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Chapter 4

Paso Robles Subbasin Groundwater Sustainability Plan

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Close of 45-day public comment period: **pending recommendation by the Cooperative Committee at the October 17, 2018 Regular Meeting*	***December 10, 2018**

Revisions have been proposed to Section 4.7 of the Draft GSP Chapter 4 that was originally received by the Cooperative Committee at the September 12, 2018 Special Meeting. This revised Draft GSP Chapter 4 (attached) is available for public review and comment and will be brought back to the Committee at the October 17, 2018 Regular Meeting. Comments from the public are being collected using a comment form available at www.pasogcp.com. If you require a paper form to submit by postal mail, please contact your local Groundwater Sustainability Agency (GSA).

- County of San Luis Obispo
- Shandon-San Juan Water District
- Heritage Ranch CSD
- San Miguel CSD
- City of Paso Robles

Pending the Cooperative Committee's recommendation on October 17, 2018, the attached revised Draft GSP Chapter 4 will be distributed to the five Paso Robles Subbasin GSAs to receive and file.

Draft
Paso Robles Subbasin
Groundwater Sustainability Plan
Chapter 4

Prepared for the Paso Robles Subbasin Cooperative Committee and the Groundwater Sustainability Agencies

October 10, 2018

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CHAPTER 4. HYDROGEOLOGIC CONCEPTUAL MODEL

This chapter describes the hydrogeologic conceptual model of the Paso Robles Subbasin, including the Subbasin boundaries, geologic formations and structures, and principal aquifer units. The chapter also summarizes general Subbasin water quality, the conceptual interaction between groundwater and surface water, and generalized groundwater recharge and discharge areas. This chapter draws upon previously published studies, primarily hydrogeologic and geologic investigations by Fugro Consultants Inc. completed for San Luis Obispo County in 2002 and 2005. Fugro Consultants' 2002 and 2005 reports are the definitive geologic reports of the Subbasin. All subsequent investigations, such as the 2016 groundwater model update, adopted the geologic interpretations of the 2002 and 2005 Fugro Consultant reports. The Hydrogeologic Conceptual Model presented in this chapter is not intended to be exhaustive, but is a summary of the relevant and important aspects of the Subbasin hydrogeology that influence groundwater sustainability. More detailed information can be found in the original reports (Fugro, 2002 and 2005). This chapter, along with Chapter 3 – Basin Setting, sets the framework for subsequent chapters on groundwater conditions and water budgets.

4.1 Subbasin Topography and Boundaries

The Subbasin is a structural northwest-trending trough filled with sediments that have been folded and faulted by regional tectonics. The top of the Subbasin is the ground surface. The elevation of the Subbasin ranges from approximately 2,000 feet above mean sea level (msl) at the southeastern corner to approximately 600 feet above msl in the northwest where the Salinas River exits the Subbasin. The central part of the Subbasin forms a broad plain with relatively minor relief.

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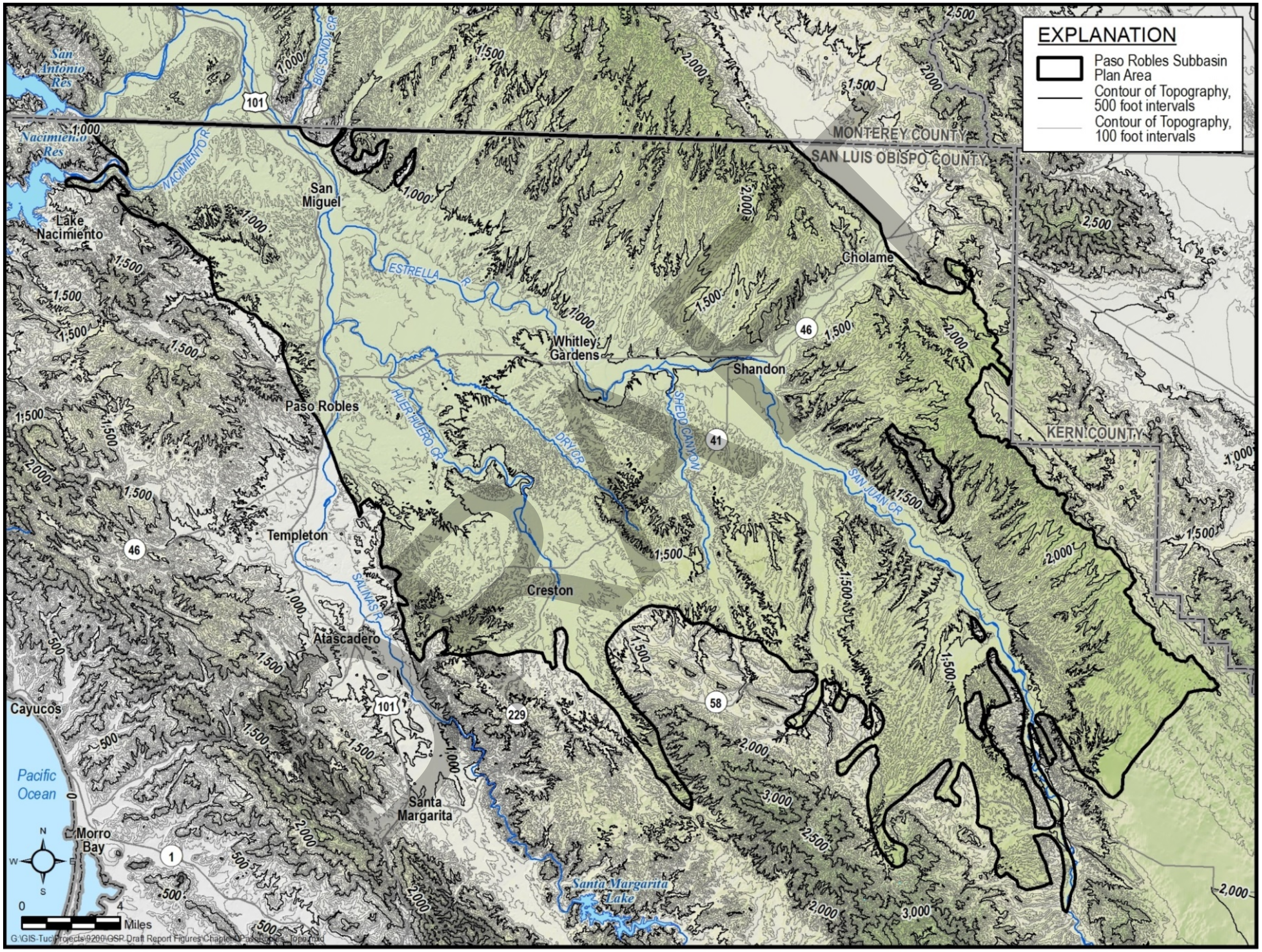

Figure 4-1. Paso Robles Subbasin Topography

Figure 4-1 shows the topography of the Subbasin using 100-foot contour intervals. The Subbasin is bