with data only in the last five years were rated low.
- Trends – Each hydrograph was assessed for continuity of monitoring, representation of local or regional trends, and presence of outliers or unrealistic data.

The top scoring wells are shown in **Figure 4-2**. These wells are representative of local groundwater elevation conditions and are appropriate for inclusion in the GSP groundwater elevation monitoring network with well-by-well definition of sustainability criteria (such as undesirable results, minimum thresholds, management objectives). With GSP development and implementation, the network of such key wells will likely need to be revised, for example to add new wells for specific purposes (shallow monitoring) or to remove wells that are not actively monitored.

Long term changes in groundwater elevations in the Basin are illustrated in these representative hydrographs (**Figures 4-3** through **4-7**). Over time, groundwater elevations have varied in response to varying precipitation, groundwater pumping, importation of water, and managed aquifer recharge programs. **Figure 4-3** shows a long-term hydrograph in with a record extending back to 1935. The hydrographs in **Figures 4-4** through **4-7** show conditions since January 1975 and thus encompass the GSP study period beginning in 1976. The hydrographs are presented by recognized areas (Bolsa, Hollister Valley, San Juan Valley, Paicines) to better illustrate regional responses to drought conditions and to management activities led by SBCWD.

As a matter of historical overview, groundwater elevations are estimated to have been at historical highs prior to 1913 before intensification of groundwater pumping. In many wells, historical lows occurred because of pumping coupled with the drought conditions of the late

1970s; groundwater elevations in Hollister Valley declined more than 160 feet from the estimated highs (Kilburn 1972).

Figure 4-3 is the long-term hydrograph for a well in Hollister Valley (well 11-5-35G1) with drought periods and other important dates highlighted. Droughts were identified using a three-year moving average of annual precipitation less than 80 percent.

As shown in **Figure 4-3**, groundwater elevations at this well generally decreased from the 1940s to the 1970s reflecting increased groundwater production and a state of overdraft. Responses to drought involved short-term declines of 30 feet or more with a decline of 50 feet in response to the extreme 1976 to 1977 drought. At that time, the Basin relied solely on groundwater (albeit recharged from local reservoirs) and groundwater elevations reached the historical low. In 1987, SBCWD began importation of CVP water and groundwater elevations subsequently began to rise in the Hollister and San Juan valleys. Elevations also increased in Bolsa, although that area does not directly receive CVP water. A multiple year drought from 1988 through 1992 slowed the recovery of groundwater elevations because of reduced CVP imports and reduced recharge from rainfall and surface water. Following that drought, CVP imports increased, allowing reduction of groundwater pumping and recovery of groundwater elevations due to "in lieu" recharge. In addition, from 1994 to 2004, managed recharge of CVP water along stream channels (e.g., San Benito River) ranged from 1,000 AFY to over 11,000 AFY, with a total recharge volume exceeding 40,000 AF over the 11-year period. The result of in lieu and SBCWD managed aquifer recharge (MAR) programs was significant recovery. This is shown in **Figure 4-3** and occurred most notably in the Hollister and San Juan valleys where imported water is delivered, with some recovery also in Bolsa and areas south of Paicines.

With groundwater elevation recovery, SBCWD shifted its managed aquifer recharge program from recovery to maintenance and local management of groundwater elevations. For example, in response to the latest multiple year drought (2012 through 2015) groundwater elevations declined broadly across the Basin; this was not unexpected but reflected conjunctive management of surface water and groundwater supplies, with use of groundwater storage during drought with long term planning to replenish that storage in wet years. As illustrated in **Figure 4-3**, with the end of drought in 2016 and increased imported water allocations, groundwater elevations have recovered. Recovery occurred in most areas of the Basin over 2016 and 2017.

Given the history of the basin, recovery can be accelerated with targeted management actions in the areas with the most need, given availability of replenishment water (for in-lieu or managed aquifer recharge) and, where MAR is practiced, accessibility to recharge sites. While the broad trends are similar across the basin, each region shows unique groundwater trends.

Figure 4-4 shows key hydrographs for the Bolsa region, which is predominantly agricultural and depends solely on groundwater pumping. Locally confined conditions in the northeast along Pacheco Creek result in artesian wells, wells with groundwater elevations above the ground surface. Groundwater elevations for wells 11-5-21E2 and 11-5-28B1 show fluctuating groundwater elevations before about 1995, reflecting responses to and recovery from droughts in the 1970s and 1980s. In recent years, elevations have risen to above ground surface with artesian conditions. Because there is no mechanism at these wells to measure elevations above ground surface, the hydrographs show elevations equal to the ground surface. Both wells (likely agricultural irrigation wells) show a strong seasonal pattern before about 1995. To the south, groundwater elevations in well 12-5-06L1 show a gradual increasing trend since 1975 and well 12-5-17D1 shows a gradual decreasing trend. The different trends in these wells, located within two miles from each other, likely reflect changing land use and pumping patterns. For example, well 12-5-17D1 with a decreasing trend may be in an area with increasing groundwater pumping. Both wells (likely irrigation wells) show a significant seasonal pattern.

Figure 4-5 shows representative hydrographs for the Hollister Valley, which encompasses diverse conditions in terms of water supply and recharge, land use and water demand, and groundwater management. The artesian well zone in the northeast Bolsa extends into the northwest Hollister Valley. The hydrograph for well 12-5-03B1 shows the similar signature with groundwater elevation fluctuations until the 1990s with groundwater elevations recovering to and remaining at ground surface elevations, as potential higher elevations are not recorded. The hydrograph for well 11-5-13D1, along the upper Pacheco Creek, is characterized by groundwater elevations that have remained steady with 2017 groundwater elevations near historical highs. This pattern likely reflects recharge from the creek and limited local pumping. Well 12-5-24N1 shows a substantial recovery of groundwater elevations from the historical lows of the late 1970s, which were near mean sea level at this well. Groundwater elevations slowly increased by 180 feet, reflecting the availability of CVP supply and reduced local pumping. The hydrograph for well 12-5-34P1, located near the San Benito River in the southern valley, shows fluctuations reflecting drought declines and recovery. In this well, groundwater elevations were at historical lows during the early 1990s and increased quickly by 90 feet within three years; the rapidity of recovery in this well likely reflects SBCWD managed aquifer recharge along the river.

Figure 4-6 shows hydrographs of selected wells in the San Juan Valley. San Juan Valley is characterized by agriculture supplied with groundwater and CVP water (since 1987) and by recharge activities along the San Benito River. The hydrograph for well 12-4-26G1 shows the typical fluctuations in the 1970s and 1980s, reflecting responses to and recovery from droughts. In the 1990s, the hydrograph shows a steep rise in groundwater elevations, more than 80 feet in five years. This reflects not only the effect of in-lieu recharge due to CVP importation, but also rapid filling of available groundwater storage space with natural recharge and managed aquifer recharge along the San Benito River. Well 12-4-17L20 is located further downstream near the outlet of the Basin. The hydrograph shows a slight recovery over the same period in the 1990s; relative to well 12-4-26G1, the effect is muted because groundwater elevations already were near ground surface and there was no available groundwater storage capacity. The remaining hydrographs, for three wells arrayed along the southern valley, generally do not meet the selection criteria for representative wells in terms of having long, complete records that extend to the present. Despite the obvious deficiencies, these three hydrographs are the best available in this portion of the

Basin and will need to suffice until a suitably long, complete, and current monitoring is developed.

Figure 4-7 shows representative hydrographs for wells in the southern Basin near Paicines. Unlike the other hydrographs within elevations of 0 to 300 feet msl, these elevations range from 750 feet msl (in the Wildlife Center well) in the south to around 400 feet (in well 13-6-19K1) near the confluence of the Tres Pinos Creek and San Benito River. The gradient reflects the topography of the Basin (see Cross section A to A' on **Figure 3-7**) as well as the strong northern gradient and flow direction.

Review of **Figure 4-7** indicates generally slight but widespread groundwater declines. The longest hydrograph is for well 13-6-19K1 near the confluence of Tres Pinos Creek and the San Benito River, which shows a decline of about 20 feet during the most recent drought. Hydrographs for the two wells along Tres Pinos Creek south of Paicines also show a decrease in groundwater elevations during the most recent drought and a modest recovery in recent years. The Wildlife Center well experienced a decline of 40 feet and Donati 2 a decline of 15 feet. The Schields 4 well located along the San Benito River Valley shows a decline of about 20 feet.

4.1.4. Groundwater Flow

Figures 4-8 and **4-9** are groundwater elevation contour maps constructed to examine current groundwater flow conditions using data from 2017. Contours were developed based on available groundwater elevation data for all wells.

For the purposes of this discussion, the contours were not prepared assuming local faults (most notably the Calaveras Fault) as groundwater barriers. The Calaveras Fault and others probably provide some impedance to groundwater flow; however, this effect is likely to vary over the length of the fault and with depth (and relative groundwater elevations). The numerical groundwater flow model has examined these non-linear impacts over a variety of flow conditions through calibration. More information is provided in the numerical model documentation report included in **Appendix G**.

Figures 4-8 and **4-9** show groundwater contours for Spring 2017 and Fall 2017, respectively. Spring groundwater elevations reflect seasonal highs and the fall map reflects seasonal lows. By way of comparison, groundwater elevations in wells typically fluctuate 5 to 15 feet on a seasonal basis (**Figure 4-5**, for example) except in the Bolsa (**Figure 4-4**) where groundwater elevations may have seasonal fluctuations of 30 to 40 feet (Yates 2003).

Groundwater flow generally parallels the major surface streams from the southeast and eastern portions of the Basin toward the northwestern portions and the Pajaro River. In the Bolsa, groundwater flow converges into areas of low groundwater elevations (indicated by closed contours such as the 100-foot contour) that are caused by groundwater pumping.

For a historical perspective, **Figure 4-10** shows the groundwater contour map from 1968 (Kilburn 1972), prior to importation of CVP water. Relative to **Figures 4-8** and **4-9**, the 1968 map presents different basin boundaries and different interpretations of fault and geologic effects on groundwater elevations and flow. Nonetheless the 1968 map shows effects on areal groundwater elevations and flow during a period of intense groundwater pumping without imported water. As shown, in 1968 the Basin was characterized by groundwater elevation depressions not only in the Bolsa, but also in the Hollister and San Juan valleys; these are indicated by closed 60- and 80-foot contours with hachures. Comparison of **Figure 4-10** and **Figures 4-8** and **4-9** indicate that the groundwater depressions in Hollister and San Juan valleys have filled and general northward groundwater flow has resumed.

4.1.5. Vertical Groundwater Gradients

The current monitoring network for groundwater elevations provides little information about vertical head (groundwater elevation) gradients within the Basin. Available data are almost entirely from water supply wells, which are typically screened between 200 and 500 feet bgs. The potentiometric head at the depth of the well screen can be different from the true water table, which is the first zone of saturation reached when drilling down from the ground surface. This was documented in a study of shallow groundwater conditions in the San Juan Valley (Yates et al. 1999). At that time, downward head gradients in several shallow-deep well pairs were in the range of 0.10 to 0.80. The maximum value for fully saturated conditions is 1.00. Larger gradients indicate that there is an unsaturated zone between the shallow well screen and the deep well screen. The study noted that when deep groundwater elevations were tens of feet lower in prior decades, shallow zones of saturation were probably hydraulically disconnected from deep aquifers and therefore unaffected by deep pumping.

Flowing wells discharge at the ground surface without the aid of a pump and are an indication of upward vertical head gradients between the depth of the well screen and the ground surface. When regional groundwater elevations recovered in the late 1990s, wells began flowing in two areas where flowing wells had been reported under near-predevelopment conditions (Clark, 1924): along Lovers Lane and Shore Road south of Pacheco Creek and in the vicinity of Prescott Lane northwest of San Juan Bautista. Although the vertical gradient at these wells is certainly upward, it has not been quantified.

Vertical head gradients are an important factor affecting the viability of riparian vegetation. As discussed in greater detail in Section 4.11.3, Riparian Vegetation, phreatophytic vegetation along streams generally survives droughts even when groundwater elevations in wells are tens of feet below the ground surface for two or more years. This suggests that some shallow zones of saturation persist even when head in deep aquifers declines. This implies the presence of large vertical head gradients within the aquifer system.

4.2. Changes In Groundwater Storage

SBCWD provides conjunctive use of groundwater and surface water sources, involving use of groundwater in storage when surface water supplies are diminished and replenishment of groundwater storage when surface water supplies are available. Accordingly, groundwater storage is characterized by changes in the short term but has been stabilized for much of the Basin for the long term, given availability of CVP supply since 1987.

SBCWD Annual Groundwater Reports historically have assessed annual changes in groundwater storage; this has been intended to detect overdraft and, if overdraft were to occur, to track accumulated overdraft as a basis for sustainability planning. This assessment has been based on autumn to autumn comparisons of groundwater elevations (while GSP Regulations require spring to spring) and has been focused on Zone 6 and adjacent areas and thus has not addressed the entire North San Benito Basin. Nevertheless, the previous reports provide insight into the magnitude of groundwater storage changes.

The Annual Groundwater Report for 1997-1998 (JSA 1998) provided an estimate of net change in storage from 1913 historical highs to 1997; the historical storage decrease (or accumulated overdraft) over that period was estimated at 126,096 acre feet (AF). This estimated included Zone 6 and the Bolsa with respective cumulative storage declines of 99,338 and 26,756 AF, respectively. Zero storage change in Paicines and Tres Pinos Creek Valley basins was indicated, as those groundwater basin areas were considered to remain full over that historical period (JSA 1998).

More recently, the Annual Groundwater Report for 2017 (Todd, 2017, pp. 28 to 29) provided estimates of annual groundwater storage change during the most recent multiple year drought (water years 2013, 2014, 2015, and 2016). These change in storage estimates were based on evaluation of groundwater elevation changes. Estimated annual storage declines for the four years were 10,392 AF in 2013, 24,380 AF in 2014, 11,155 AF in 2015, and 3,970 AF in 2016 with a total storage decrease of around 50,000 AF for the four-year drought. These storage change estimates are based on available groundwater elevation data that are limited geographically and temporally and thus include uncertainty. In addition, the storativity or the storage coefficient (the volume of water released from storage per unit decline in hydraulic head) is largely unknown across the Basin. The total volume of groundwater in storage is calculated by multiplying the groundwater elevation changes and the storage coefficient. Storage coefficient values in the Basin will be recalibrated as part of the numerical model update and included in **Appendix G**.

Annual groundwater storage changes that are computed with the water budgets (inflow-outflow=change in storage) generally result in larger values; for example, the accumulated total groundwater storage decrease over the four years was computed at about 86,000 AF. Accordingly, these values are presented only to provide a general estimate of groundwater storage amounts relied on during recent drought. Annual and cumulative groundwater changes in storage for the entire Basin, evaluated using the numerical model, will be presented in Chapter 5, Water Budget.

4.3. LAND SUBSIDENCE AND POTENTIAL FOR SUBSIDENCE

Land subsidence is the differential lowering of the ground surface, which can damage structures and facilities. This may be caused by regional tectonism or by declines in groundwater elevations due to pumping. The latter process is relevant to the GSP. In brief, as groundwater elevations decline in the subsurface, dewatering and compaction of predominantly fine-grained deposits (such as clay and silt) can cause the overlying ground surface to subside.

This process is illustrated by two conceptual diagrams shown on **Figure 4-11**. The upper diagram depicts an alluvial groundwater basin with a regional clay layer and numerous smaller discontinuous clay layers. Groundwater elevation declines associated with pumping cause a decrease in water pressure in the pore space (pore pressure) of the aquifer system. Because the water pressure in the pores helps support the weight of the overlying aquifer, the pore pressure decrease causes more weight of the overlying aquifer to be transferred to the grains within the structure of the sediment layer. If the weight borne by the sediment grains exceeds the structural strength of the sediment layer, then the aquifer system begins to deform. This deformation consists of re-arrangement and compaction of fine-grained units[1], as illustrated on the lower diagram of **Figure 4-11**. The tabular nature of the fine-grained sediments allows for preferred alignment and compaction. As the sediments compact, the ground surface can sink, as illustrated by the right-hand column on the lower diagram of **Figure 4-11**.

Land subsidence due to groundwater withdrawals can be temporary (elastic) or permanent (inelastic). Elastic deformation occurs when sediments compress as pore pressures decrease but expand by an equal amount as pore pressures increase. A decrease in groundwater elevations from groundwater pumping causes a small elastic compaction in both coarse-and fine-grained sediments; however, this compaction recovers as the effective stress returns to its initial value. Because elastic deformation is relatively minor and fully recoverable, it is not considered an impact.

4.3.1. Inelastic Deformation

Inelastic deformation occurs when the magnitude of the greatest pressure that has acted on the clay layer since its deposition (preconsolidation stress) is exceeded. This occurs when groundwater elevations in the aquifer reach a historically low groundwater elevation. During inelastic deformation, or compaction, the sediment grains rearrange into a tighter configuration as pore pressures are reduced. This causes the volume of the sediment layer to reduce, which causes the land surface to subside. Inelastic deformation is permanent because it does not recover as pore pressures increase. Clay particles are often planar in form and more subject to permanent realignment (and inelastic subsidence). In general, coarse-grained deposits (e.g., sand and gravels) have sufficient intergranular strength and do not undergo inelastic deformation within the range of pore pressure changes encountered from groundwater pumping.

[1] Although extraction of groundwater by pumping wells causes a more complex deformation of the aquifer system than discussed herein, the simplistic concept of vertical compaction is often used to illustrate the land subsidence process (LSCE et al. 2014).

The volume of compaction is equal to the volume of groundwater that is expelled from the pore space, resulting in a loss of storage capacity. This loss of storage capacity is permanent but may not be substantial because clay layers do not typically store significant amounts of usable groundwater (LSCE, et al. 2014). Inelastic compaction, however, may decrease the vertical permeability of the clay resulting in minor changes in vertical flow.

The following potential impacts can be associated with land subsidence due to groundwater withdrawals (modified from LSCE, et al. 2014):

- Damage to infrastructure including foundations, roads, bridges, or pipelines;
- Loss of conveyance in canals, streams, or channels;
- Diminished effectiveness of levees;
- Collapsed or damaged well casings; and
- Land fissures.

Inelastic subsidence has not been a known issue in the Basin. Nonetheless, its potential was recognized in the 2003 Groundwater Management Plan (Kennedy/Jenks, 2003), which established a specific water quantity criterion to manage groundwater elevations, to maintain groundwater storage, and to limit drawdown to historical low levels of about 1977 to preclude and/or minimize the potential for ground settlement (i.e., inelastic land subsidence). SBCWD management of groundwater elevations has been successful in meeting these objectives, except for local declines at the end of the 2012 to 2014 drought, and there have been no reports of subsidence problems.

Direct measurements of subsidence have not been made in the Basin using specialized equipment (e.g., extensometers) or using repeated measurement of benchmarks. However, two sources of subsidence data are available: interferometric synthetic aperture radar (InSAR) data that provide spatial coverage using radar images from satellites and data from UNAVCO (a university-organized global geodesy program; see www.unavco.org), which provides temporal land elevation measurements from thousands of globally distributed permanent stations.

4.3.2. Interferometric Synthetic Aperture Radar (InSAR)

InSAR data provided by DWR on its SGMA Data Viewer (DWR 2019b) provide information on vertical displacement of the land surface across a broad area of California from May 31, 2015 to April 30, 2017; this area extended across the central San Joaquin Valley and included portions of the Paso Robles Basin, Salinas Valley, and the entire Basin. Figure 4-12 shows the mapping within the North San Benito Basin. Subsidence, measured in inches, is depicted with darker gray tones indicating land subsidence as much as six inches over the two years while lighter tones indicate land rise of up to four inches. Most of the Basin is characterized by no change to small decline (0 to -2 inches) with some areas of land rise (as much as 4 inches) mostly along basin margins and some scattered areas of decline as much as 6 inches. The general distribution of the scattered areas of decline suggest a relationship to local groundwater pumping; however, the data are limited to only two years. Moreover, the magnitude of reported vertical displacement appears inconsistent with the lack of perceived problems.

4.3.3. UNAVCO

Data are available from UNAVCO from numerous stations in San Benito County (reflecting its position along the San Andreas Fault, a major tectonic plate boundary), including eight within or near the Basin, **Figure 4-13**. The locations are shown in the inset map on **Figure 4-14** and the data are shown in the graphs as cumulative displacement (change) in inches. Seven of the eight graphs are similar and show short-term elastic variability (on the order of days) and long-term stability or upward movement that is likely tectonic. The graph for Station P242 is distinct, showing short-term variability, seasonal changes of generally two inches, and a long-term declining trend. This trend and the proximity of this station to mapped areas of decline suggest inelastic subsidence related to local groundwater pumping. However, the UNAVCO data, which represent measured vertical displacement, indicate cumulative changes generally less than two inches, while the InSAR mapping suggests greater displacement over shorter periods. When additional InSAR mapping is available, spanning a longer period, detailed comparison of UNAVCO and InSAR data will be warranted.

4.4. GROUNDWATER QUALITY ISSUES

The natural quality (chemistry) of groundwater is generally controlled by the interaction between rain water and rocks/soil of the vadose zone and aquifers (Drever 1988). As rainfall infiltrates through the soil column, changes in water chemistry occur as anions and cations are dissolved into the water. These changes are influenced by soil and rock types, weathering, organic matter, and geochemical processes occurring in the subsurface. Once in the groundwater system, changing geochemical environments continue to alter groundwater quality. A long contact time between the water and sediments may allow for more dissolution and more concentrated groundwater (Drever 1988). The natural groundwater quality in a basin is the net result of these complex subsurface processes that have occurred over time.

The quality of groundwater in the Basin has been described as highly mineralized and of marginal water quality for drinking and agricultural purposes. The mineralized water quality is typical of other relatively small Coast Range groundwater basins and reflects the geologic formations in the Central Coast watersheds (e.g., marine sediments) and the relatively low permeability of groundwater basin sediments, which leads to long contact time with groundwater.

Groundwater in the Basin has also been impacted by human activities including agricultural, urban, and industrial land uses. State agencies with regulatory oversight for water quality in the Basin include the Central Coast Regional Water Quality Control Board (RWQCB) and the State Water Resources Control Board – Division of Drinking Water (SWRCB-DDW).

4.4.1. Monitoring Networks

San Benito County Water District
SBCWD currently monitors a distributed network of 18 wells for water quality, shown in **Figure 4-15**. The SBCWD maintains a comprehensive water quality database, created in 2004 (Todd 2004) with a State Local Groundwater Assistance Grant and updated every three years. The database has been regularly updated with readily available data from the SBCWD, Regional Water Quality Control Board, California State Water Resources Control Board, Tres Pinos Water District, City of Hollister, and SSCWD. Updates have been presented on a triennial basis in SBCWD Annual Groundwater Reports (e.g., Todd 2007, 2010, 2013b, 2016 and 2019). The database contains more than one million records from more than 170 water systems or regulated facilities and over 2,000 monitoring locations in the North San Benito Basin including data from Santa Clara County portions of the Basin.

Irrigated Lands
The RWQCB regulates discharges from irrigated agricultural lands to protect surface water and groundwater, using a permit called a Conditional Waiver of Waste Discharge Requirements that applies to owners and operators of irrigated land used for commercial crop production. The RWQCB is focusing on priority water quality issues, such as pesticides and toxicity, nutrients, and sediments, especially nitrate impacts to drinking water sources.

San Benito landowners belong to the Central Coast Groundwater Coalition. Together with landowners in Salinas Valley, Pajaro Valley, and Llagas subbasin, they collect water quality data and have prepared a report *Northern Counties Groundwater Characterization* (LSCE 2015). The report summarizes nitrate concentrations from 1,105 wells in the Gilroy-Hollister Valley (including the Hollister and San Juan Valleys and the Bolsa area in the Basin).

Data for the Irrigated Lands Program will be included in the SBCWD Water Quality Database for annual GSP reports.

Division of Drinking Water
There are 110 drinking water systems, with a total of 320 well locations in the San Benito County portion of the Basin and 2 systems with a total of 4 well locations in the Santa Clara County portion of the Basin. These stations report water quality data to the SWRCB-DDW. Each system monitors and reports water quality parameters to SWRCB-DDW and is required to participate in the Drinking Water Source Water Assessment Program (DWSAP) to assure wells are not subject to local contamination. **Figure 4-16** shows the approximate location of drinking water systems in the Basin.

4.5. Other Studies

4.5.1. Salt and Nutrient Management Plan

Consistent with the 2013 State Water Resources Control Board (SWRCB) Recycled Water Policy, a Salt and Nutrient Management Plan (SNMP) was developed for the San Benito

County portion of the Basin in 2014.[2]. The purpose of the SNMP was to identify sources of salts and nutrients (current and future) as context for assessing potential impacts of recycled water projects and to plan for management of salt and nutrient sources to ensure that groundwater is safe for drinking and all other beneficial uses. Beneficial uses of water and respective water quality objectives are defined by the RWQCB in the Central Coast Water Quality Control Plan (Basin Plan).

The SBCWD SNMP analysis demonstrated that the recycled water irrigation projects planned through 2021 will use less than one percent of the available TDS and nitrate assimilative capacity, namely the difference between average salt and nutrient concentrations in the Basin and the respective Basin Plan objectives. Therefore, the recycled water irrigation projects satisfy Recycled Water Policy criteria. The SNMP analysis found that recycled water use can be increased while still protecting groundwater quality for beneficial uses.

Based on the analysis, the SNMP concluded no additional implementation measures are warranted beyond those that have been implemented and those that are already planned. Nonetheless, the SNMP management process is active and ongoing, and continued water quality monitoring will ascertain the effectiveness of implementation measures.

With respect to monitoring, the Recycled Water Policy states that the SNMP should include a monitoring program that consists of a network of monitoring locations "... adequate to provide a reasonable, cost-effective means of determining whether the concentrations of salts, nutrients, and other constituents of concern as identified in the salt and nutrient plans are consistent with applicable water quality objectives." Additionally, the SNMP is required to focus on basin water quality near water supply wells and areas proximate to large water recycling projects, particularly groundwater recharge projects (Todd 2014).

The SNMP Monitoring Plan laid out a program wherein the data collected and compiled by the SBCWD are analyzed and reported to the RWQCB every three years as part of the SBCWD Groundwater Report. The analyses include time concentration plots, water quality concentration maps, and more.

4.6. THREATS TO WATER QUALITY

4.6.1. Regulated Facilities

The RWQCB has regulated more than 123 facilities with soil and groundwater contamination in the Basin (119 in San Benito and 4 in Santa Clara County). Of those, 45 sites are active in (or adjacent to) the Basin (44 in San Benito and 1 in Santa Clara County). The active and inactive sites are shown on **Figure 4-17**. Data for 892 wells monitored by these facilities are

[2] Santa Clara County areas of the Basin were not included in the nominal SNMP study area. Nonetheless, data are provided on maps, including available land use and water quality data. No recycled water projects have been planned for these areas.

currently included in the SBCWD Water Quality database and will continue to be included in the updates. These facilities range from large-scale soil and groundwater clean-up operations to leaking underground storage tanks. RWQCB files for such regulated facilities have been and will continue to be checked regularly as part of the SBCWD water quality monitoring program.

4.6.2. Septic Systems

Most residences and businesses in unincorporated areas of the Basin rely on on-site wastewater treatment (OWTS or septic systems). These represent sources of salt and nutrient loading to groundwater, as well as potential sources of other contaminants. San Benito County Department of Environmental Health is the permitting agency for septic systems and wells in San Benito County. Similarly, the Santa Clara Department of Environmental Health is responsible for OWTS in the small Santa Clara portions of the Basin. The San Benito County Department of Environmental Health maintains an inventory of septic system installations from 1953 to the present, including address and/or assessor parcel number. While it is unclear how many of these septic systems are still operating, San Benito County has 1,000s of permits on file.

4.6.3. Oil and Gas

The Hollister Oil and Gas Field overlies parts of the Basin near the Bolsa and San Juan regions. The location, along with a 0.5-mile buffer is shown on **Figure 4-17**. Hydrocarbons exist approximately 600 feet below the base of fresh water and is not likely to impact drinking water. A San Benito County Fracking Ban Initiative ballot question was approved by voters in November 2014. This measure was designed to prohibit hydraulic fracturing, known as fracking, and related gas and oil extraction activities, as well as other "high-intensity petroleum operations," including acid well stimulation and cyclic steam injection. It also banned any new gas or oil drilling activity including conventional, low-intensity activity in areas of the county zoned for residential or rural land use (Aspen 2015).

4.6.4. Non-point Sources

Nonpoint Source (NPS) pollution is defined by the SWRCB as contamination that “does not originate from regulated point sources and comes from many diffuse sources.” NPS could occur when rainfall carries contaminants to surface water ways or percolates contaminants to groundwater. One example is loading to groundwater of nitrate from agricultural or landscaping land applications.

4.7. Key Constituents of Concern

Total dissolved solids (TDS) and nitrate are the indicator salts and nutrients and key constituents of concern (COCs) for the Basin. TDS data are available for both inflows and outflows from the Basin. There is elevated natural background TDS concentrations in groundwater. This has been documented since the 1930s and has been ascribed to the subsurface sediments. In addition, TDS can be an indicator of anthropogenic impacts (e.g., infiltration of urban runoff, agricultural return flows, and wastewater disposal), The SNMP analysis of salt loading found that all but two areas (Bolsa area and Tres Pinos Valley) have predicted stable or decreasing trends in TDS concentrations.

Nitrate is the primary form of nitrogen detected in groundwater and natural nitrate levels in groundwater are generally very low. Elevated concentrations of nitrate in groundwater are associated with agricultural activities, septic systems, confined animal facilities, landscape fertilization, and wastewater treatment facility discharges. The maximum contaminant level (MCL) for nitrate (as nitrate, NO_3) is 45 milligrams per liter (mg/L). Nitrate data are available for basin inflows and outflows, and as documented in the SNMP, elevated nitrate concentrations have been a recognized, long-term concern in the Basin. The SNMP analysis of nitrate loading found that most areas had predicted small increasing trends in nitrate in groundwater.

Previous water quality studies have identified other constituents of concern including boron, chloride, hardness, metals, sulfate, and potassium. In some parts of the Basin, groundwater does not meet water quality standards for these constituents relative to the intended beneficial uses of the groundwater.

4.7.1. Water Quality Goals

The RWQCB has established General Basin Plan Objectives (GBPOs) for groundwater with municipal and domestic water supply and agricultural water supply beneficial uses in the Central Coast as shown in **Table 4-1** below. For TDS, the SWRCB-DDW has adopted Secondary Maximum Contaminant Levels (SMCLs); SMCLs address aesthetic issues related to taste, odor, or appearance of the water and are not related to health effects. The recommended SMCL for TDS is 500 mg/L with an upper limit of 1,000 mg/L. It has a short-term limit of 1,500 mg/L. Elevated TDS concentrations can affect water supply suitability for irrigation uses; in general crop yields decrease above a threshold TDS value, which is crop-dependent.

The primary maximum contaminant level (MCL) for nitrate (as N) is 10 milligrams per liter (mg/L), or as expressed in this report, in terms of nitrate (as NO_3), the MCL is 45 mg/L. These MCLs are based on health concerns due to methemoglobinemia, or “blue baby syndrome”.

The SNMP also presented basin-specific plan objectives, as listed in **Table 4-2** below for the Hollister and Tres Pinos Subbasins (as previously defined by DWR). In addition, for the San Juan and Bolsa Subbasins, a TDS assimilative capacity benchmark of 1,200 mg/L was assigned. Ambient groundwater quality in the San Juan Bautista and Bolsa area is similar to or slightly poorer than in the Hollister area; thus, use of the same TDS objective for these subbasins is deemed reasonable. For nitrate- NO_3, a basin-specific plan objective of 22.5 mg/l was applied to Hollister Subbasin and an assimilative capacity benchmark of 45 mg/L) was applied to assimilative capacity calculations in the DWR San Juan Bautista and Bolsa Subbasins (Todd 2014).

TABLE 4-1. GENERAL BASIN PLAN OBJECTIVES

Parameter	Units	Municipal	Agricultural
TDS	mg/L	500/1,000/1,500[1]	450
Nitrate (as NO_3)	mg/L	45	100[2]
Nitrate + Nitrite-N	mg/L	10	100 [2]

mg/L – milligrams per liter
1 - Objectives for TDS are recommended SMCLs.
2 - For livestock watering

TABLE 4-2. BASIN-SPECIFIC BASIN PLAN OBJECTIVE

Parameter	Units	DWR Subbasin	
		Hollister	Tres Pinos
TDS	mg/L	1,200	1,000
Nitrogen (as N)	mg/L	5	5
Nitrate (as NO_3)	mg/L	22.5	22.5

4.7.2. Key Constituents in Groundwater

Table 4-3 shows current average concentrations for TDS and nitrate for four representative areas across the Basin. The values were developed by averaging all drinking water and ambient monitoring events that occurred from water year 2015 to 2017; water quality samples from regulated facilities were not included in the analysis. These average conditions serve as a snapshot and allow a comparison of water quality conditions across the Basin.

TABLE 4-3. AVERAGE CONSTITUENT CONCENTRATIONS BY AREA 2015-2017

Region	Nitrate (NO_3, mg/L)	Total Dissolved Solids (TDS, mg/L))
San Juan Valley	37.1	1,806
Paicines Area	39.4	895
Hollister Valley	47.9	810
Bolsa Area	50.3	839

4.7.3. Total Dissolved Solids (TDS)

As documented in **Table 4-3**, TDS concentrations are generally high throughout the Basin and the average TDS concentrations exceed the secondary MCL for drinking water (500 mg/L).

The relatively high TDS concentrations are also indicated in **Figure 4-18**, which show TDS concentrations over time in selected wells across the Basin. While concentrations are high (e.g., exceeding 500 mg/L), recent years (2014 through 2017) are characterized by TDS concentrations that are stable or decreasing. For example, in the San Juan Valley, some wells downstream of the historical wastewater treatment ponds (e.g., MW47) show a general decrease in concentrations, possibly due to the reduced percolation of wastewater in recent years. However, water quality samples in this area continue to have high TDS concentrations relative to the rest of the Basin; lowest TDS concentrations are indicated in Well MW42 (in the Bolsa area).

Figure 4-19 shows the average concentrations at each well in the Basin that has been sampled in water years 2014 to 2017 for TDS, the wells locations are shown in Figure 4-16. Generally, the eastern and northern edges of the Basin show lower concentrations of TDS. Higher TDS areas reflect geology (e.g., fault zones and older sediments) and historical wastewater disposal among other factors. In some areas, including the Bolsa, TDS concentrations vary over time, most likely due to a local sources and variability of groundwater conditions (i.e. changes in pumping resulting in changes to groundwater flow direction).

4.7.4. Nitrate as NO_3

As documented in **Table 4-3**, average nitrate conditions are high throughout the Basin; the average nitrate concentrations in Hollister and Bolsa areas are above the 45 mg/L MCL for nitrate as nitrate. These areas have long histories of intensive irrigated agricultural and local wastewater disposal.

Nitrate, long identified as a COC in the Basin, has multiple and widespread sources including fertilizer application and wastewater disposal (both municipal and domestic). Given that these sources are on or near the ground surface, shallow groundwater typically is characterized by higher concentrations than deep groundwater. In fact, the highest recent concentrations occurred in shallow wells in the eastern San Juan area.

Figure 4-20 shows the average concentrations at each well in the Basin that has been sampled in water years 2014 to 2017 for nitrate. **Figure 4-21** shows nitrate time concentration plots from selected monitoring wells. Nitrate concentrations are elevated above natural concentrations (typically less than 10 mg/L), but most samples have indicated nitrate concentrations below the MCL of 45 mg/L. With some exceptions, concentrations are relatively stable over time.

Additional review of basin nitrate concentrations was performed by Luhdorff and Scalmanini for the Irrigated Lands program. The report indicated that, for the 1,105 wells used in analysis of nitrate concentrations in the Gilroy-Hollister Valley, 26 percent had average concentrations over the MCL of 45 mg/L (this includes Llagas Basin in Santa Clara County, LSCE 2015).

Water quality in the Basin has not changed significantly since the SNMP concluded that recycled water would not adversely impact water quality. With local exceptions, concentrations of nitrate and TDS remain fairly stable across the subbasin.

4.8. OTHER CONSTITUENTS

4.8.1. Hardness

Hardness (total hardness, as $CaCO_3$) indicates that high concentrations of calcium and magnesium ions in water will form insoluble residues with soap. It is a naturally-occurring condition but can be impacted by anthropogenic sources that add calcium or magnesium to the groundwater. Hardness above about 120 to about 150 mg/L is considered hard water with objectionable properties for consumers. A value of more than 200 mg/L can result in scale deposition to pipes. Because there are no drinking water standards for hardness, the practical limitations of hard water (greater than 200 mg/L hardness) and very hard water (greater than 300 mg/L hardness) are used as guidelines for the analysis.

Groundwater is considered hard to very hard throughout most of the Basin. The only water with hardness of less than 200 mg/L is found in the east-central Basin and in the northwest along the Pajaro River.

The natural hardness of the groundwater indirectly relates to increases in groundwater salinity in localized areas due to the use of water softeners. Water softeners work by exchanging the calcium and magnesium ions with sodium ions from sodium chloride. As such, sodium and chloride are concentrated in wastewater. Because much of the wastewater is returned to the Basin through septic tank discharges or wastewater percolation ponds, water softeners have impacted groundwater (JSA 1998).

4.8.2. Boron

Boron is associated with marine clays, thermal springs, and closed-basin evaporates; clay deposited from marine waters contains 400 to 600 mg/L of boron (Reynolds 1972). Boron may also occur from anthropogenic sources because it is used in glass manufacturing, soaps and detergents, and flame retardants. Although there are no drinking water standards for boron, DHS has designated an action level of 1.0 mg/L (1,000 micrograms per liter, ug/L). Plants are especially sensitive to boron, and agricultural standards are set at 0.7 mg/L (700 ug/L) to 0.75 mg/L (750 ug/L). Some damage can occur to crops at even lower concentrations.

Boron has been identified as a COC in the Basin because elevated concentrations historically contributed to abandonment of orchards in Hollister Valley (Eaton et al. 1941). The highest concentrations are associated with a north-south trending band in the Hollister Valley, which is thought to be controlled by geologic conditions and may be related to changing water chemistry along a fault plane at depth.

4.8.3. Perchlorate

Perchlorate (ClO^{4-}) is a byproduct of solid rocket fuel manufacturing and testing, munitions manufacturing, and flare and pyrotechnics manufacturing (Motzer 2001). It can occur naturally in some fertilizers, kelp, and in caliches and playa crusts. Perchlorate compounds have relatively high water (aqueous) solubilities and densities. Once dissolved in water, the perchlorate anion becomes relatively nonreactive, very stable, and extremely mobile. The California DHS action level and the agricultural water quality limit are both 6 ug/L.

Perchlorate has been associated with three facilities in the Basin: McCormick Teledyne, Whittaker, and the Hollister WWTP. Both the former Whittaker Ordnance facility and the former Teledyne facility have been documented as using perchlorate and releasing it to the environment. Ordnance manufacturing occurred on the Whittaker site since 1957 (Acton Mickelson 2000) while historical activities on the McCormick Teledyne site included use of perchlorate and TCE. Although more than 140 wells in the Basin have been sampled for perchlorate, 94 of those wells are located on the two sites. Offsite monitoring data downgradient of Whittaker and McCormick Teledyne are limited. Both facilities are regulated by RWQCB and perchlorate concentrations are closely monitored on and off site.

4.8.4. Metals

Arsenic. Arsenic is naturally-occurring and leaches from aquifer materials into groundwater. For California public drinking water systems, the primary MCL for arsenic is 10 µg/L. Long-term exposure to arsenic has been linked to multiple forms of cancer, while short-term exposure to high doses of arsenic can cause other adverse health effects. While there have no exceedances of the MCL, approximately 74 samples in groundwater wells showed concentrations 5 to 10 ug/L (including SBCWD monitoring wells MW-17, MW-21, MW-42, and MW-43).

Chromium. Chromium occurs in three oxidation states readily found in nature: Cr(0), which occurs in metallic or native chromium (but is rarely found); Cr(III), which occurs in chromic compounds; and Cr(VI), which occurs in chromate and dichromate compounds. Cr(VI) is also known as hexavalent chromium. Most compounds containing Cr(VI) are toxic. Most chromium concentrations in groundwater are low, averaging less than 1.0 µg/L (WHO 2003). The MCL for Chromium is 50 ug/L and the Health-Based Screening Levels (HBSLs) for Hexavalent Chromium 20 ug/L. There have been no recent exceedances of the MCL or HBSL, but approximately 144 samples in groundwater wells showed concentrations of 10 to 20 ug/L for hexavalent chromium.

Iron. In natural water, iron (Fe) is generally analyzed as total iron, which includes Fe^{3+} and Fe^{2+}. Soluble Fe^{2+} is more common in groundwater under reducing conditions, occurring at concentrations ranging from 1.0 to 10 mg/L (Manaham 1991 and Hounslow 1995). The MCL is 300 ug/L and no recent sampled exceeded this limit; however, approximately 44 samples have iron concentrations within 150 to 300 ug/L.

Manganese. Manganese is generally associated with iron under anaerobic conditions where the more soluble forms may occur. In general, if water has more than 0.20 mg/L, manganese will precipitate upon encountering an oxidizing environment. This will cause an undesirable taste, deposition of black deposits in water mains, water discoloration and laundry stains (Todd 1980 and WHO 2003). The MCL is 50 ug/L and no recent samples exceeded this limit. Approximately 60 samples have iron concentrations within 25 to 50 ug/L.

Anthropogenic sources include mining wastes, iron and steel manufacturing, cleaning oxidants, bleaching and disinfection (potassium permanganate), and as an organic compound used as an octane enhancer in gasoline (MMT) in North America (Canada and the U.S.) (WHO 2003).

Selenium. Selenium concentrations in surface water and groundwater are generally low with concentrations below 0.012 mg/L, with most stream water averaging 0.0002 mg/L. Selenium concentrations have been measured at 0.60 mg/L under unusual geologic conditions, (Hem 1989 and ATSDR 2003). The MCL for Selenium is 50 ug/L, no recent samples (outside of the regulated facilities Whittaker and John Smith Landfill) have concentrations 25 to 50 ug/L.

4.9. Vertical Variations in Water Quality

Generally, water quality monitoring programs in the Basin do not show a distinct difference of water quality in depth, in part because most of the ambient monitoring wells have long screens. Shallow wells are generally found near regulated facilities and therefore show high concentrations of constituents representing local contamination rather than regional trends. In 2006, a nested well (funded in part by a State Local Groundwater Assistance Act grant) was completed in the Hollister Subbasin to study vertical distribution of groundwater quality in an area of elevated TDS and boron. The nested well has five depth-specific ports: A through E from shallow to deep. Initial water quality sampling indicates elevated concentrations of sodium, chloride, TDS, and boron, with indications that deepest groundwater shows poorest quality, for example TDS approximately twice as high as the other shallower zones. Initial water quality data indicate elevated boron in all five screened zones and show a possible trend of increasing boron with depth.

These data may reveal local changes in water quality with depth but may not capture the regional vertical trends.

Impacts to shallow groundwater likely originate from some type of anthropogenic source at the ground surface such as agricultural activities (concentration of salts, fertilizers, and soil amendments), wastewater disposal, or industrial releases. Because almost all shallow water quality data in the Basin were compiled from regulated facility monitoring wells, regulated facilities are the only place that shallow groundwater could be evaluated. In some cases, impacts to shallow groundwater can be attributed to activities at the facilities; however, for some constituents, the correlation is unclear. Regulated facilities at the edges of the alluvial basin often have shallow wells in geologic formations other than basin alluvium and, as such, may exhibit different water chemistry that is independent of anthropogenic impacts. In addition, since shallow groundwater data are missing in the remainder of the Basin, it is difficult to determine whether shallow impacts are widespread. These complications limit the evaluation of shallow groundwater in the Basin and impacts at regulated facilities. Therefore, place names and regulated facility names in this document are used as location or data source references and should not be concluded to be the source of any water quality impact unless so stated.

Based on regional geology, naturally high TDS and boron is expected at depth (Kilburn 1972). In addition, regional shallow groundwater generally has relatively high concentrations of TDS and nitrate reflecting agricultural drainage and other anthropogenic sources.

4.10. Seawater Intrusion Conditions

Basin is located inland from Monterey Bay approximately 20 miles upstream from the mouth of the Pajaro River; lowest elevations (at the confluence of the San Benito River and Pajaro River) are above about 110 feet. No risk of seawater intrusion exists in the Basin given its location.

4.11. Interconnection of Surface Water and Groundwater

Interconnection of groundwater and surface water occurs wherever the water table intersects the land surface and groundwater discharges into a stream channel or spring. These stream reaches gain flow from groundwater and are classified as gaining reaches. Conversely, connection can occur along stream reaches where water percolates from the stream into the groundwater system (losing reaches), provided that the regional water table is close enough to the stream bed elevation that the subsurface materials are fully saturated along the flow path.

Groundwater pumping near interconnected surface waterways or springs can decrease surface flow by increasing the rate of percolation from the stream or intercepting groundwater that would have discharged to the stream or spring. If a gaining stream is the natural discharge point for a groundwater basin, pumping anywhere in the basin can potentially decrease the outflow, particularly over long time periods such as multi-year droughts.

Because of the long dry season that characterizes the Mediterranean climate in San Benito County, vegetation exploits any near-surface water sources, including the water table along perennial stream channels, the wet soil areas around springs, and areas where the water table is within the rooting depth of the plants. Plants that draw water directly from the water table are called phreatophytes. They are able to continue growing vigorously during the dry season and typically stand out in summer and fall aerial photographs as patches of vegetation that are denser, taller and brighter green than the adjacent vegetation.

Three types of data available for northern San Benito County were evaluated to identify locations of interconnected surface water and groundwater: stream flow, depth to groundwater, and vegetation. Each of these data sets has limitations or inconsistencies—as described below—so they were evaluated collectively to obtain a more reliable indication of groundwater-surface water interconnection.

4.11.1. Stream Flow Measurements

Manual measurements of flow at multiple locations along a stream during steady flow conditions can reveal reaches that gain or lose water. This was done on multiple dates in the late 1990s and early 2000s for many of the creeks that flow across the Basin (JSA 1999a, 1999b, 2000, and 2001, Yates et al. 1999; Yates 2002, 2003, 2005a, and 2005b). Those measurements identified the patterns of gaining and losing reaches along the creeks shown in **Figure 4-22**. In general, the creeks and rivers lose water except where they approach a fault or a narrow spot in the valley floor alluvium. For example, Pacheco Creek has a short gaining reach where it crosses the Ausaymas Fault at Highway 156 and a longer gaining reach as it approaches San Felipe Lake and the Calaveras Fault. Similarly, the San Benito River gains flow as it nears Highway 101 at the downstream end of the San Juan Valley. The Pajaro Rive likewise gains flow as it approaches the narrow gap at the west end of the Lomerias Muertas hills. Farther up the San Benito River, gaining flow reaches were inferred from the presence of dense riparian vegetation and topography rather than from flow measurements.

4.11.2. Depth to Groundwater

Depth to groundwater provides a general indication of locations where gaining streams and riparian vegetation are likely to be present. However, available data are of limited use for this purpose due to insufficient geographic and vertical coverage. Available data are almost entirely from water supply wells, which are typically screened 200 to 500 feet below the ground surface. The groundwater elevation (potentiometric head) at the depth of the well screen can be different from the true water table, which is the first zone of saturation reached when drilling down from the ground surface. Large downward head gradients within the aquifer system have been documented from pairs of shallow and deep wells, and upward gradients are present where there are flowing wells (see Section 4.1.5, Vertical Groundwater Gradients). The persistence of riparian vegetation through droughts also implies the occurrence of large downward gradients, as discussed below.

The second limitation is the sparse geographic distribution of groundwater elevation monitoring wells. Creeks and rivers that lose water commonly form a mound in the water table near the creek. The height and width of the mound depends on the transmissivity of the shallowest aquifer. For example, groundwater elevations in a shallow well adjacent to the Arroyo Seco in the Salinas Valley rose 5 to 10 feet more than groundwater elevations in wells 1,000 feet away when the river started flowing (Feeney 1994). A groundwater ridge up to 12 feet high develops beneath Putah Creek in Yolo County during the flow season, but the width of this ridge was estimated to be only a few hundred feet (Thomasson et al. 1960). These examples suggest that shallow wells within 100 to 200 feet of a stream channel would be needed to confirm the presence of hydraulic connection between surface water and groundwater when groundwater elevations in deep water supply wells are within perhaps 30 feet of the river bed elevation.

Contours of depth to groundwater in fall 2017 correlate in a general way with locations of observed gaining stream reaches (**Figure 4-22**). These depth to groundwater contours were interpolated from monitored well measurement for the purpose of evaluating correlations to surface water bodies. The gaining reaches along the lower ends of Pacheco Creek, Tequisquita Slough and the San Benito River are all where contoured groundwater elevations in wells are about 20 feet below the ground surface. Similarly, the gaining reach and riparian vegetation along the San Benito River where it approaches the Calaveras Fault coincide with relatively shallow depth to water.

4.11.3. Riparian Vegetation

Vegetation patterns along streams can also be used to map potential interconnection of surface water and groundwater because growth is more vigorous where plant roots can reach the water table. There are limitations to this approach, however. First, some plant species are facultative phreatophytes, which means they will establish and grow with or without access to the water table. An example is mulefat (Baccharis salicifolia), which in the Natural Communities Commonly Associated with Groundwater (NCCAG) map was dominant along broad, gravelly reaches of the San Benito River where shallow groundwater was not likely present (DWR et al. 2018). More obligate phreatophytes such as cottonwood (Populus fremontii) correlated more closely with gaining stream reaches.

A second limitation is that streams that convey releases from upstream reservoirs can “irrigate” riverbank vegetation in summer, mimicking the effect of a shallow water table. In northern San Benito County, the District currently manages releases from Hernandez Reservoir to provide summer flow down the San Benito River as far as Lucy Brown Road near San Juan Bautista, when water is available to do so. Similarly, releases from Pacheco Reservoir sustain flow down Pacheco Creek as far as Highway 156 from June to October in most years (substantially less during droughts).

A third limitation is that land clearing for agriculture has reduced the width of the riparian vegetation corridor along many stream reaches to less than 100 feet. Where shallow groundwater is present, the width of the riparian vegetation corridor would typically be wider in the absence of clearing.

For the purposes of this GSP, phreatophytic riparian vegetation was mapped from fall 2016 aerial photographs where the riparian corridor width exceeded 100 feet and tree canopy density exceeded 80 percent (see **Figures 4-23** and **4-24** for locations). The width criterion selects for areas more likely to have shallow groundwater (rather than streambank "irrigation" by a losing stream). Although riparian corridors can be as little as two tree crown diameters wide (McBride and Strahan 1984), the ecological integrity and value of riparian vegetation as measured by macroinvertebrate diversity has been shown to increase with corridor width up to about 250 feet in northern California streams (Mahoney and Erman 1984). Also, a minimum buffer zone for land development of 100 feet along creeks is designated in Humboldt and Ventura Counties (Woodroof and Roberts 1984, Capelli and Stanley 1984). The density criterion also tends to differentiate between phreatophytic and non-phreatophytic vegetation, based on other indicators of the presence of shallow groundwater.

4.11.4. Springs and Seeps

Springs, seeps and wetlands supported by groundwater within the Basin were identified by selecting from candidate sites included as springs, seeps or wetlands in the NCCAG geodatabase. NCCAG compiled the sites from other databases based on the frequency of flooding. About half of the features are classified as seasonally flooded, which is more likely to be associated with localized ponding of rainfall runoff than discharge of regional groundwater. Accordingly, the seasonally flooded sites were omitted. Sites along stream channels were also omitted, as those areas were already addressed in the evaluation of gaining/losing stream reaches and riparian vegetation. The remaining sites were each compared with a fall 2016 high-resolution aerial photograph to verify that greener vegetation was present at the site, which is the typical effect of perennial shallow groundwater. This screening process resulted in the identification of 25 sites that could plausibly be locations of groundwater discharge. Of those, eight were in upland areas far from large wells and thus unlikely to be impacted by pumping. An additional five were stock ponds whose source of water was uncertain. Some might be excavated springs; others might be simply runoff impoundments. Vegetation around the ponds did not show evidence of a shallow water table. Finally, the stock ponds were also in upland areas where effects of pumping in the valley floor areas would likely be negligible. The remaining 12 sites were on the upgradient side of a fault, where shallow groundwater is or could be present. Ten of those were sag ponds along the Calaveras Fault or depressions feeding into San Felipe Lake, and two were on the southwest side of the San Andreas Fault near San Juan Bautista. Those seeps and springs could potentially be impacted by groundwater pumping.

As an empirical check of whether low groundwater elevations might have impacted the springs and seeps during the 2013 to 2014 drought, each site was examined in Google Earth aerial images for several dates between 2010 and 2016. Only four of the 25 sites appeared drier in 2016 than 2010, and three of those were along the upgradient side of the Calaveras Fault near Tequisquita Slough and San Felipe Lake. Those wet areas might have been diminished by low groundwater elevations. However, a reduction in surface inflow during the drought could possibly have caused similar effects.

4.11.5. Annual Depletion of Groundwater

The degree to which groundwater pumping depletes stream flow depends partly on groundwater elevations. When groundwater elevations are low—such as during the decades prior to surface-water importation or during prolonged droughts—vertical head gradients within the Basin exceed 1.0 in places, which means there is an unsaturated zone between shallow aquifers and deeper aquifers tapped by water supply wells. Under that circumstance, additional groundwater pumping and groundwater elevation lowering has no effect on stream flow. The rate of stream percolation is governed by the permeability of the creek bed. When groundwater elevations are very high—as occurs during wet years or sequences of wet years—stream percolation is reduced due to lack of vacant storage space within the groundwater system. This reduction in percolation is called "rejected recharge" and became noticeable beginning in the late 1990s (JSA 2001 and 2002, Yates, 2003, 2004, and 2005).

An empirical test of stream flow depletion by pumping was obtained using the groundwater model. A baseline simulation of current land and water use patterns was completed for the water year 1975 through 2017 hydrologic period. A second simulation was completed with the same inputs except that pumping was omitted. Return flows from irrigation, urban stormwater percolation and wastewater percolation were retained. Such a scenario would result if all water used in the Basin were obtained from imported surface water. [Results to be prepared and discussed after modeling has been completed.]

To be completed later: Figure 4-25 Estimated Annual Depletion of Interconnected Surface Water [Annual bar chart pairs of basin-wide STR percolation with and without pumping.]

4.11.6. Identification of Groundwater-Dependent Ecosystems

Groundwater-dependent ecosystems (GDEs) can include plants and animals. Species in those habitats depend on the presence of a shallow water table, pond or stream flow. Evaluating the connection between groundwater pumping and the health of those species requires careful evaluation of biological and hydrological factors, including the role of groundwater in the life history of the species (fish passage, spawning, dry-season growth), the timing of water utilization (seasonal, drought survival), the sources of water supplying the habitat (regional groundwater discharge, seasonal wetlands, irrigation tailwater, wastewater), and the hydraulic connection between shallow and deep groundwater. These factors are considered separately for vegetation and animals, below.

4.11.6.1. Vegetation

The distribution of wetlands and phreatophytic riparian vegetation was used to help delineate locations where groundwater and surface water are interconnected, as described above in Sections4.11.3 and 4.11.4. Riparian vegetation was considered phreatophytic where the vegetation corridor was at least 100 feet wide and consisted primarily of trees with at least 80 percent canopy coverage. Vegetation matching these criteria was present in fall 2016 along much of Pacheco Creek and the Pajaro River, several locations along the San Benito River, and short reaches along several smaller streams (**Figures 4-23** and **4-24**). The total area of phreatophytic vegetation was 1,650 acres. A comparison of these areas with vegetation polygons in the NCCAG vegetation map indicated that common species in the phreatophyte areas along the San Benito River (which had more thorough mapping than other streams in the Basin) are Fremont cottonwood, southwestern North America riparian, flooded and swamp forest, mulefat, valley oak (in upper stream terrace locations), and valley foothill riparian.

Phreatophytic riparian vegetation will exploit shallow groundwater throughout the dry season whenever it is available. However, the plant species have varying ability to survive on soil moisture alone if the water table drops below the bottom of the root zone, such as during a drought. Furthermore, groundwater elevations in shallow aquifers are typically more stable than groundwater elevations in deeper ones utilized for water supply. For both of these reasons, the relationship between groundwater elevations in water supply wells and vegetation health is complex.

An empirical method for relating vegetation health to groundwater elevations in wells is to compare aerial photographs of phreatophytic riparian vegetation before and after droughts. If the low groundwater elevations during the drought affected the shallow water table and plants significantly, die-back of the riparian canopy would be expected. This approach was implemented by comparing aerial photographs taken in November 2012 and October 2016, which were before and after a drought during which groundwater elevations in many wells declined 20 to 40 feet. Only a few of the areas mapped as riparian vegetation appeared to experience a reduction in vegetation coverage during the drought. Close-up aerial photographs for both dates are shown for two of these areas in **Figure 4-23**. The locations are on Tres Pinos Creek and the San Benito River (**Figure 4-22**). Examples of areas where vegetation density and/or vigor appeared to have decreased between the two dates are circled in the figure. There are no monitoring wells near site A on Tres Pinos Creek, and groundwater elevations in wells near site B on the San Benito River declined 30 feet during the drought.

The general conclusion that can be drawn from the pre- and post-drought aerial photograph comparison is that riparian vegetation tends to persist even when groundwater elevations in nearby water supply wells are 35 to 40 feet below the ground surface for a period of two years. A small percentage of phreatophytic riparian vegetation appears to die back during such drought events but later regenerates.

The relatively minor effects of groundwater declines during the 2013 to 2014 drought in northern San Benito County can be contrasted with the more pronounced effects of groundwater declines during the 1976 to 1977 drought in the Carmel Valley, a coastal basin 30 miles to the south. Groundwater elevations along a two-mile segment of the narrow alluvial valley near a cluster of large municipal wells declined only about 6 feet during summer in typical years but declined 25 to 30 feet over the two-year drought period (Kapple et al. 1984 and Kondolf and Curry 1986). This amount and duration of decline killed most of the riparian vegetation in that area, and decay of the tree roots that normally bind the river bank soils led to unprecedented amounts of bank erosion in subsequent peak flow events. Key differences between the two locations are that the Carmel Valley alluvial aquifer is only

80 to 100 feet thick with no confining layers, and the municipal wells were all within a few hundred feet of the river. Thus, drawdown was focused close to the river, and the groundwater elevations in the wells reflected the actual water table. In northern San Benito County, large irrigation and municipal wells are typically screened between 200 and 500 feet below the ground surface, and the stratigraphy in most places includes fine-grained layers that attenuate the effects of deep pumping on the water table in the shallowest aquifer. A study of shallow groundwater conditions in the San Juan Valley found groundwater elevation differences of up to 20 feet between a well 10 feet deep and a nearby well 89 feet deep, even in a wet year (Yates et al. 1999). At another location with a longer historical record, groundwater elevations in a well 130 feet deep were up to 40 feet lower than in a nearby well 78 feet deep. Also, pumping in northern San Benito County is not focused near streams and rivers to the extent that it is in Carmel Valley. The horizontal and vertical separation of the pumping stress in deep aquifers from the water table in the shallowest aquifer in San Benito riparian areas appears to have diminished the impact of pumping, allowing the vegetation to survive.

4.11.6.2. Animals

Animals that depend on groundwater include fish and other aquatic organisms that rely on groundwater-supported stream flow and amphibious or terrestrial animals that lay their eggs in water. Management of habitat for animals typically focuses on species that are listed as threatened or endangered under the state or federal Endangered Species Acts. That convention is followed here. The biological resources element of the 2010 San Benito County General Plan identifies three listed species that require aquatic habitat: California red-legged frog, California tiger salamander, and steelhead trout (EMC Planning Group, Inc. 2015). Critical habitat areas for those species are shown in **Figure 4-24** (USFWS 2005 and 2010).

Critical habitat for red-legged frog is present along the San Benito River from Bird Creek up through the Paicines Valley, along Tres Pinos Creek between Tres Pinos Creek Valley and Southside Road, and in the hills surrounding Pacheco Creek Valley as it approaches the Hollister Valley. Red-legged frogs live in sheltered backwaters of ponds, marshes, springs, streams, stock ponds and reservoirs. Deep pools with dense stands of overhanging willows and an intermixed fringe of cattails are considered optimal habitat. Aquatic habitat is required year-round (USFWS 2019a). Groundwater pumping along the reaches of the San Benito River and Tres Pinos Creek within the critical habitat area could potentially decrease the area of suitable habitat along those streams or cause those areas to be intermittently dry.

There are two areas of critical habitat for tiger salamander in the Basin: a large area adjacent to San Felipe Lake and in the hills north of the lower end of Pacheco Creek and an area north of Highway 25 and east of Fairview Road that is within the Basin but generally undeveloped for agriculture or urban land uses. Tiger salamanders require aquatic habitat only seasonally—generally from November to April. They estivate (enter a dormant state) in underground burrows during the dry summer period. During the wet winter months, they spawn and live in and near pools and ponds. They prefer seasonal ponds such as vernal pools or stock ponds that are allowed to go dry (USFWS 2019b). The seasonal character of the preferred pools indicates that they are not supported by regional groundwater discharge and therefore not affected by groundwater pumping.

Steelhead trout use creeks and rivers that cross the Basin only for passage between the ocean and spawning areas upstream of the Basin. Waterways designated as critical habitat are the San Benito River, Pajaro River, Pacheco Creek and Dos Picachos Creek (and the reach of Tequisquita Slough that connects it to San Felipe Lake and Pacheco Creek). Adult steelhead migrate upstream from the ocean to headwaters areas to spawn, and smolts (juveniles) migrate downstream to the ocean upon reaching a certain size and maturity. Creeks and rivers crossing the Basin provide continuous hydrologic connection between the ocean and spawning areas only seasonally—primarily during and following winter storm events. The reaches within the Basin are not used as year-round rearing habitat. Adult steelhead migrate upstream between December and March, peaking in January and February (Moyle 2002). Downstream migration of smolts occurs as winter base flow recedes in spring. This occurs earlier in southern California streams relative to northern California streams because of the shorter flow season. Migration in both directions requires that flow be continuous to the ocean and sufficiently high to provide adequate water depth for the fish to swim. Based on stream flow records for Pacheco Creek, flow becomes too low for smolt migration in April of normal years, May of wet years, and March or earlier in dry years.

The potential impact of groundwater pumping on steelhead migration is to slightly shorten the duration of windows of opportunity for migration. At the beginning of the winter flow season, percolation losses are relatively high as groundwater elevations recover. However, early-season flows are typically flashy in response to storm events, with flows that greatly exceed percolation rates. In spring, base flow recedes more gradually and usually drops below minimum migration flows before irrigation pumping ramps up for the dry season. If there is overlap between the flow season and irrigation season, flow depletion could shorten the smolt passage window. For example, if the minimum passage flow for smolt migration along Pacheco Creek were 25 cfs measured at the gauge near Dunneville, then based on typical flow recession rates, a hypothetical 3 cfs of pumping depletion would shorten the migration window by 1 to 2 days.

Additional analysis of potential groundwater pumping impacts on vegetation and animals is included in Chapter 6, Sustainability Criteria.

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FIGURES

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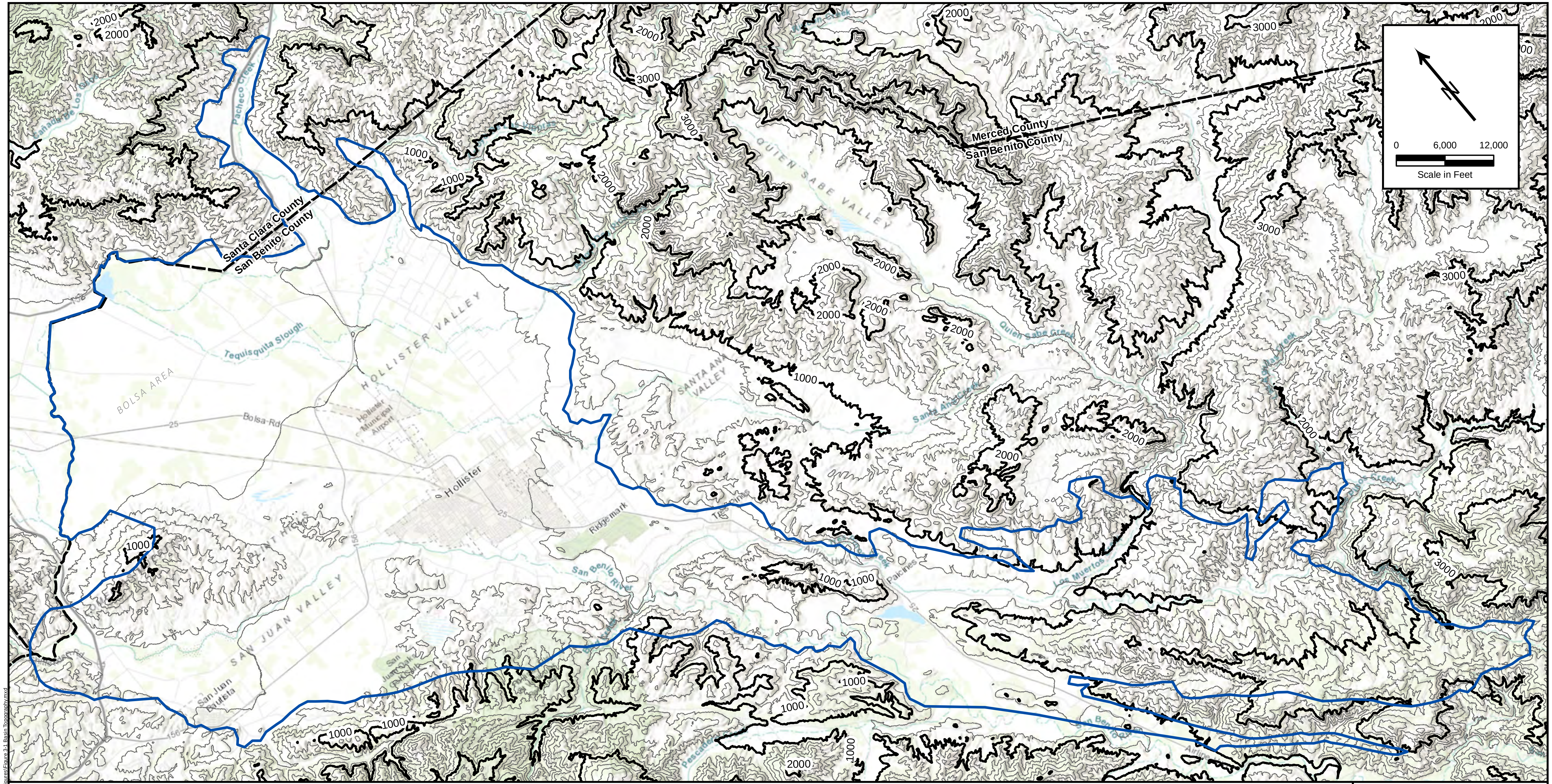

Topographic Contour, Bold on 1000 foot interval

North San Benito Basin

San Benito County

April 2019

TODD GROUNDWATER

Figure 3-1
Basin Topography

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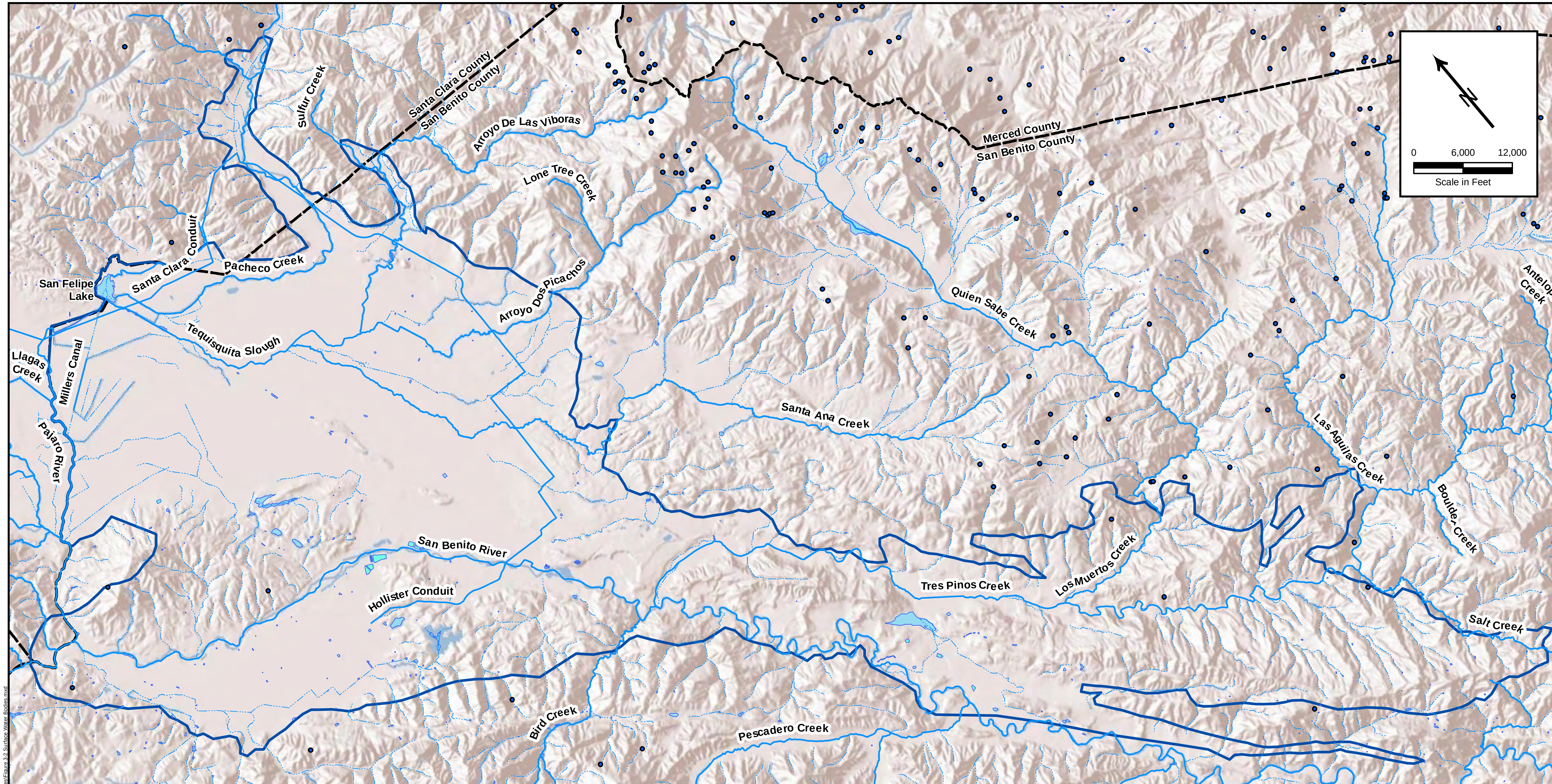

- Spring or Seep
- Major Streams
- Minor Streams
- Lake or Pond
- Reservoir
- North San Benito Basin
- San Benito County

April 2019

TODD GROUNDWATER

Figure 3-2
Surface Water Bodies Tributary To Basin

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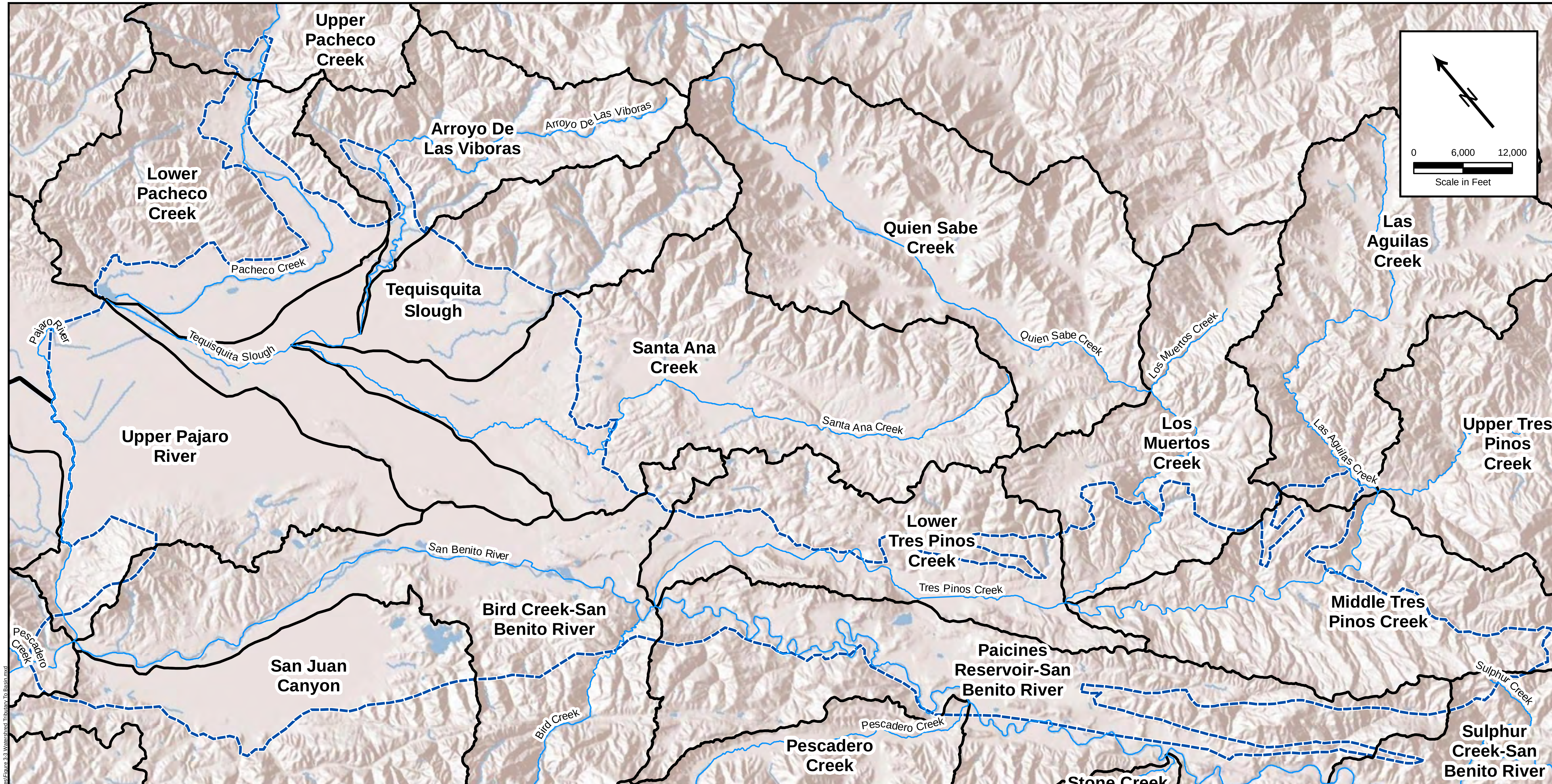


Major Stream

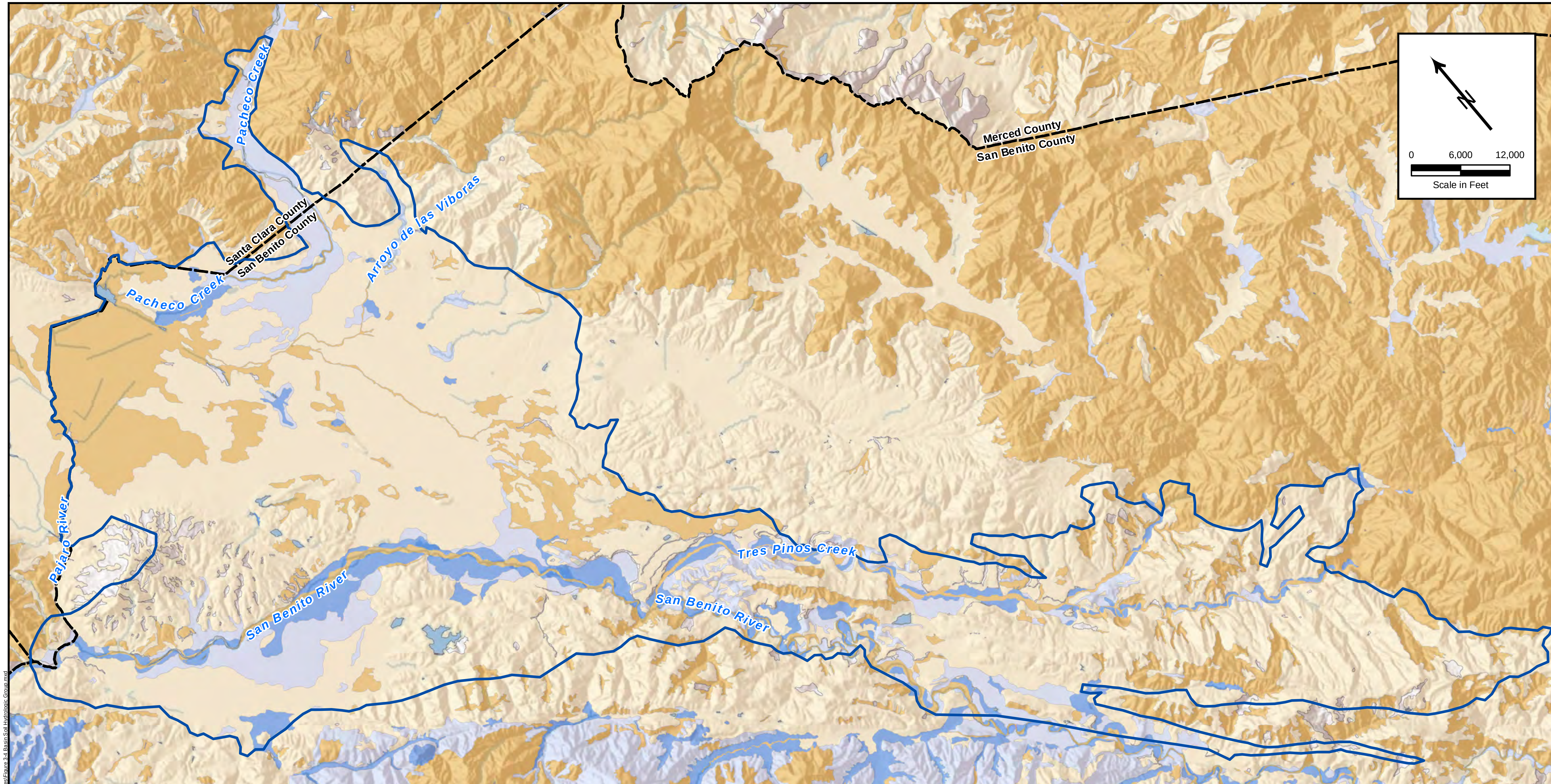
Tributary Watershed Boundaries

North San Benito Basin

April 2019

TODD GROUNDWATER

Figure 3-3
Watersheds Tributary to Basin



Soil Hydrologic Group

- A: High Infiltration Rate
- B: Moderate Infiltration Rate
- C: Slow Infiltration Rate
- D: Very Slow Infiltration Rate
- No Data

- North San Benito Basin
- San Benito County

April 2019

TODD GROUNDWATER

Figure 3-4
Basin Soil
Hydrologic Properties

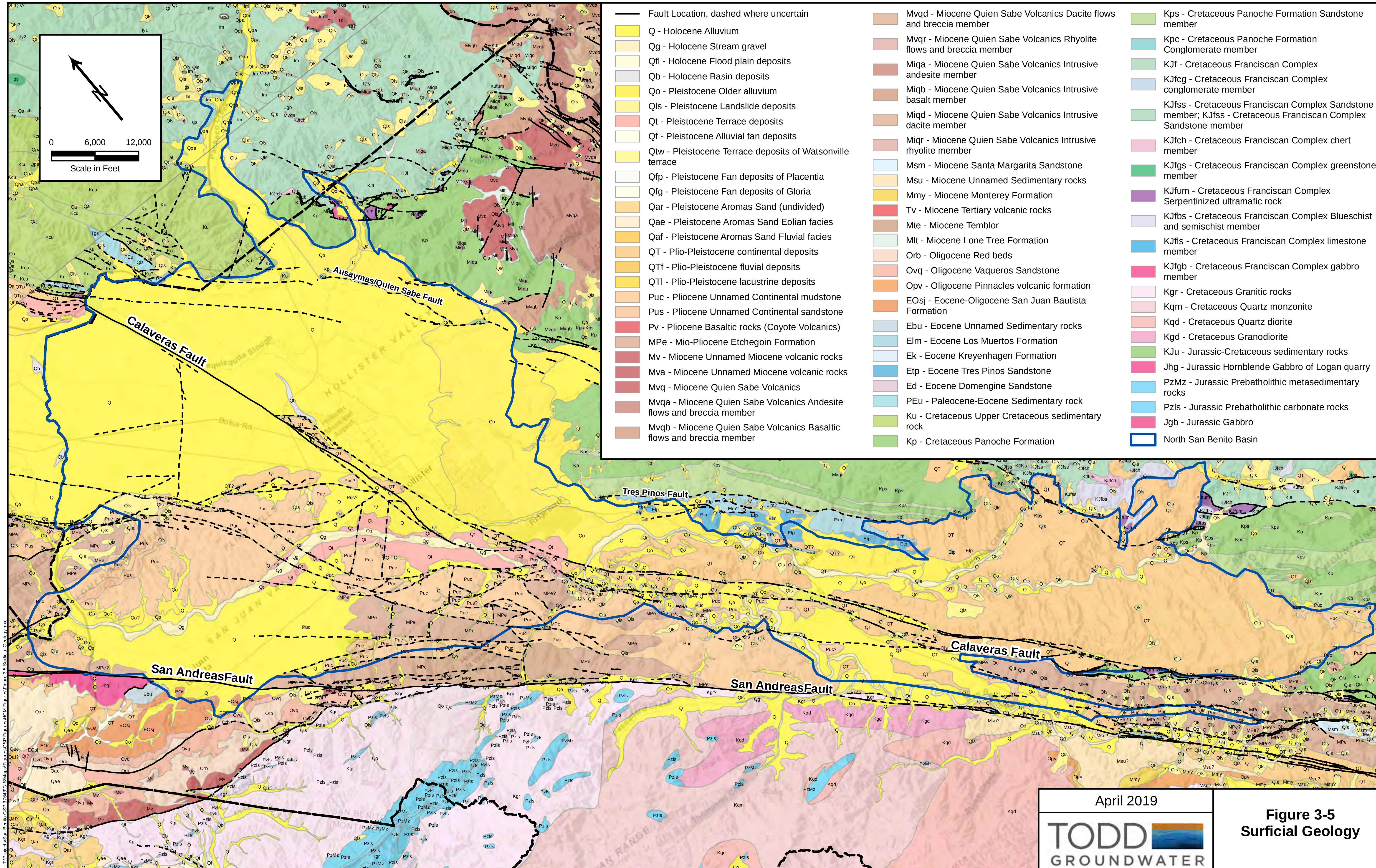
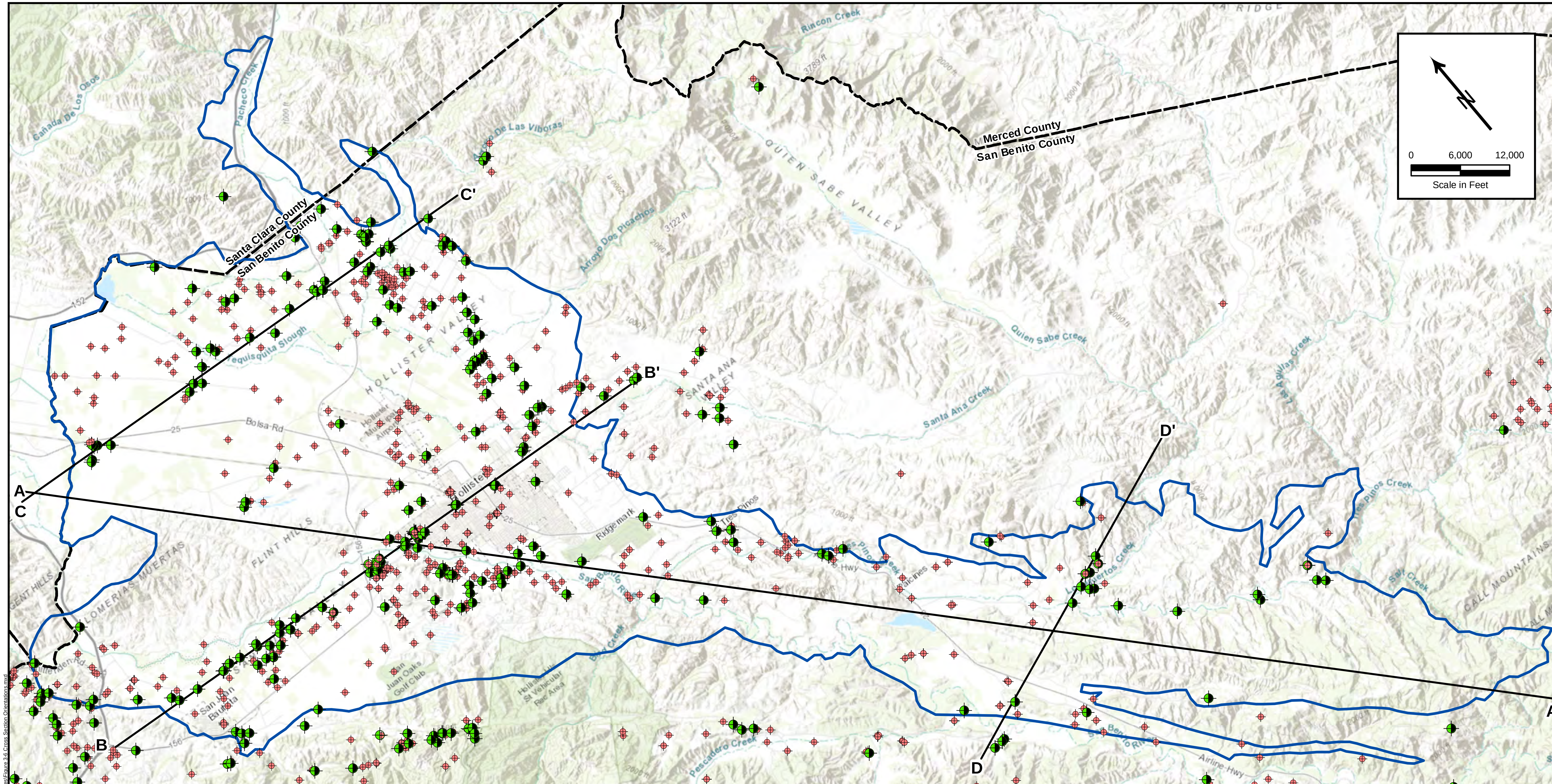


Figure 3-5
Surficial Geology

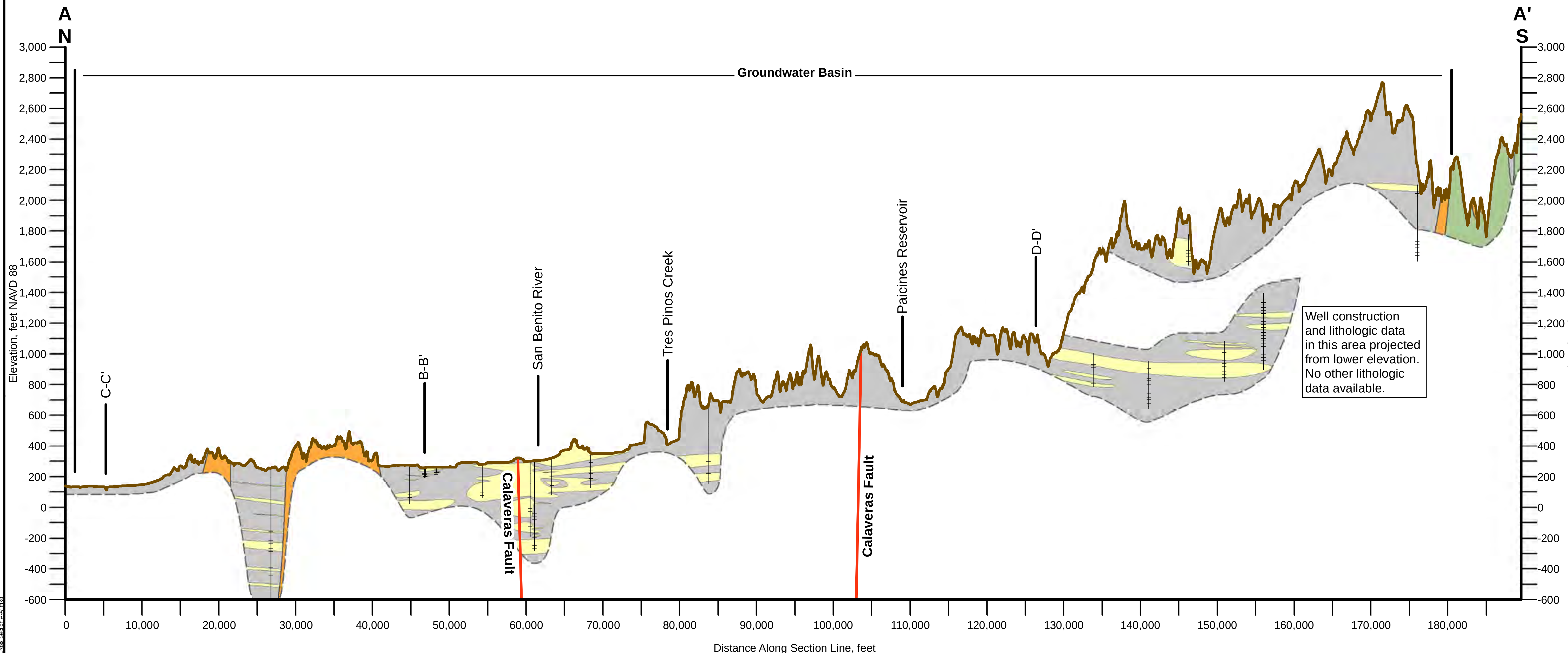


- Well with Digitized Lithology and Construction Information
- Well with Digitized Lithology Information
- Well without Digitized Information
- Cross Section Line Orientation
- North San Benito Basin
- San Benito County

April 2019

TODD GROUNDWATER

Figure 3-6
Cross Section
Line Orientations



Well Screen
Total Drilled Borehole Depth
Fault
Sand and Gravel
Silt and Clay
Puc - Unnamed Pliocene continental mudstone
Ebu - Unnamed Eocene sedimentary rocks
Kp - Panoche Formation
Kgr - Granitic rocks
KJf - Franciscan Complex
Kgd - Granodiorite
Jhg - Hornblende Gabbro of Logan quarry
Undifferentiated Bedrock
No Information

Notes:
Cross section only extended to depth of available information.

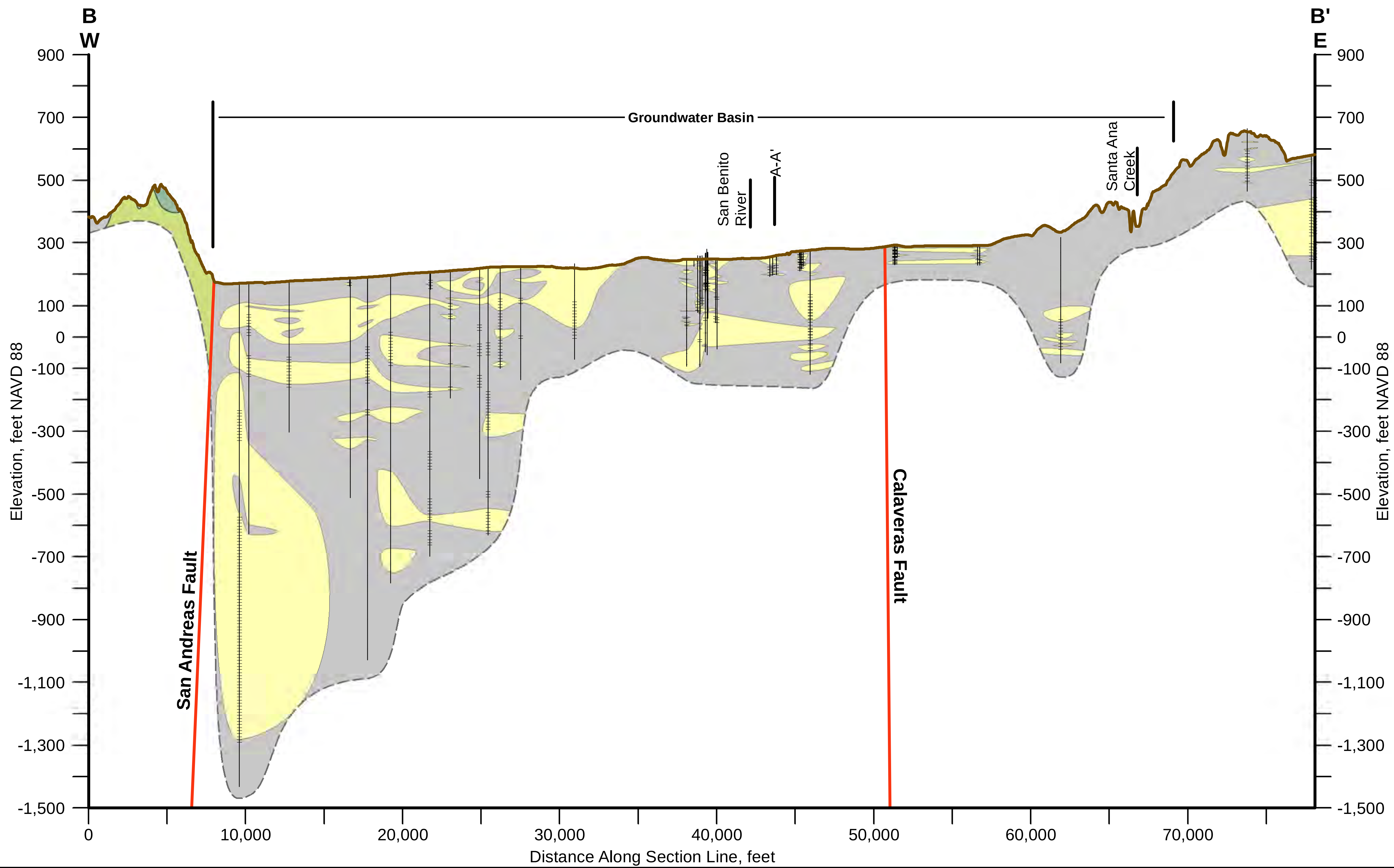
NAVD 88: North American Vertical Datum of 1988.

0 6,500 13,000
Scale in Feet
20 x Vertical Exaggeration

April 2019

TODD GROUNDWATER

Figure 3-7
Cross Section A to A'



Well Screen
Total Drilled Borehole Depth
Fault
Sand and Gravel
Silt and Clay
Puc - Unnamed Pliocene continental mudstone
Ebu - Unnamed Eocene sedimentary rocks
Kp - Panoche Formation
Kgr - Granitic rocks
KJf - Franciscan Complex
Kgd - Granodiorite
Jhg - Hornblende Gabbro of Logan quarry
Undifferentiated Bedrock
No Information

Notes:
Cross section only extended to depth of available information.

NAVD 88: North American Vertical Datum of 1988.

0 3,500 7,000

Scale in Feet

20 x Vertical Exaggeration

April 2019

TODD GROUNDWATER

Figure 3-8
Cross Section B to B'

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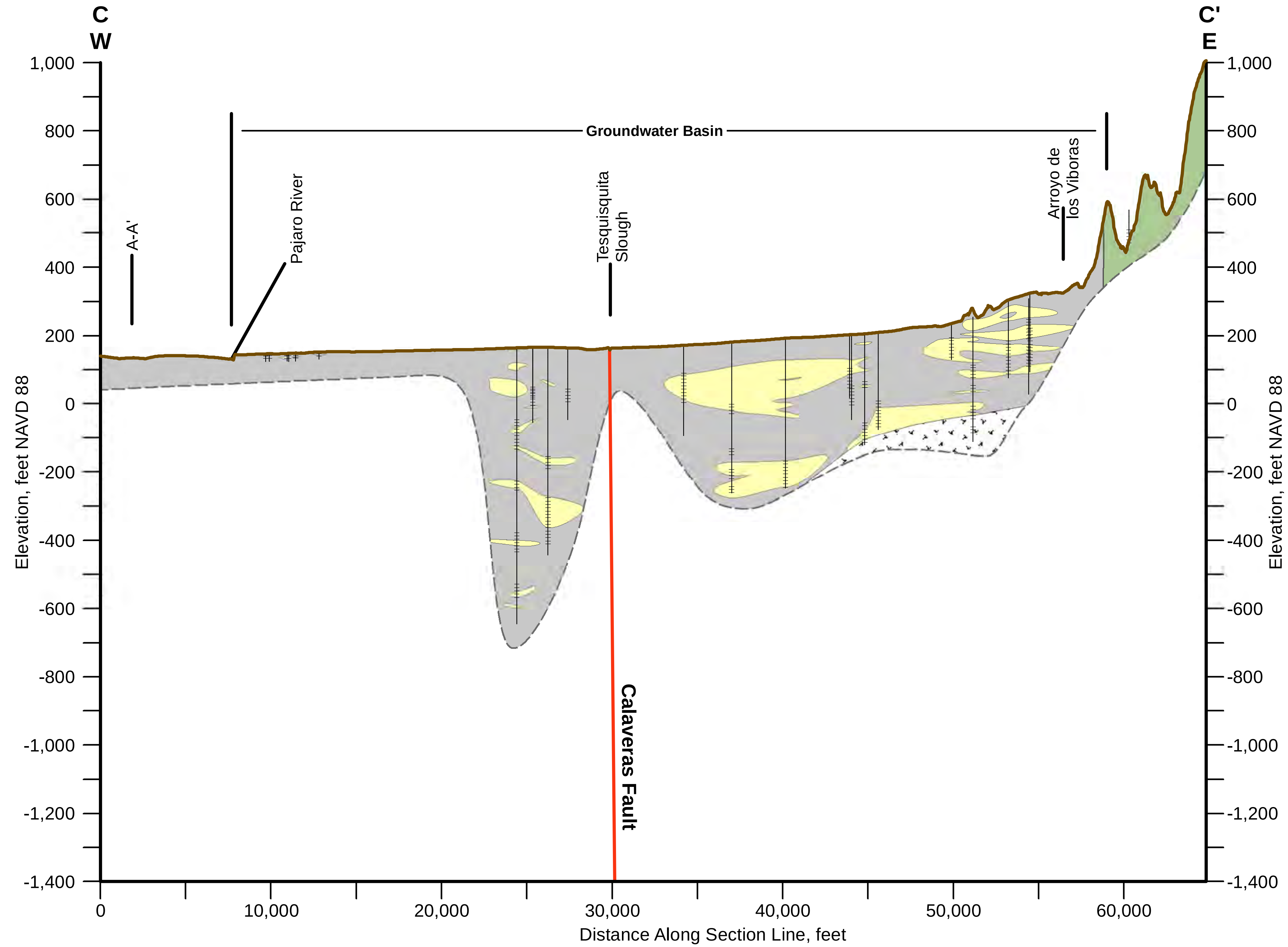

- Well Screen
- Total Drilled Borehole Depth
- Fault
- Sand and Gravel
- Silt and Clay
- Puc - Unnamed Pliocene continental mudstone
- Ebu - Unnamed Eocene sedimentary rocks
- Kp - Panoche Formation
- Kgr - Granitic rocks
- KJf - Franciscan Complex
- Kgd - Granodiorite
- Jhg - Hornblende Gabbro of Logan quarry
- Undifferentiated Bedrock
- No Information

Notes:
Cross section only extended to depth of available information.

NAVD 88: North American Vertical Datum of 1988.

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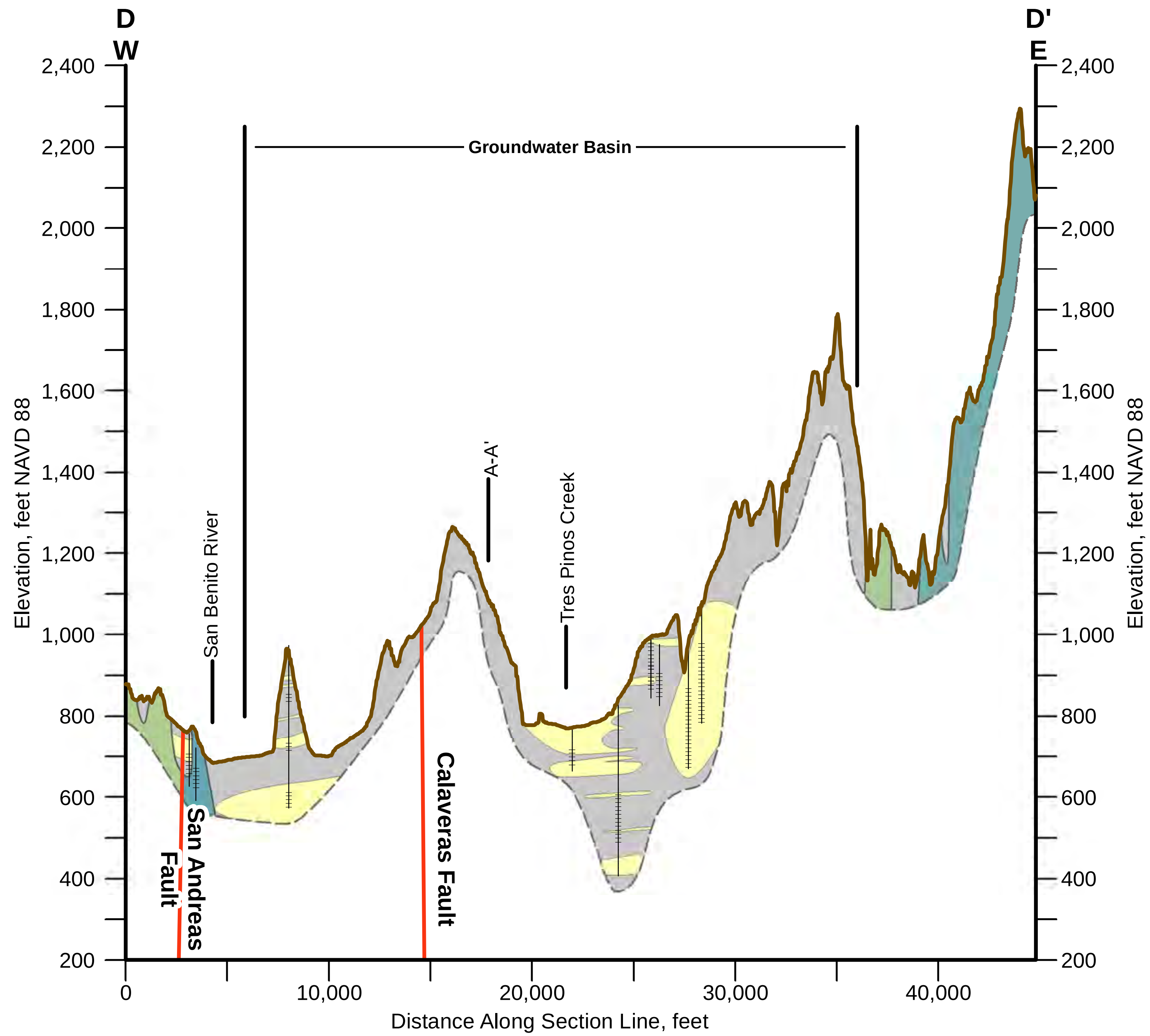
Scale in Feet
20 x Vertical Exaggeration

April 2019

TODD GROUNDWATER

Figure 3-9
Cross Section C to C'



- Well Screen
- Total Drilled Borehole Depth
- Fault
- Sand and Gravel
- Silt and Clay
- Puc - Unnamed Pliocene continental mudstone
- Ebu - Unnamed Eocene sedimentary rocks
- Kp - Panoche Formation
- Kgr - Granitic rocks
- KJf - Franciscan Complex
- Kgd - Granodiorite
- Jhg - Hornblende Gabbro of Logan quarry
- Undifferentiated Bedrock
- No Information

Notes:
Cross section only extended to depth of available information.

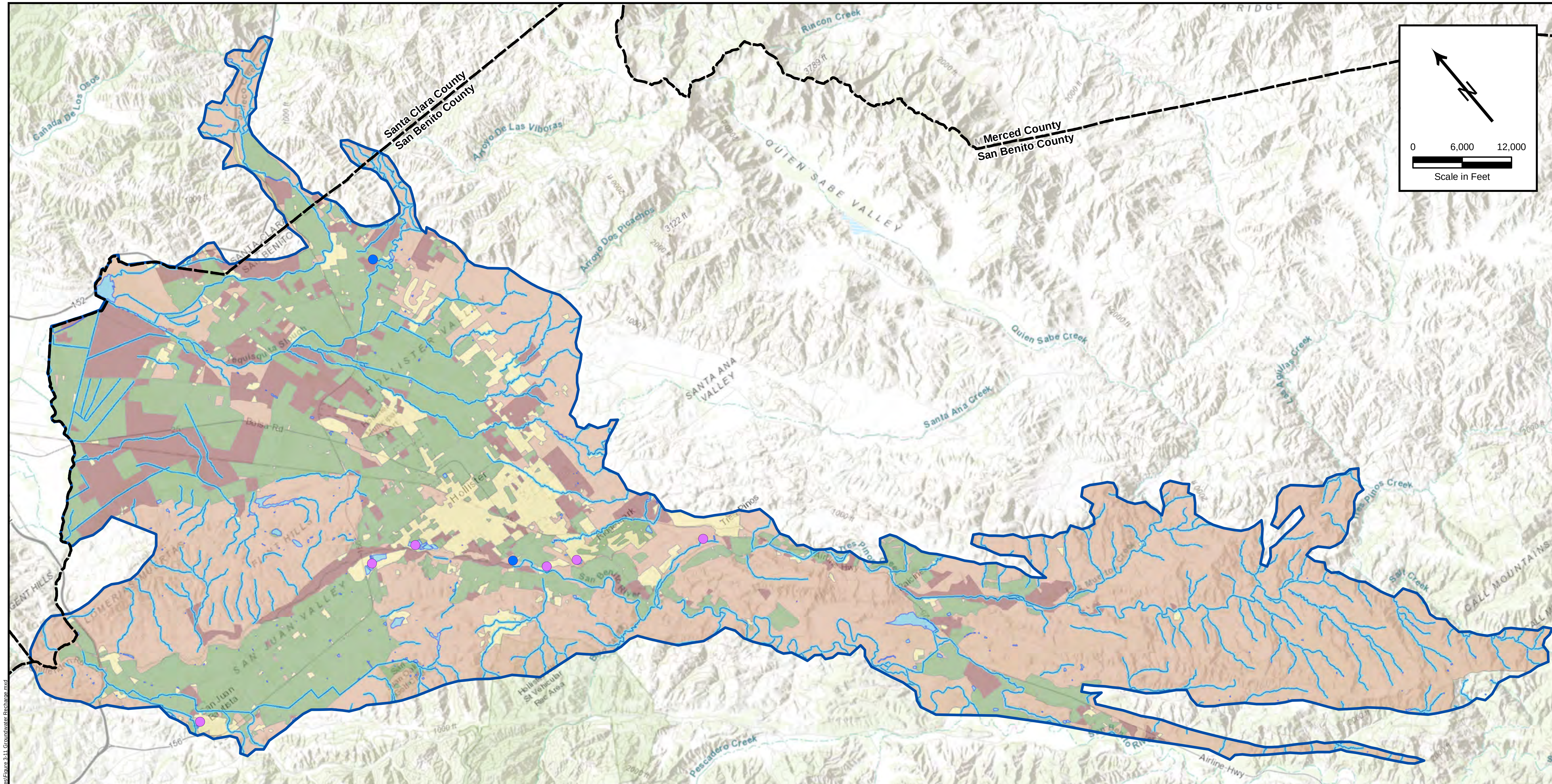
NAVD 88: North American Vertical Datum of 1988.

0 3,500 7,000
Scale in Feet
20 x Vertical Exaggeration

April 2019

TODD GROUNDWATER

Figure 3-10
Cross Section D to D'



Recharge Ponds

Wastewater Treatment Plant Recharge

Connectors, Ditches, and Streams

Irrigated Agricultural Recharge

Urban Recharge

Non-Irrigated Natural Vegetation Recharge

Other Non-Irrigated Land Recharge

Surface Water Bodies

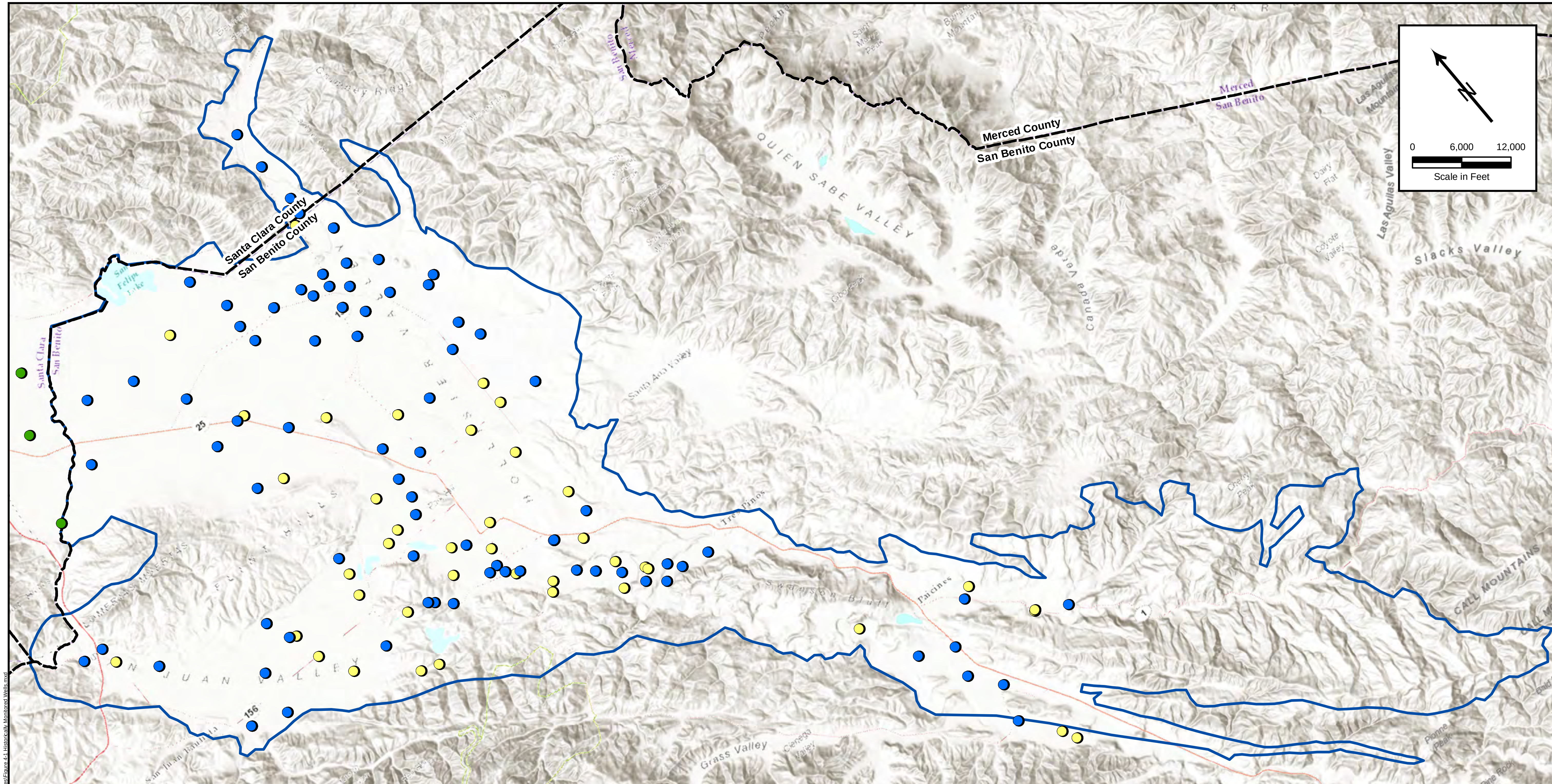
North San Benito Basin

San Benito County

April 2019

TODD GROUNDWATER

Figure 3-11
Groundwater Recharge and Discharge



SBCWD Monitored Wells, October 2017

SCVWD Monitored Wells, October 2017

Well Monitored in Prior Years and not October 2017

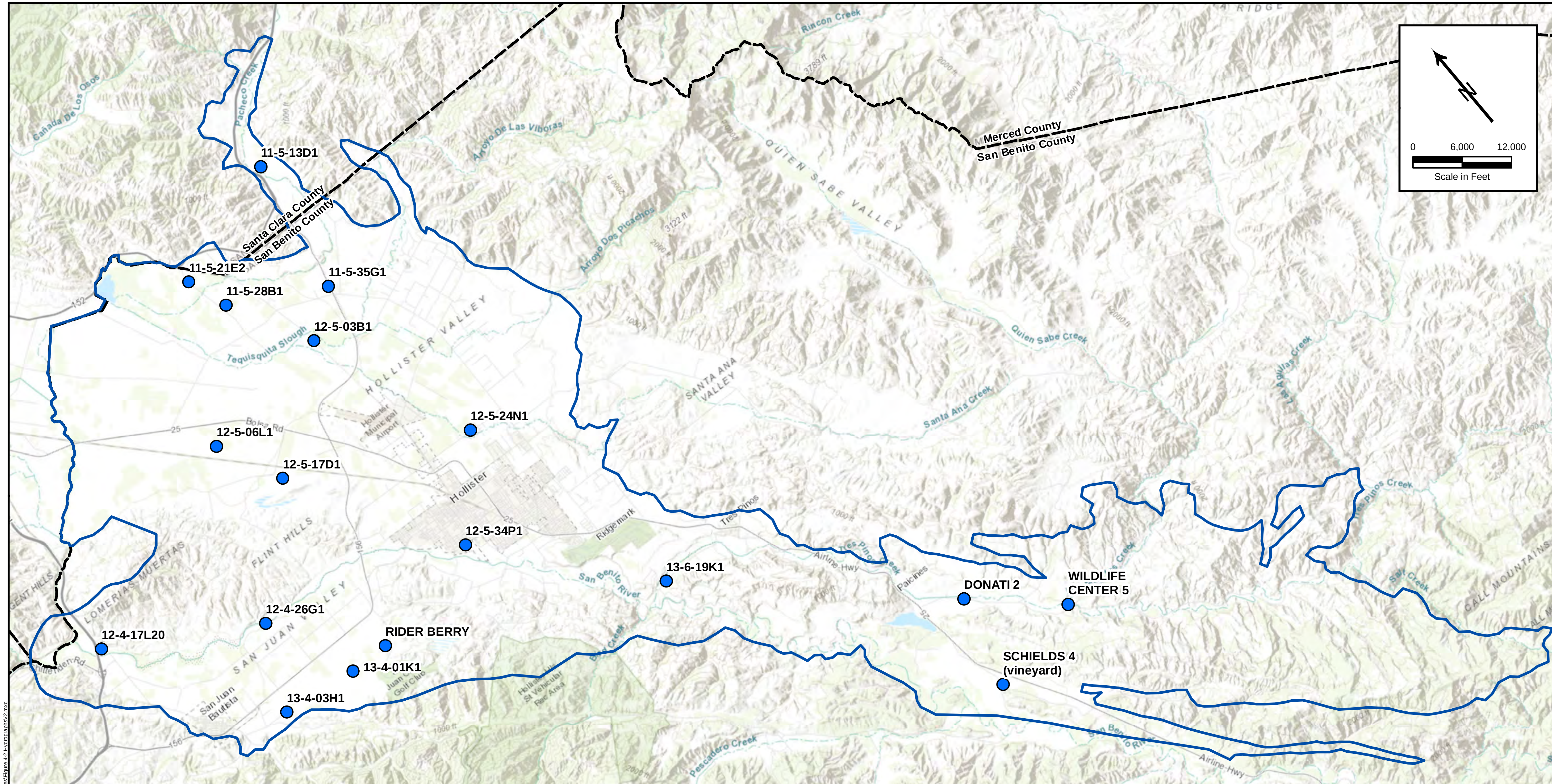
North San Benito Basin

San Benito County

April 2019

TODD GROUNDWATER

Figure 4-1
Historically Monitored Wells



Well with Representative Hydrograph

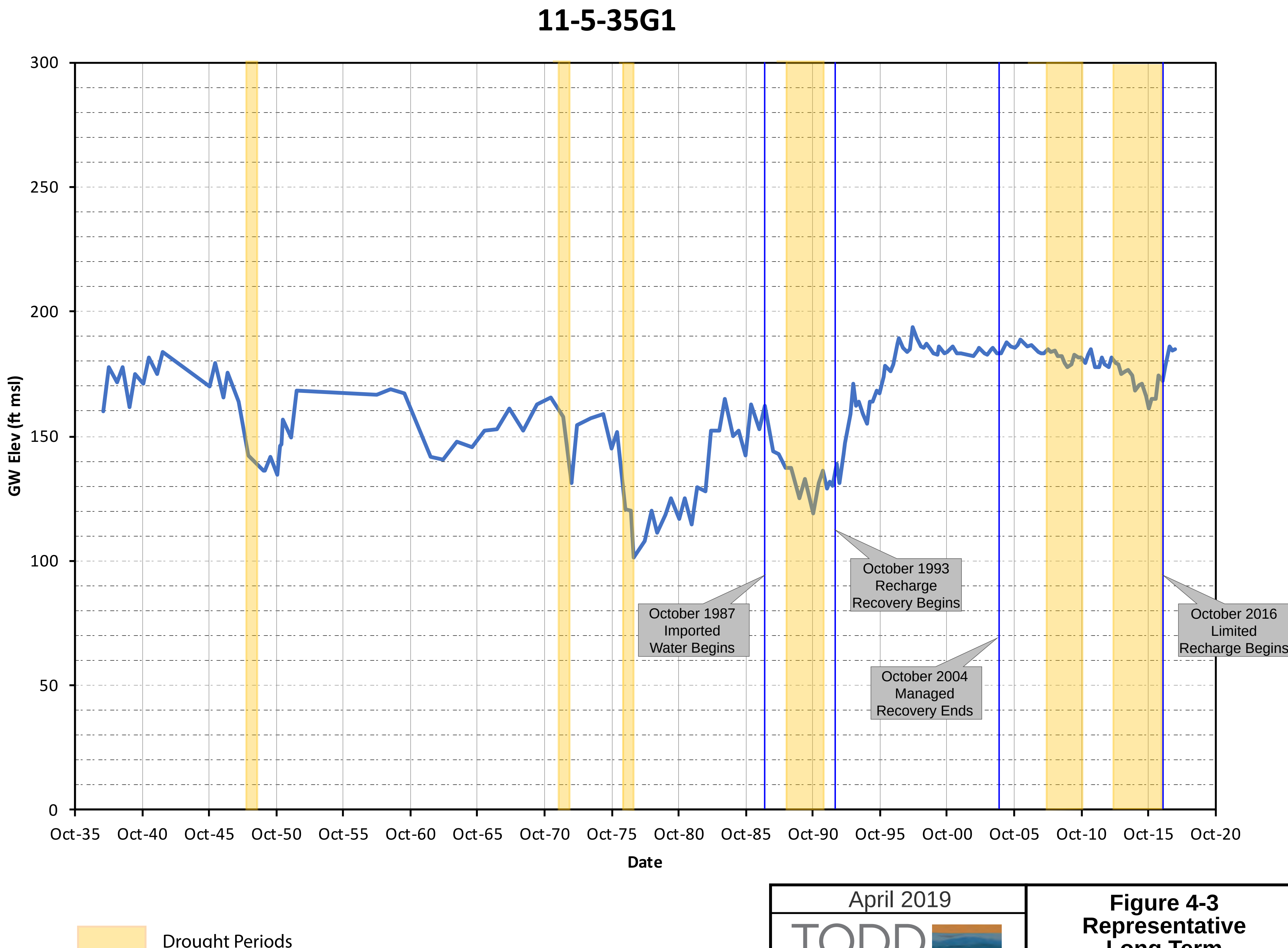
North San Benito Basin

San Benito County

April 2019

TODD GROUNDWATER

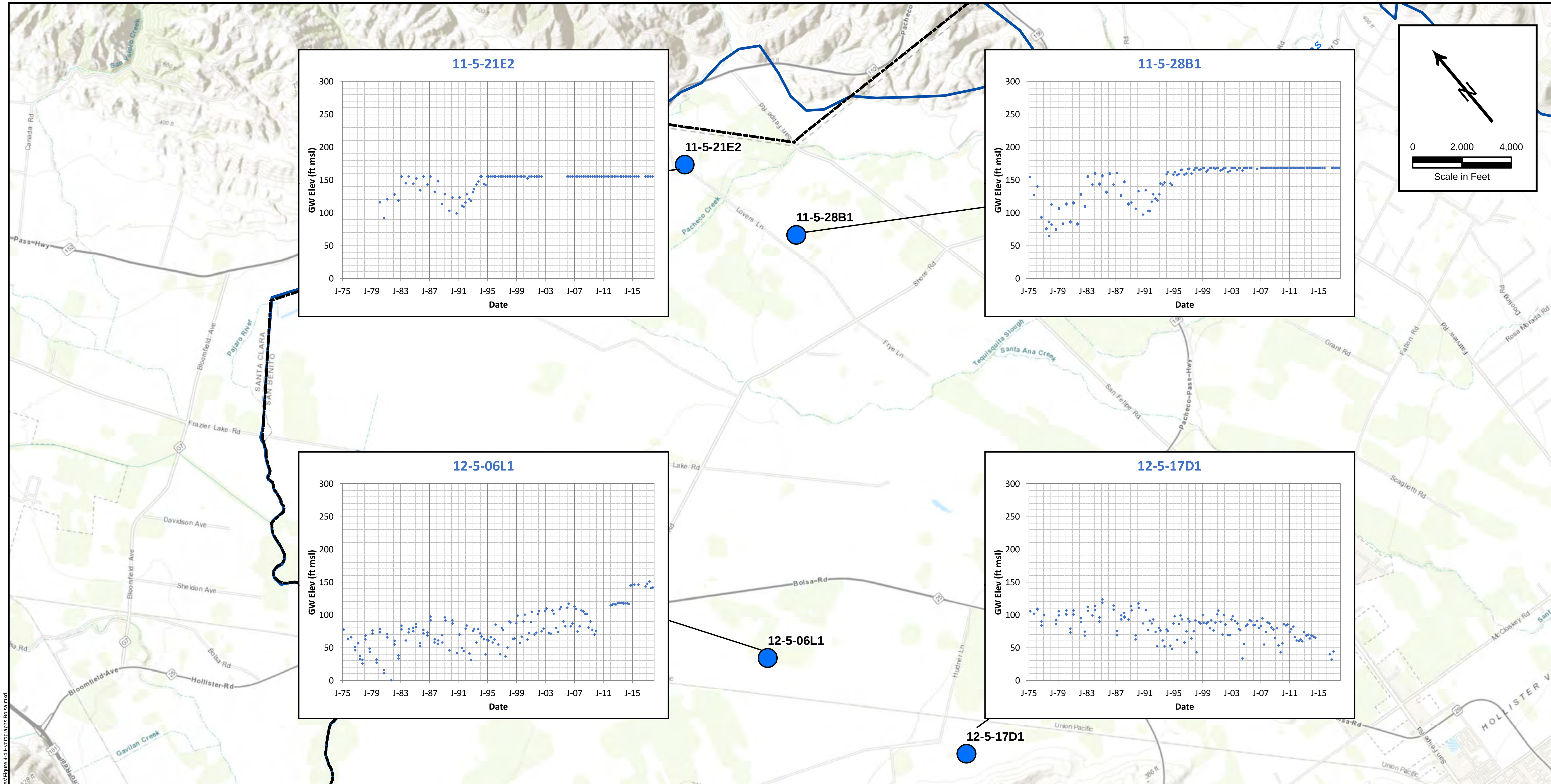
Figure 4-2
Location of Wells with Representative Hydrographs



April 2019

TODD GROUNDWATER

Figure 4-3
Representative Long Term Groundwater Elevations

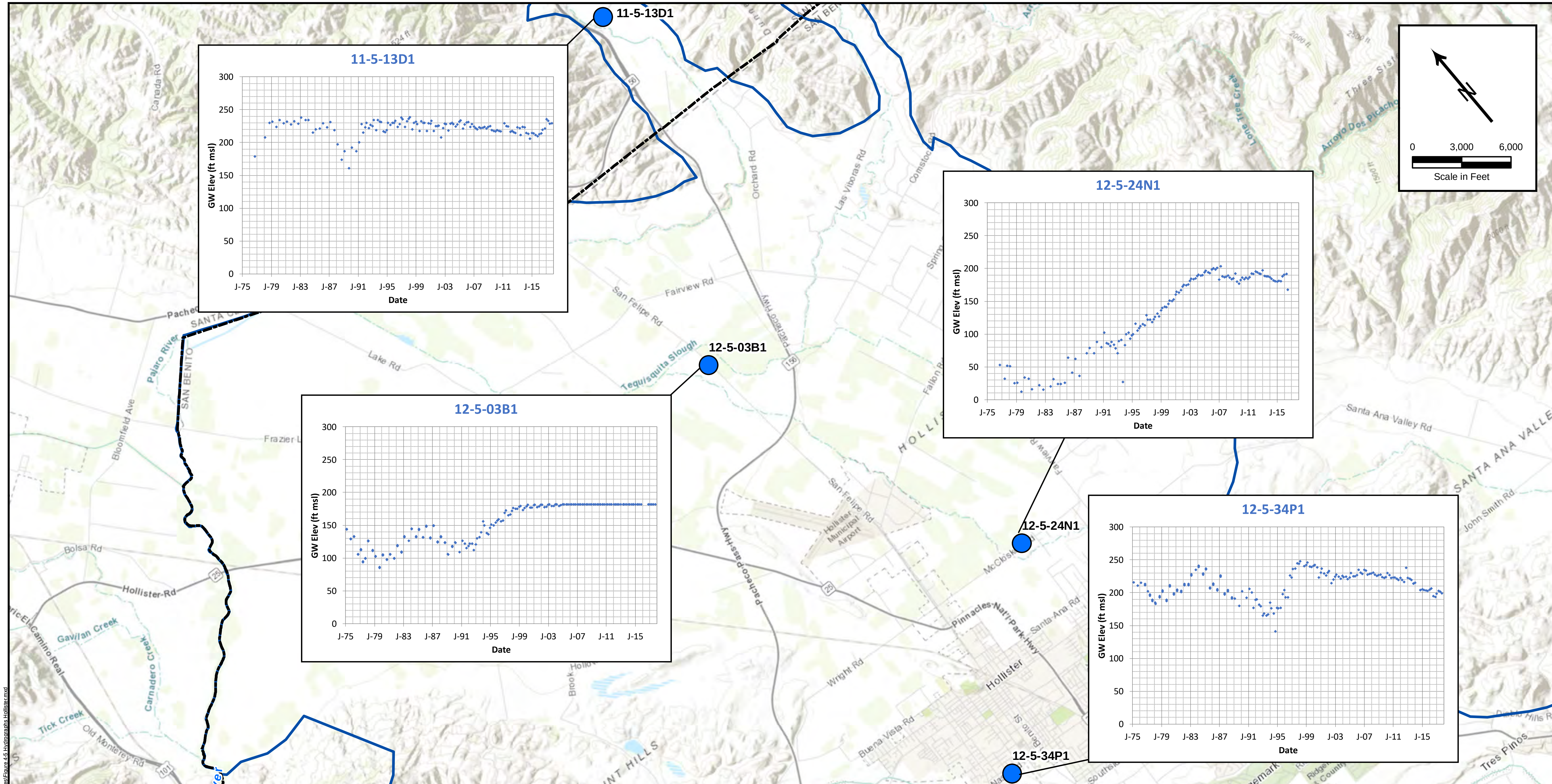


- Well with Representative Hydrograph
- San Benito County
- North San Benito Basin

April 2019

TODD GROUNDWATER

Figure 4-4
Representative Hydrographs
Bolsa Area



Well with Representative Hydrograph

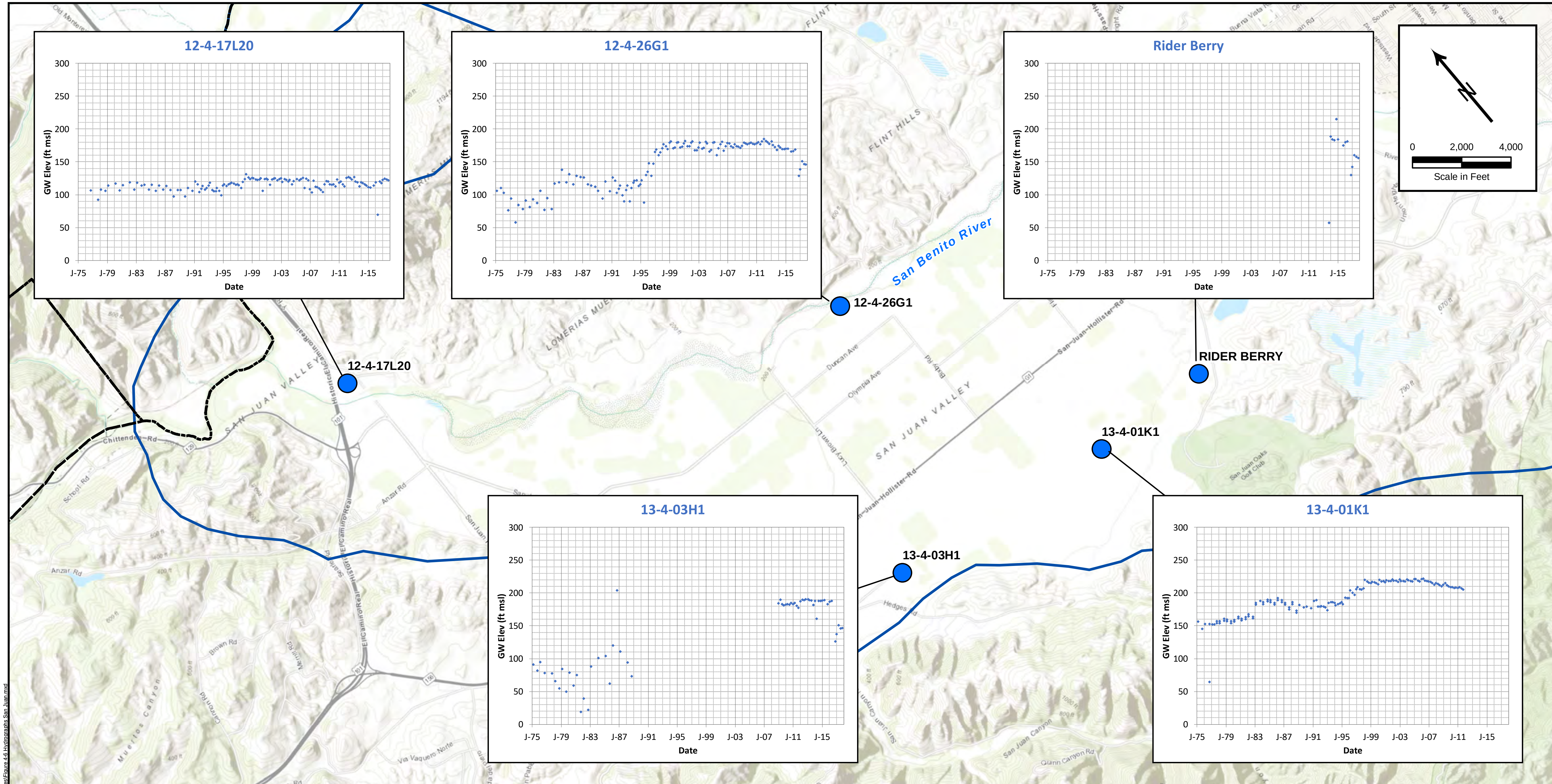
San Benito County

North San Benito Basin

April 2019

TODD GROUNDWATER

Figure 4-5
Representative Hydrographs
Hollister Valley



Well with Representative Hydrograph

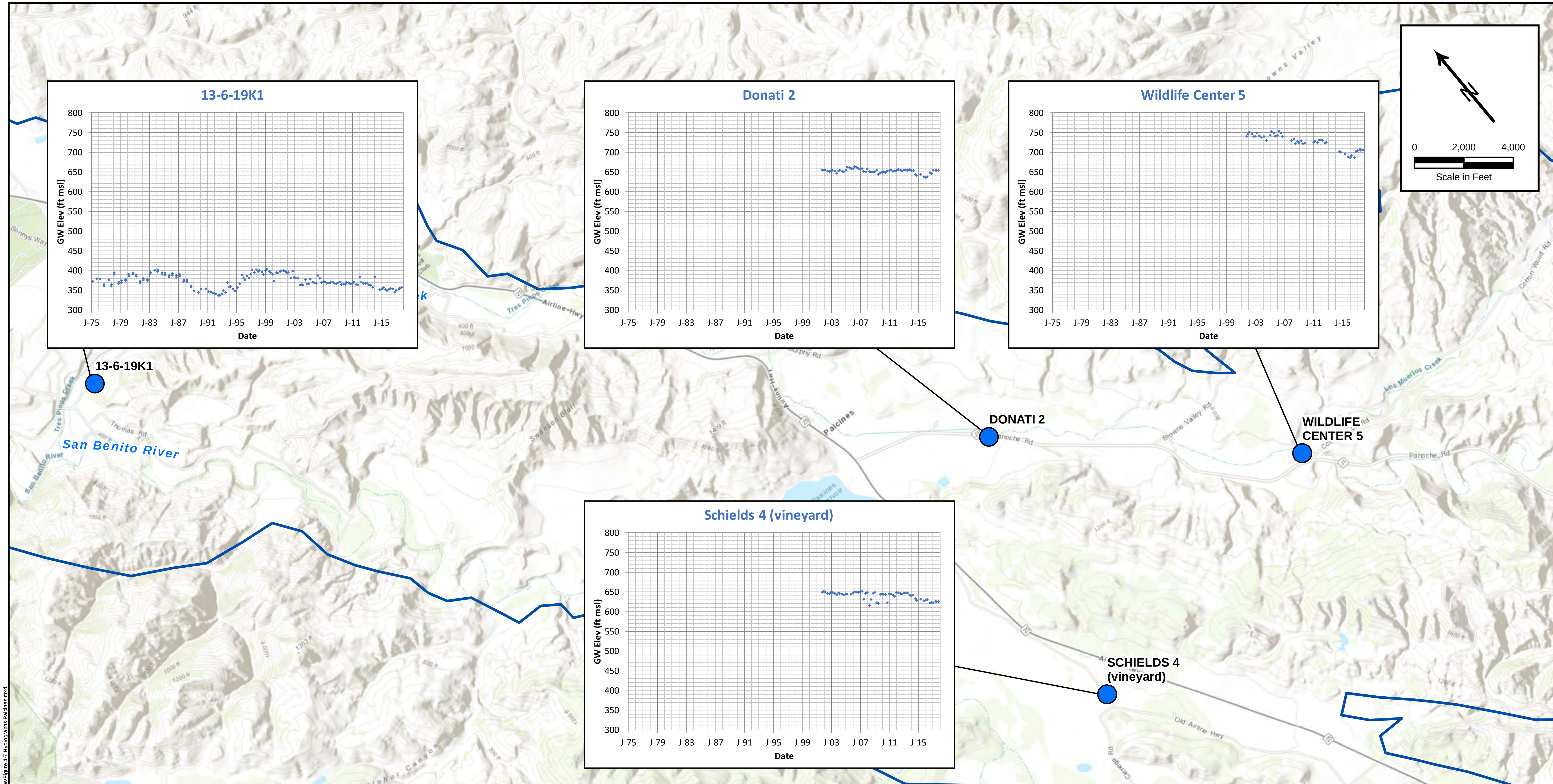
San Benito County

North San Benito Basin

April 2019

TODD GROUNDWATER

Figure 4-6
Representative Hydrographs
San Juan Valley



Well with Representative Hydrograph

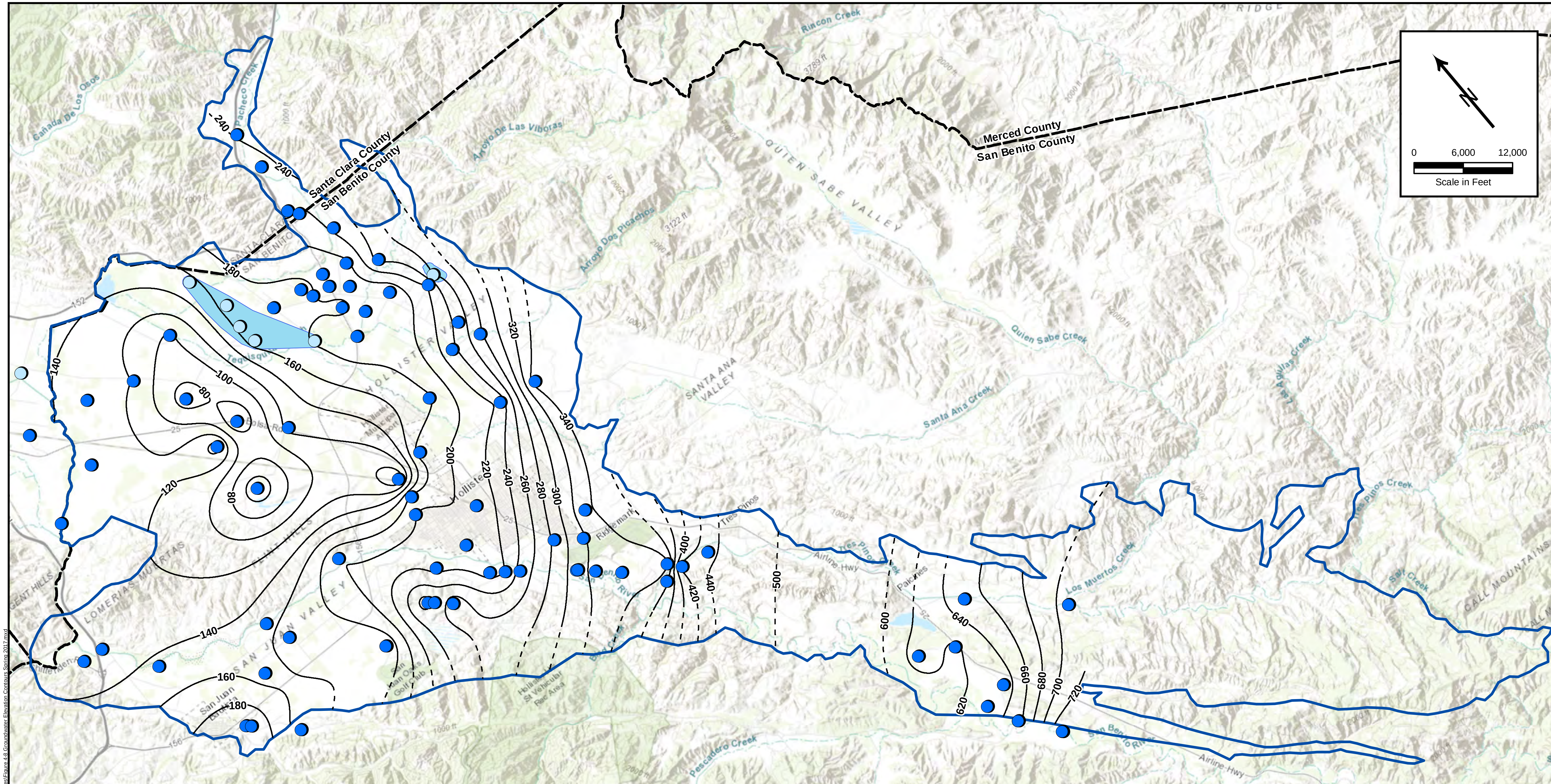
San Benito County

North San Benito Basin

April 2019

TODD GROUNDWATER

Figure 4-7
Representative Hydrographs
Paicines Area



Flowing Artesian Well, Spring 2017

Monitored Well, Spring 2017

20-foot groundwater elevation contour, feet above msl

20-foot groundwater elevation contour, dashed where uncertain due to insufficient data

Approximate Areas of Flowing Wells

North San Benito Basin

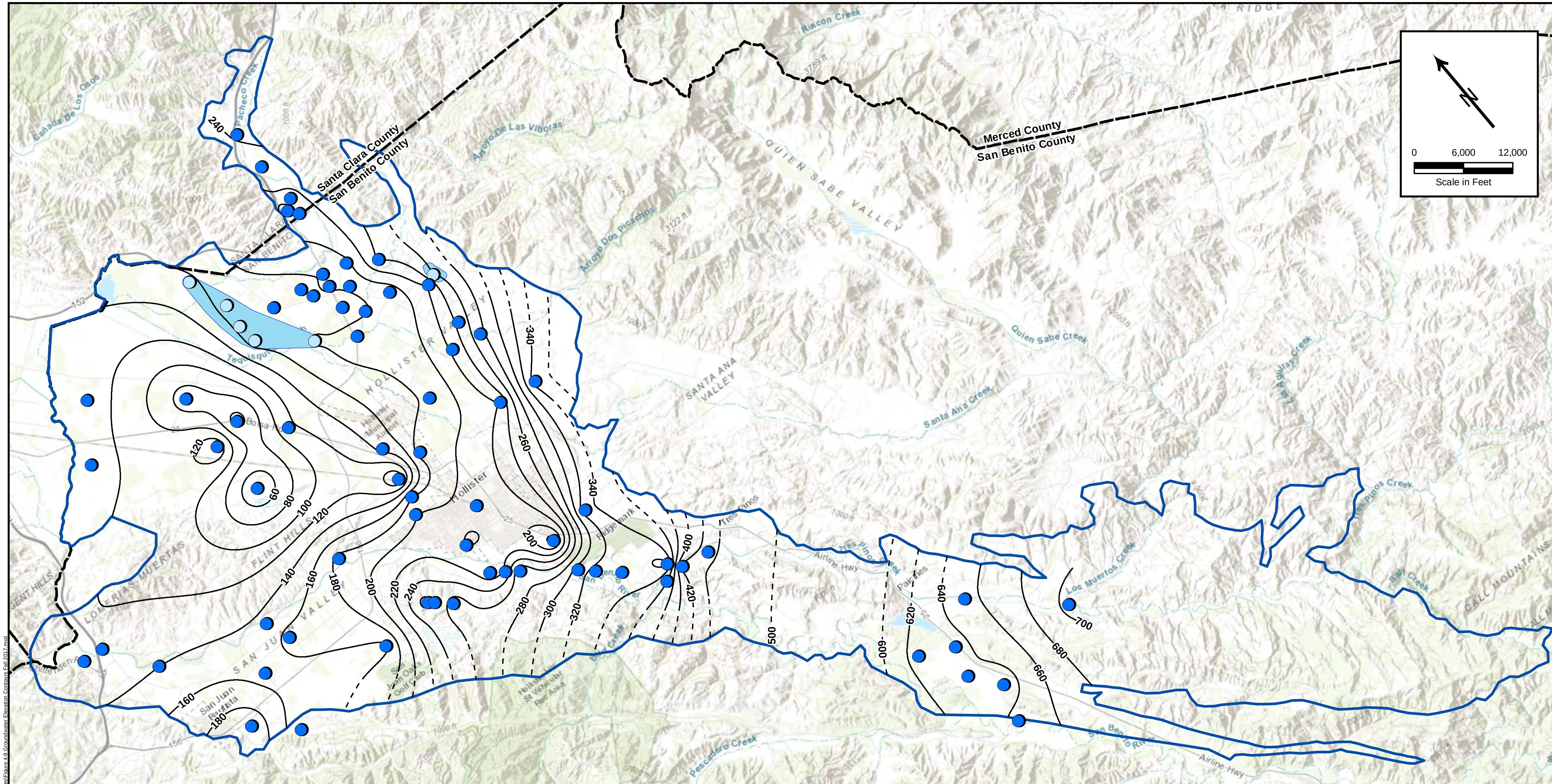
San Benito County

Note:
Groundwater elevation contours not estimated in areas of the basin with no groundwater monitoring data

April 2019

TODD GROUNDWATER

Figure 4-8
Groundwater Elevation Contours, Spring 2017



- Monitored Well, Fall 2017
- Flowing Artesian Well, Fall 2017
- 20-foot groundwater elevation contour, feet above msl
- 20-foot groundwater elevation contour, dashed where uncertain due to insufficient data
- Approximate Areas of Flowing Wells
- North San Benito Basin
- San Benito County

Note:
Groundwater elevation contours not estimated in areas of the basin with no groundwater monitoring data

April 2019

TODD GROUNDWATER

Figure 4-9
Groundwater Elevation Contours, Fall 2017

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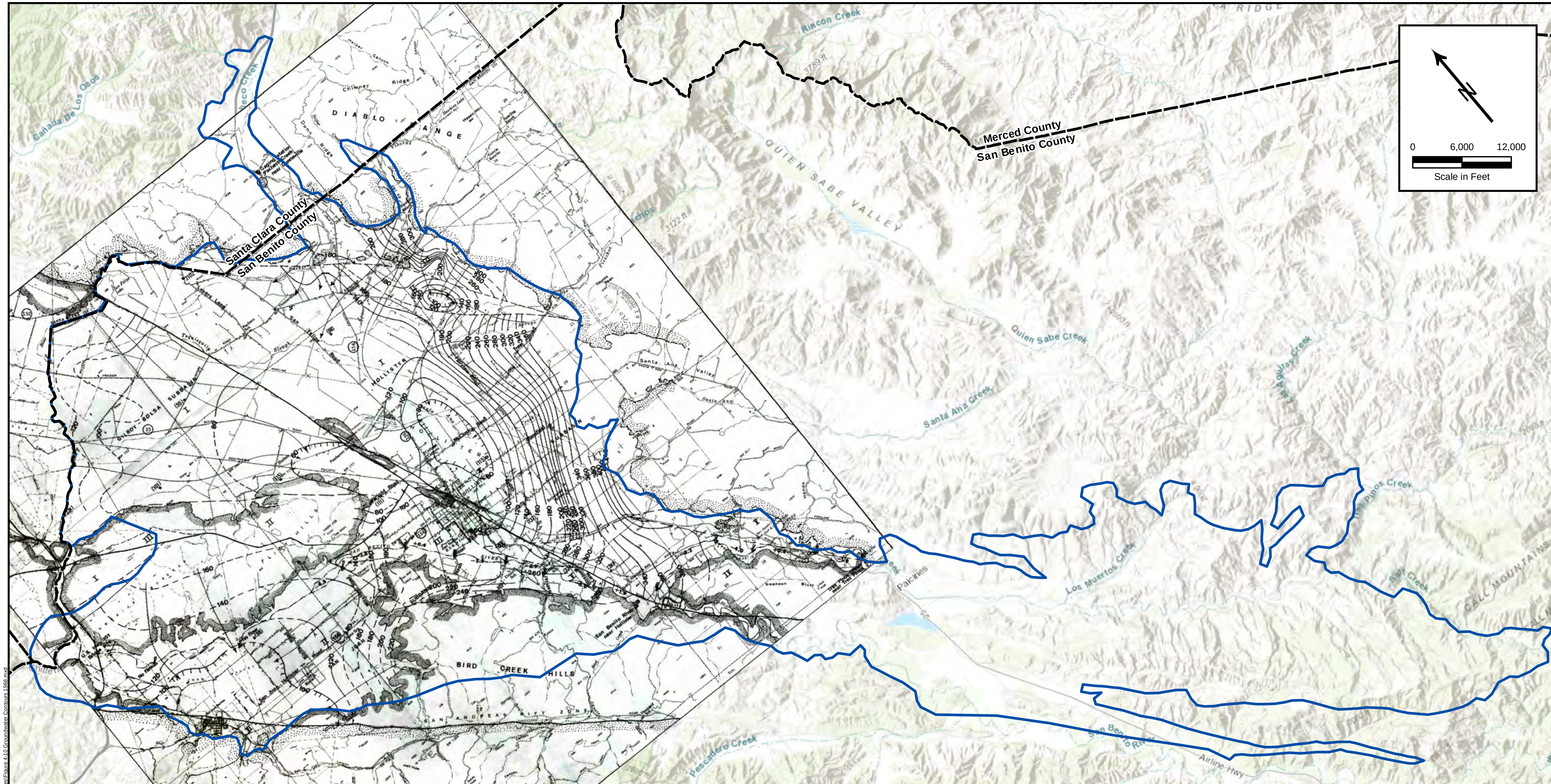


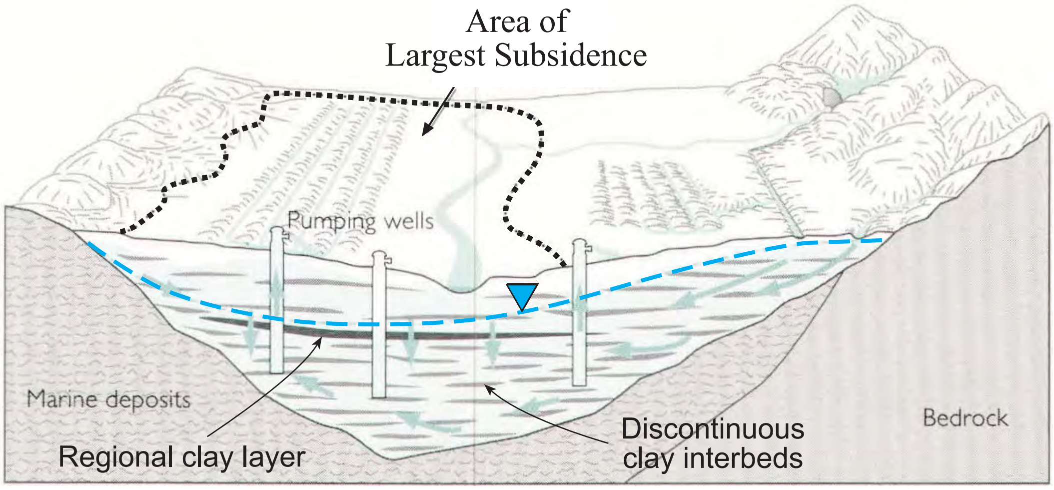
North San Benito Basin

San Benito County

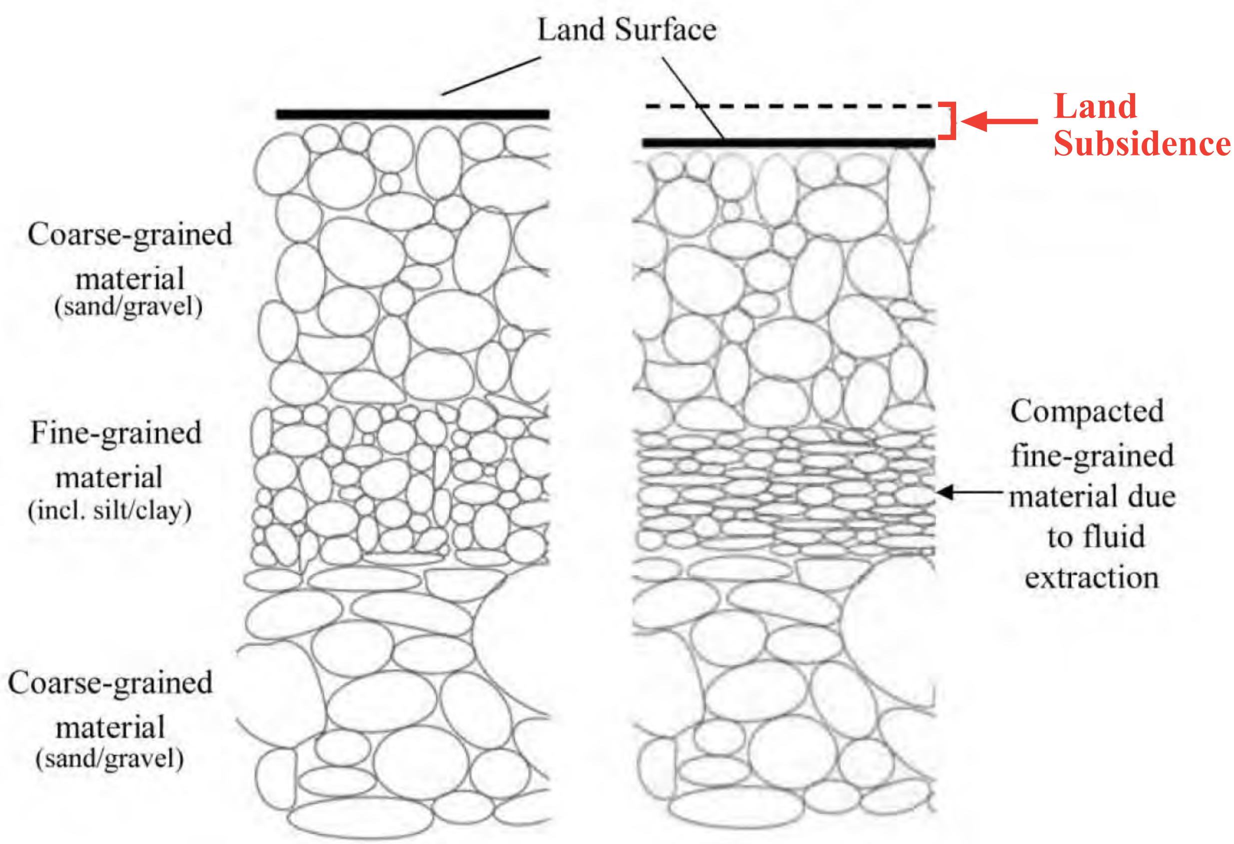
Groundwater elevation contours after Kilburn, 1973, Plate 6

April 2019

Figure 4-10
Groundwater Elevation Contours, 1968



Source: Galloway et al., 1999.

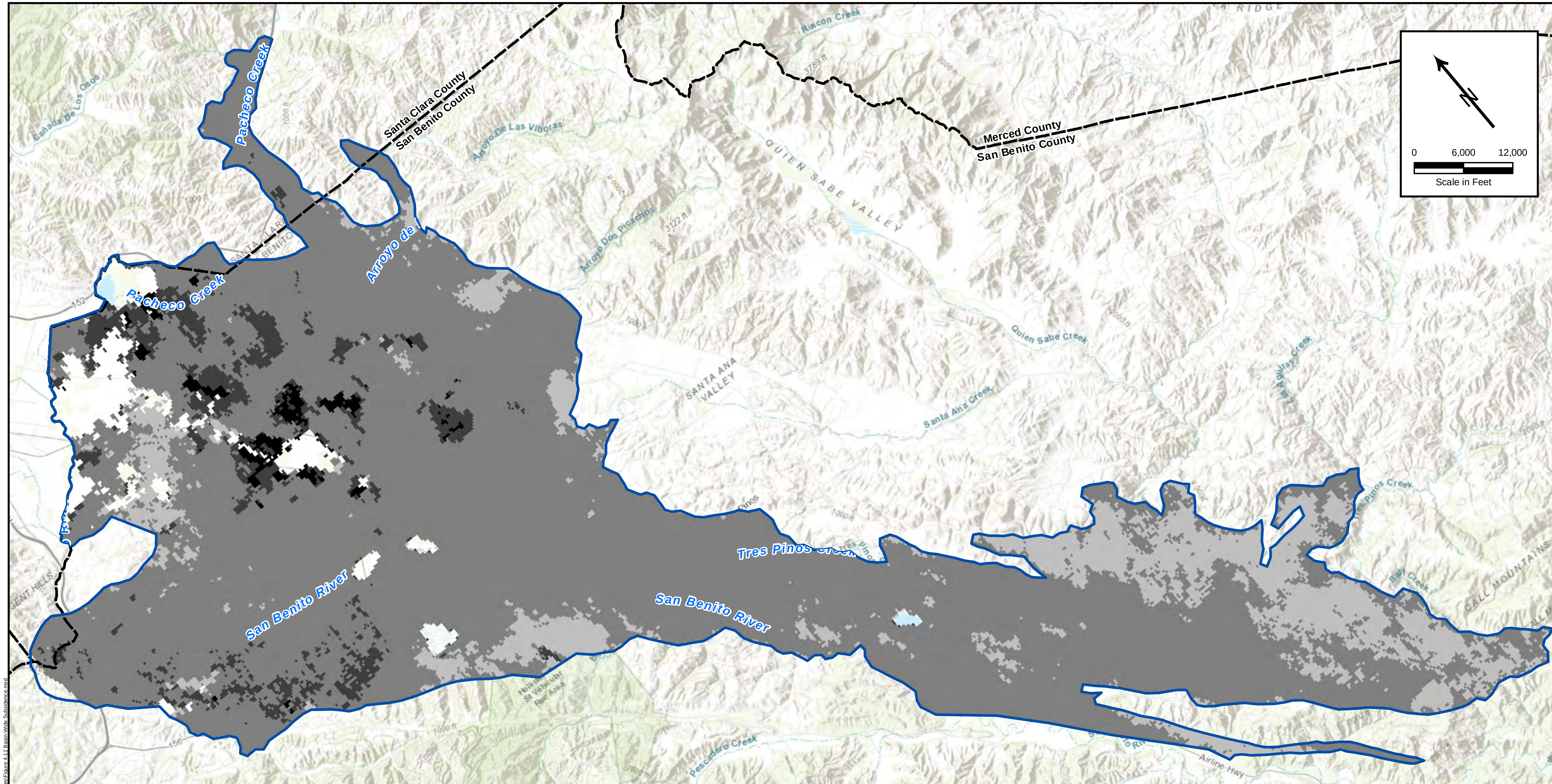


After LSCE et al., 2014.

April 2019

TODD GROUNDWATER

Figure 4-11
Concepts of
Land Subsidence



Vertical Displacement (inches)

- -6 to -4 inches
- -4 to -2 inches
- -2 to 0 inches
- 0 to 2 inches
- 2 to 4 inches

North San Benito Basin

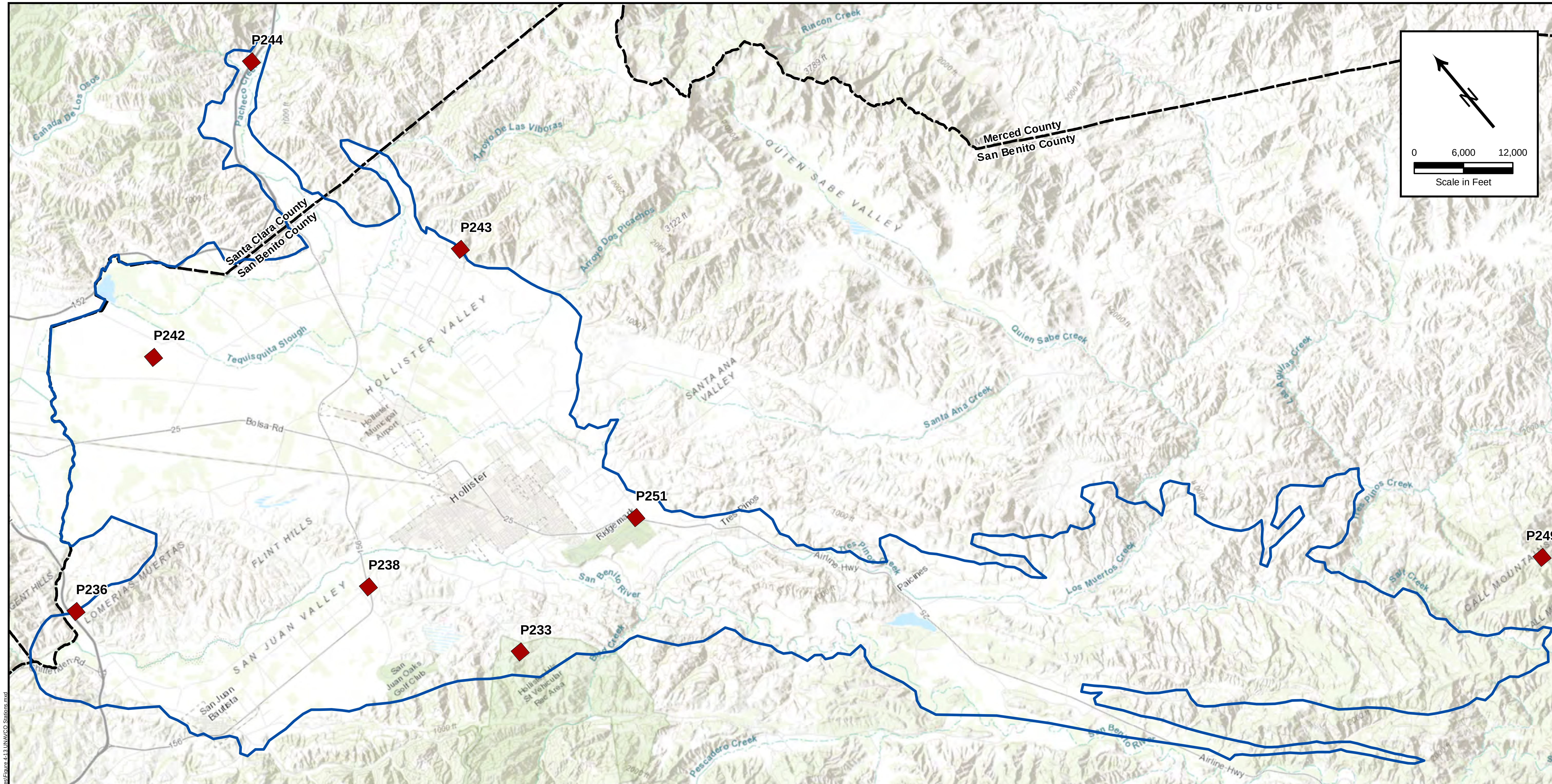
San Benito County

Note:
Displacement measured between 5/31/2015 and 4/30/2017

April 2019

TODD GROUNDWATER

Figure 4-12
Basin-Wide Subsidence Estimates from Satellite Measurements



■ UNAVCO Stations

North San Benito Basin

San Benito County

April 2019

TODD GROUNDWATER

Figure 4-13
Ground Surface Elevation Monitoring Stations

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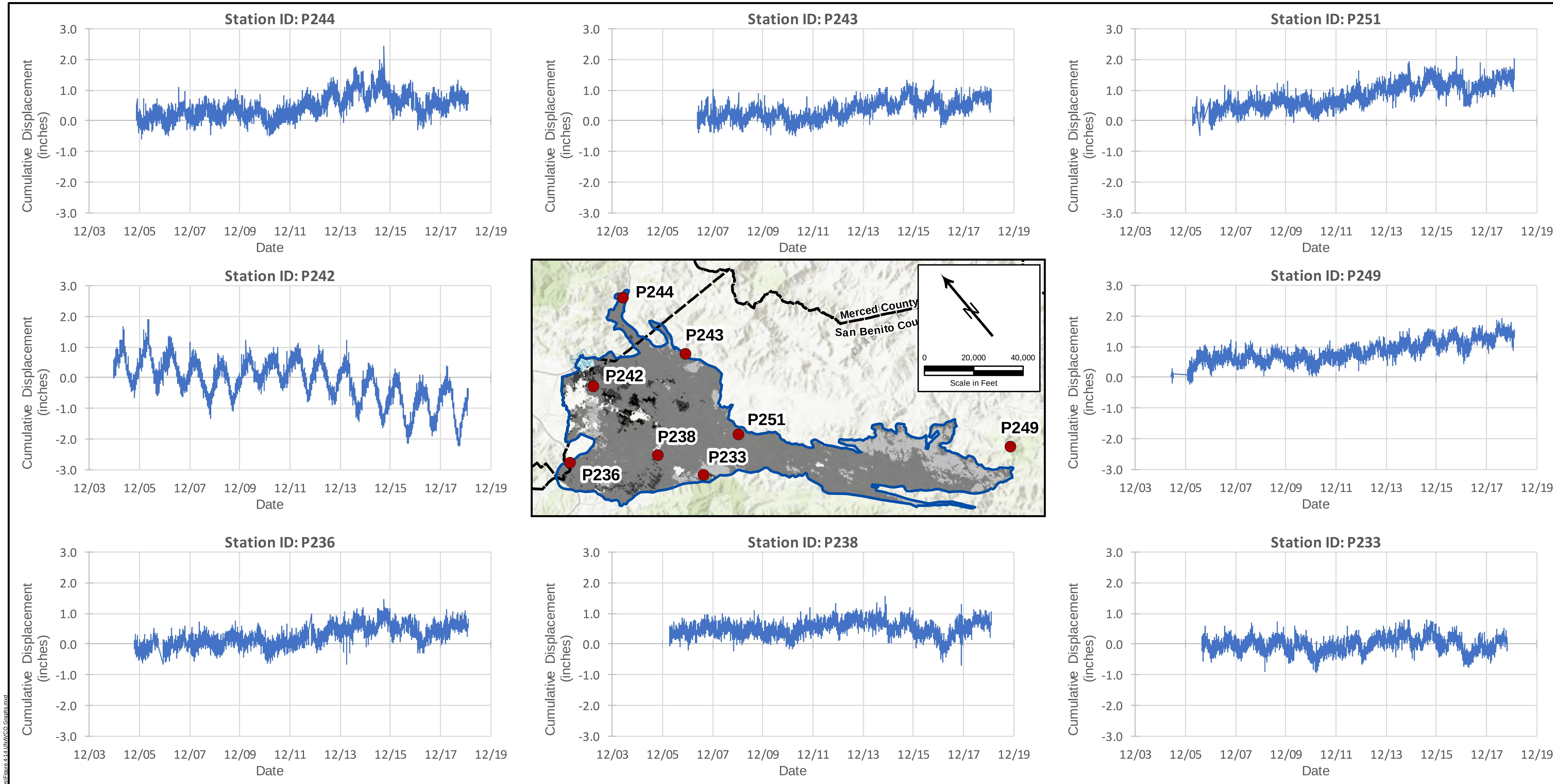


Vertical Displacement (inches)

- -6 to -4 inches
- -4 to -2 inches
- -2 to 0 inches
- 0 to 2 inches
- 2 to 4 inches

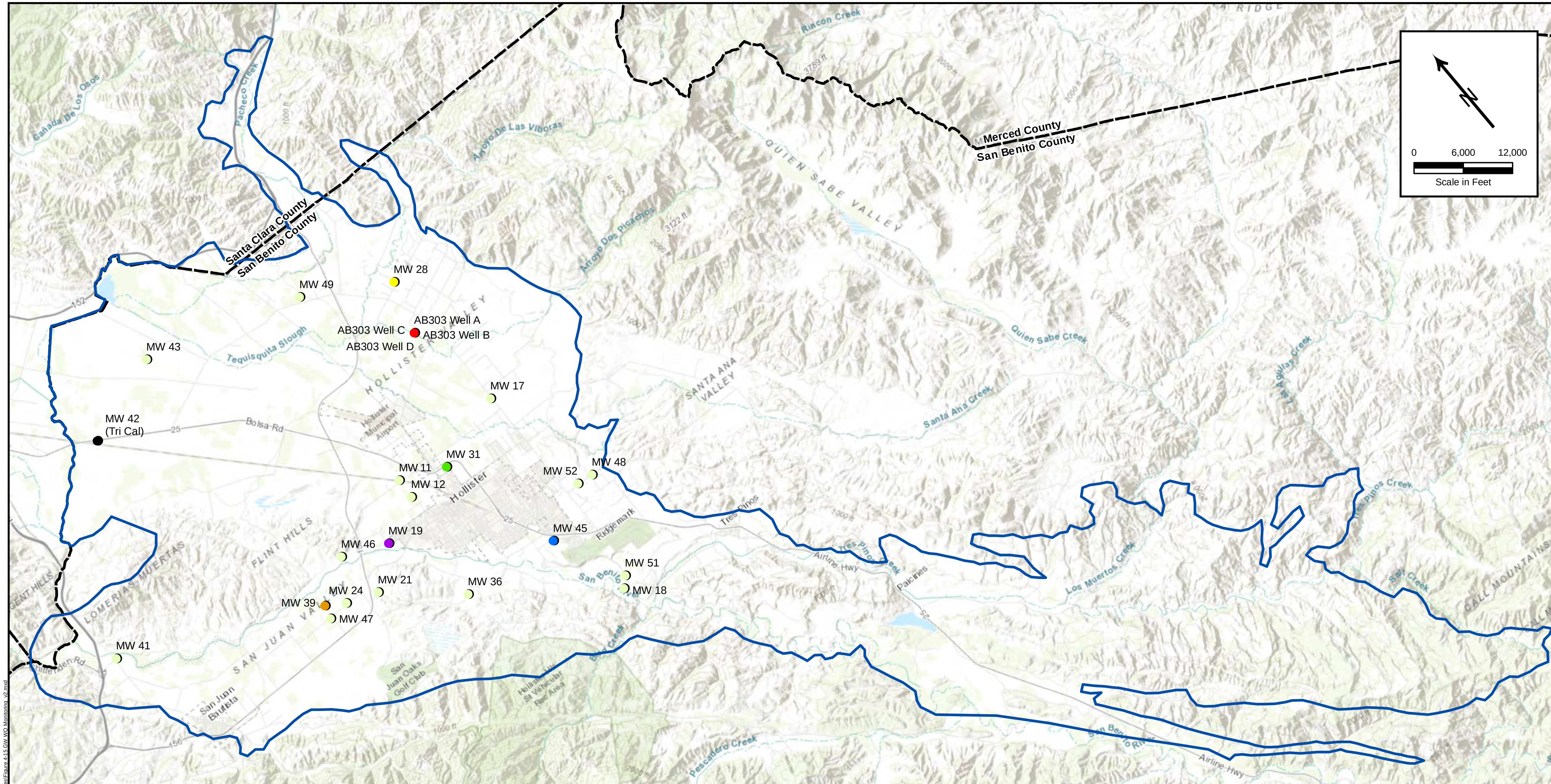
- UNAVCO Stations
- North San Benito Basin
- San Benito County

Note:
Displacement measured between 5/31/2015 and 4/30/2017

April 2019

TODD GROUNDWATER

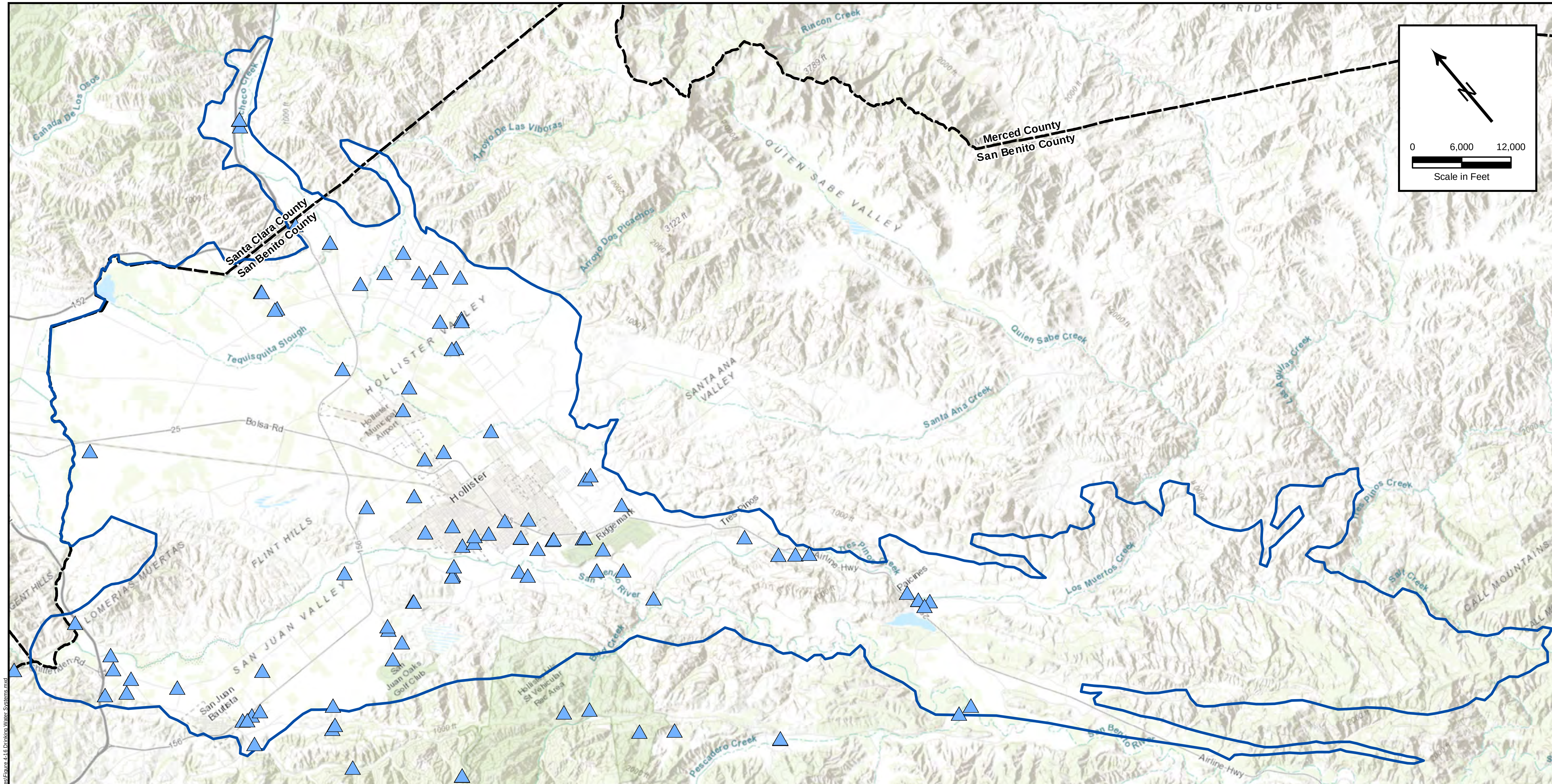
Figure 4-14
Historical Ground Surface Elevation from GPS Monitoring



April 2019

TODD GROUNDWATER

Figure 4-15
SBCWD Water Quality Monitoring Network



Drinking Water Systems

Drinking Water Locations

North San Benito Basin

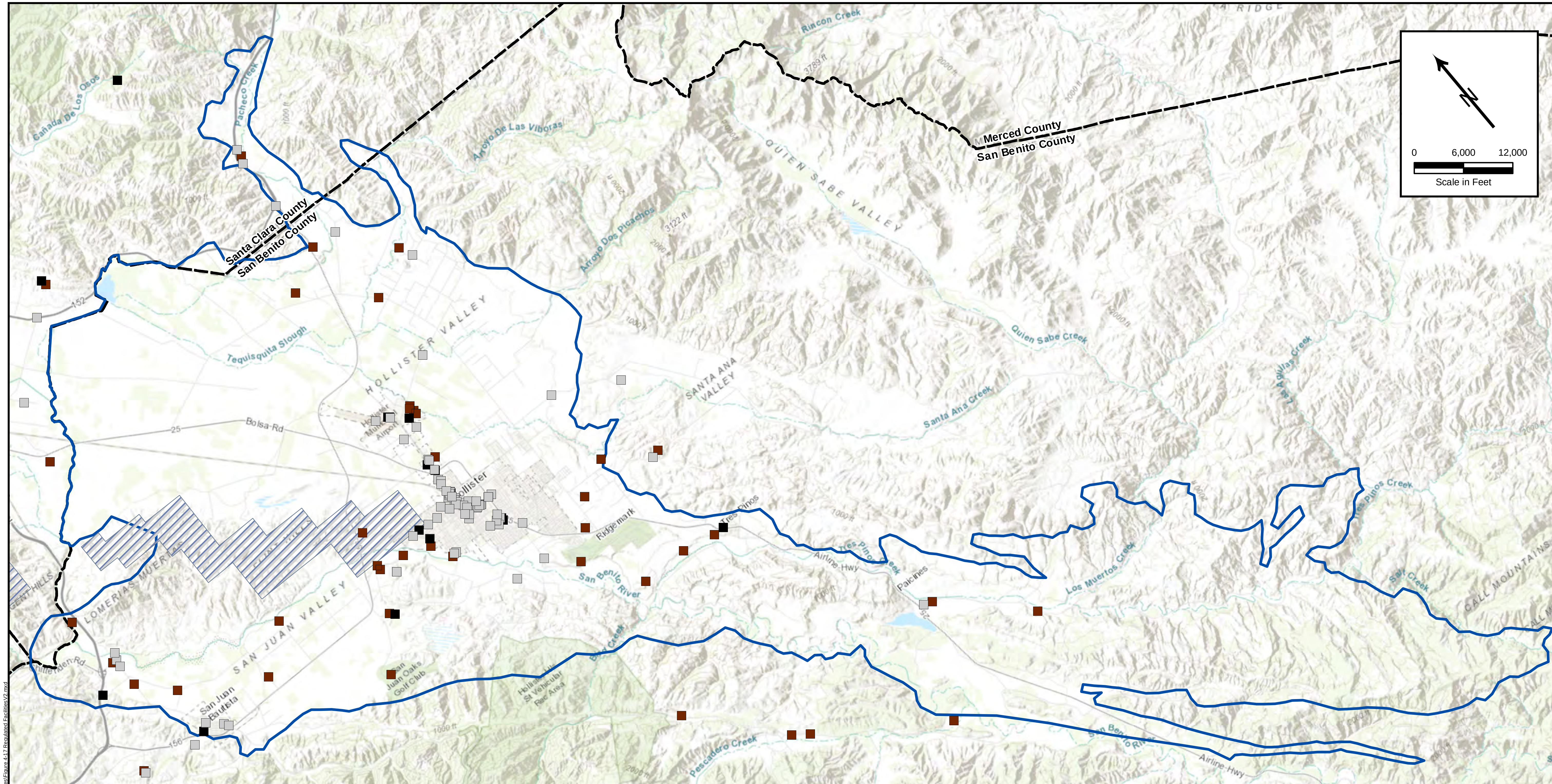
San Benito County

April 2019

TODD GROUNDWATER

Figure 4-16 Drinking Water Systems

Path: T:\Projects\San Benito GSP 37643\GIS\Maps\Figures\GSP Figures\HCM Figures\Figure 4-16 Drinking Water Systems.mxd



Regulated Facilities

Status

- Other
- Active
- Closed/ Inactive
- Open
- Oil / Gas

North San Benito Basin

San Benito County

April 2019

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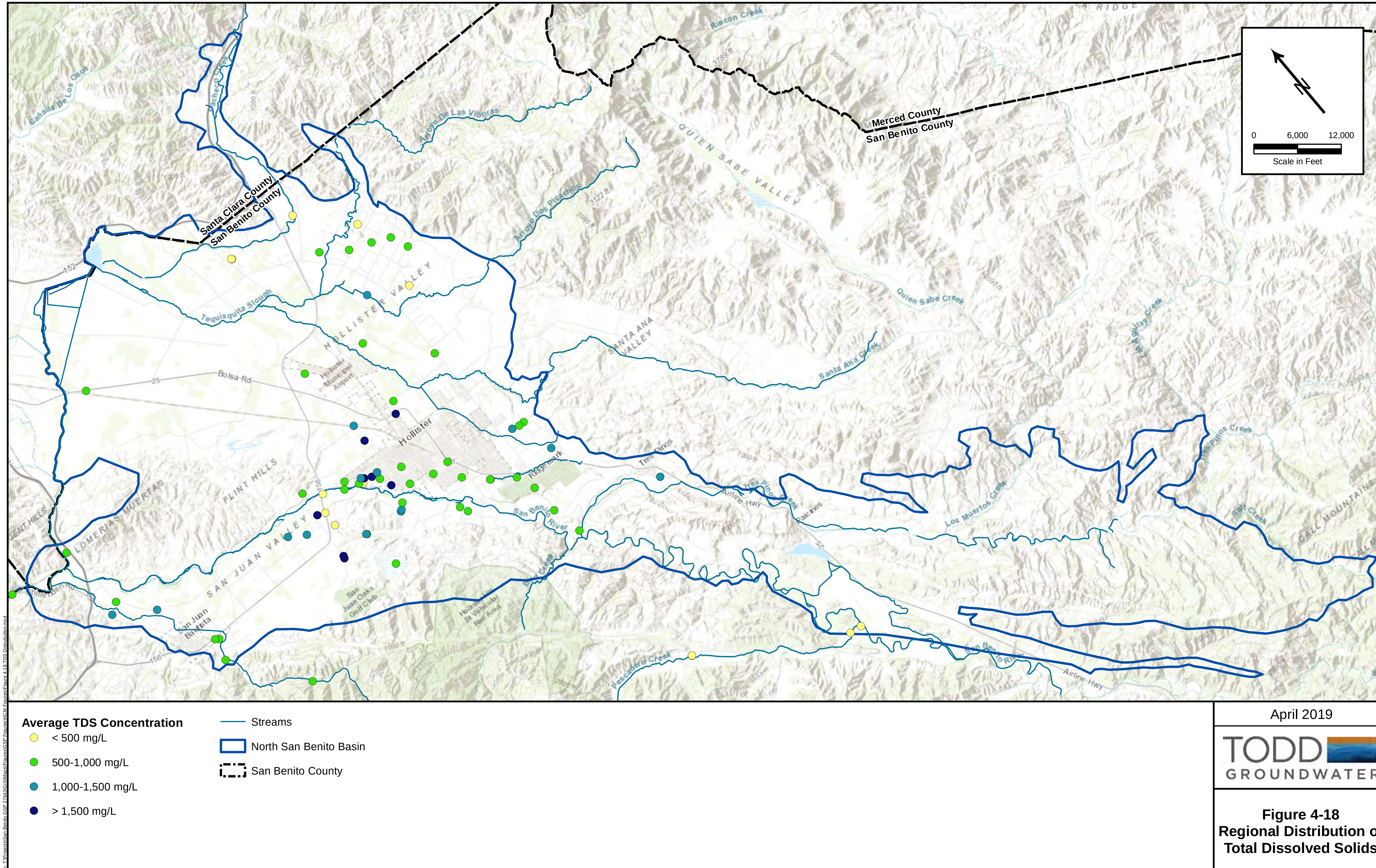
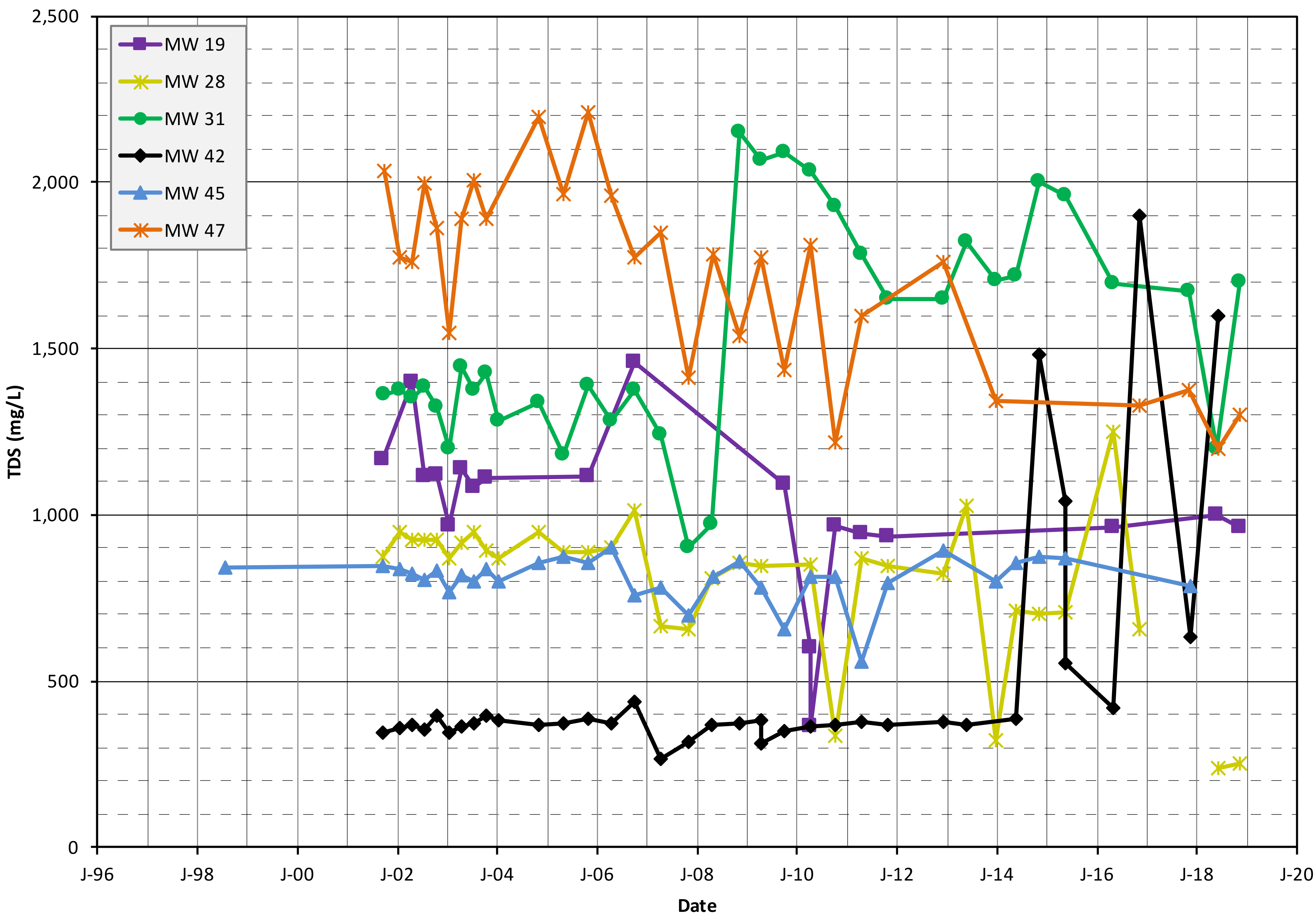
Figure 4-17
Location of Potential Point Sources of Groundwater Contaminants



April 2019

TODD GROUNDWATER

Figure 4-18
Regional Distribution of Total Dissolved Solids



April 2019

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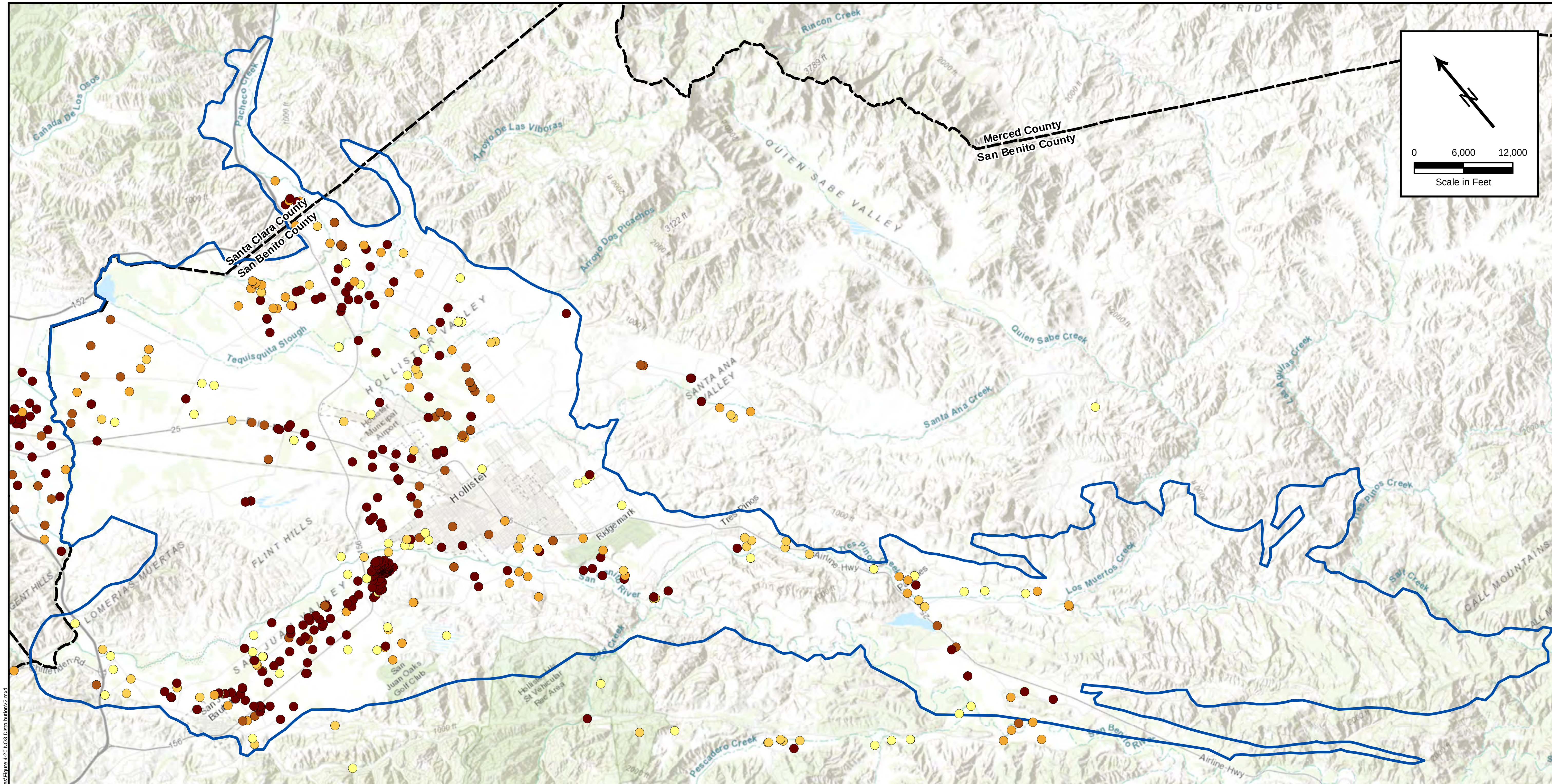
Figure 4-19
Total Dissolved Solids
Regional Trends



Nitrate Concentration

- > 5 mg/L
- 5-10 mg/L
- 10-20 mg/L
- 20-30 mg/L
- > 30 mg/L

North San Benito Basin

San Benito County

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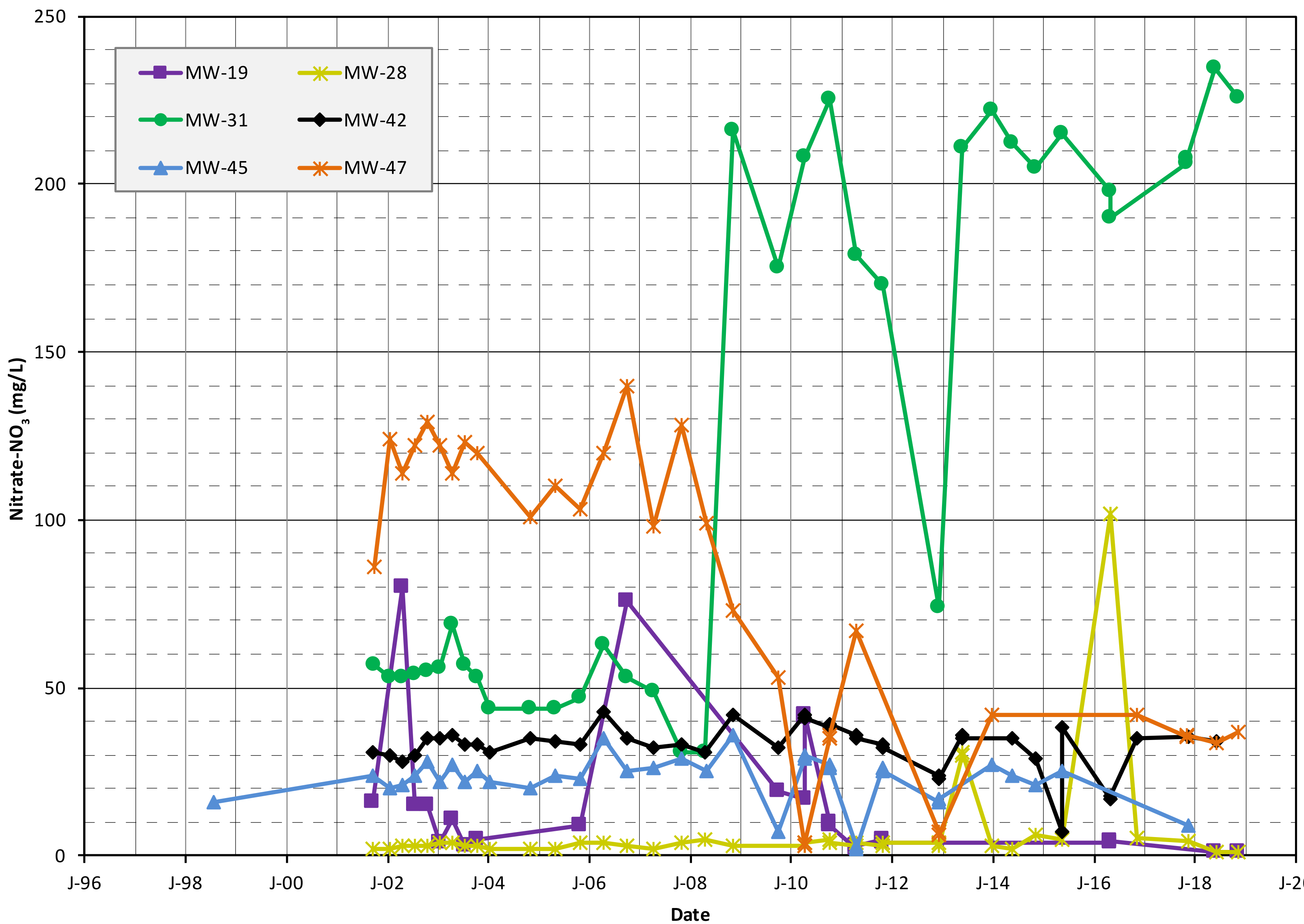
TODD GROUNDWATER

Figure 4-20
Regional Distribution of Nitrate

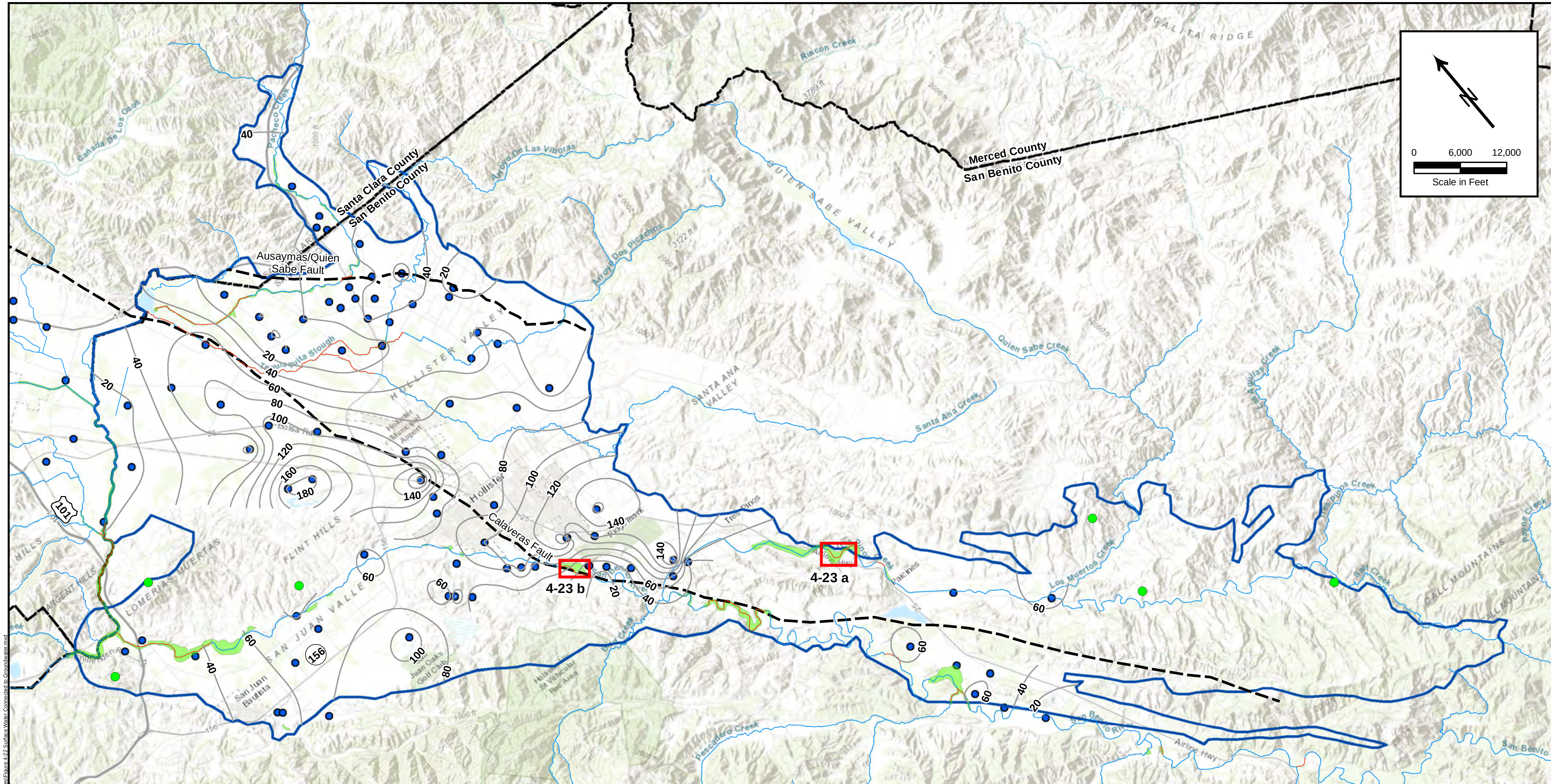
Path: T:\Projects\San Benito GSP 37643\GIS\Maps\Figures\GSP Figures\HCM Figures\Figure 4-20 NO3 DistributionV2.mxd



April 2019

TODD GROUNDWATER

Figure 4-21
Nitrate
Regional Trends



Springs and Seeps

Wells

20-foot depth to groundwater contour, feet below ground surface

Generalized Faults

Gaining Stream Reach

Losing Stream Reach

Phreatophytic Riparian Vegetation

Figure 4-23 Bounding Box

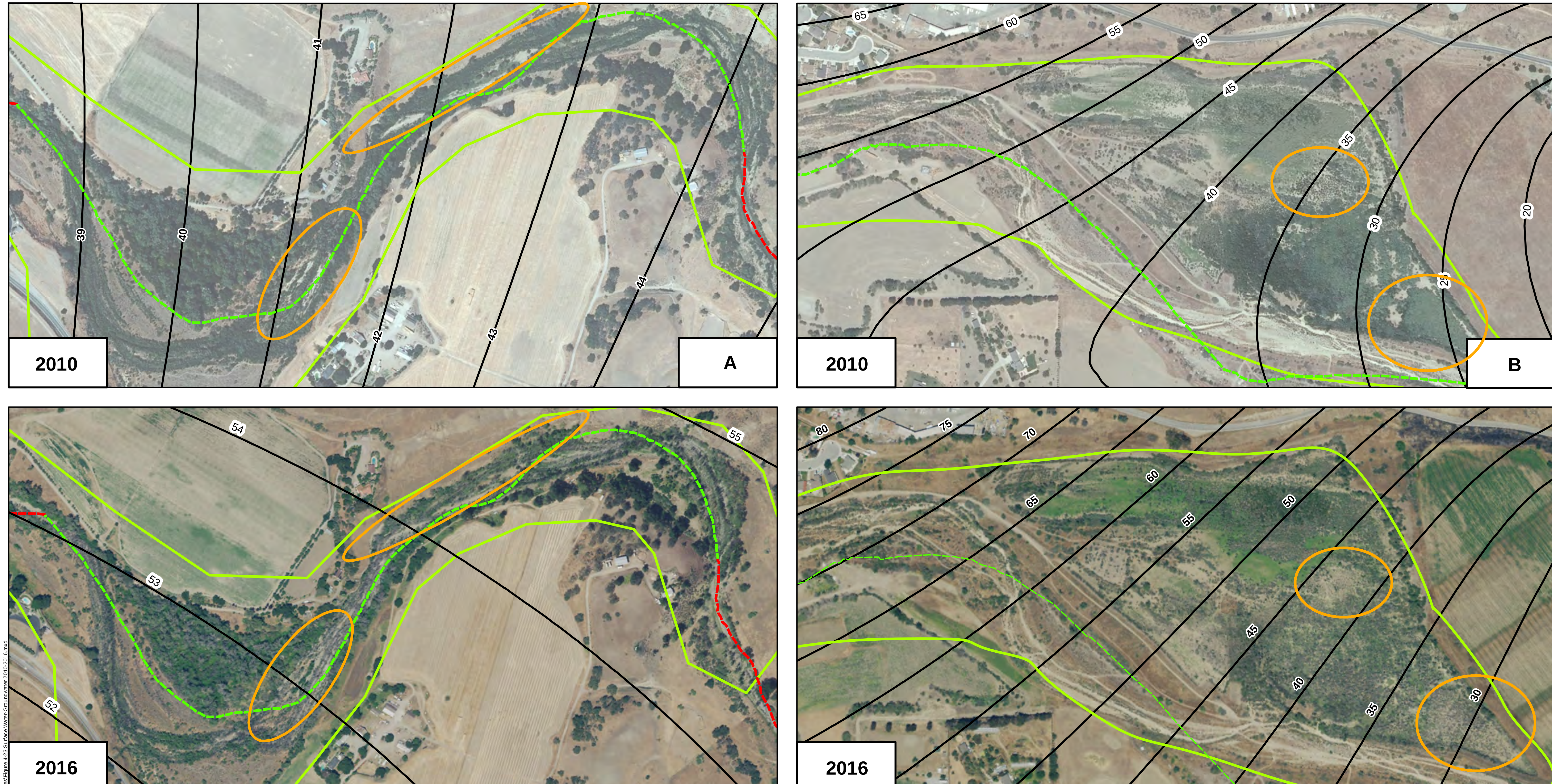
North San Benito Basin

San Benito County

April 2019

TODD GROUNDWATER

Figure 4-22
Surface Water Connected to Groundwater



Stream

Gaining Reach

Losing Reach

Depth To Groundwater Contour

Phreatophytic Riparian Vegetation

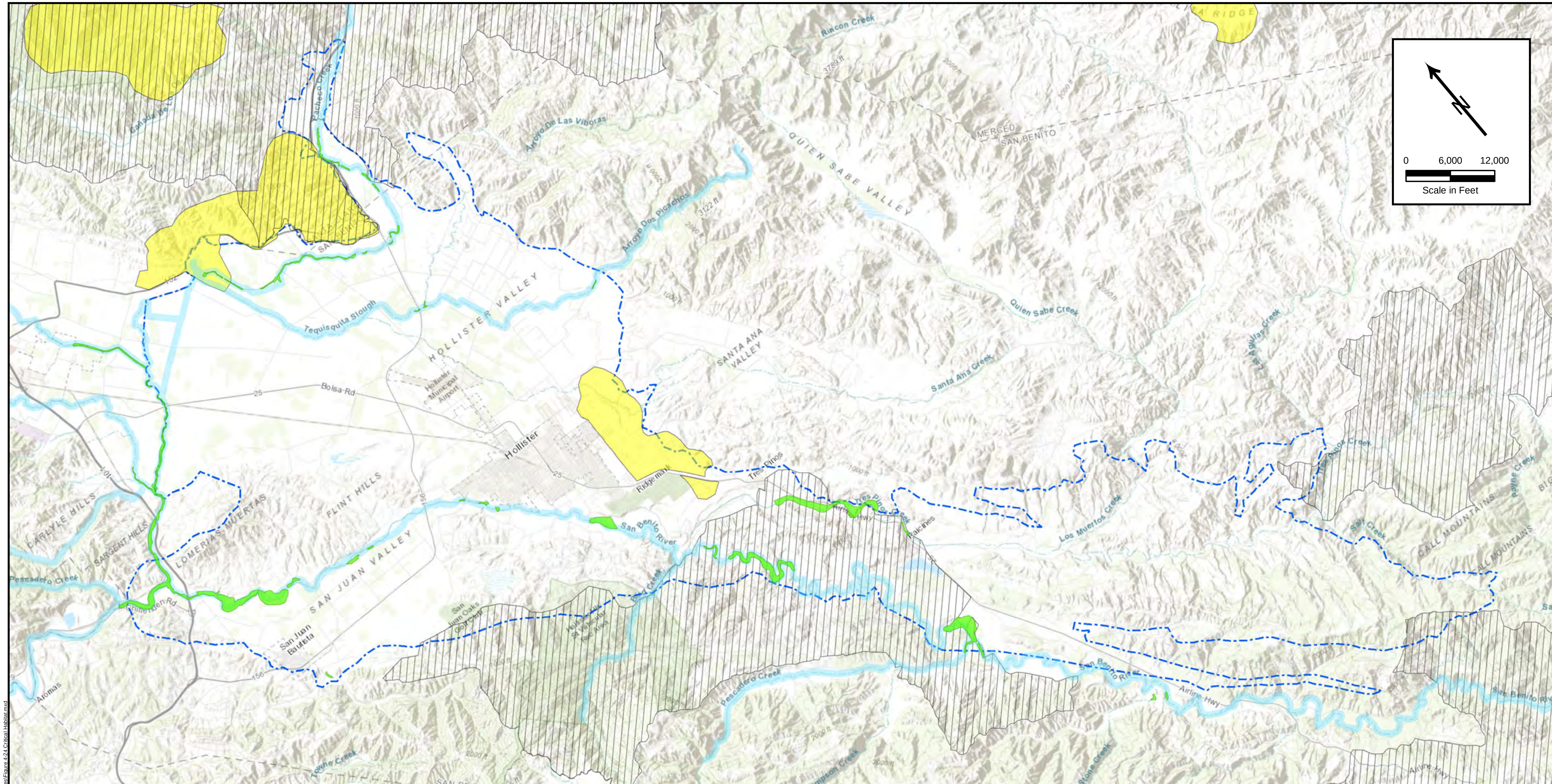
Locations of decreased vegetative cover

April 2019

TODD GROUNDWATER

Figure 4-23
Vegetation Response to Drought Conditions

Path: T:\Projects\San Benito GSP 37643\GIS\Maps\Figures\GSP Figures\HCM Figures\Figure 4-23 Surface Water-Groundwater 2010-2016.mxd



Steelhead Passage Stream

California Red-Legged Frog

California Tiger Salamander

Phreatophytic Riparian Vegetation

North San Benito Basin

April 2019

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Figure 4-24
Critical Habitat Areas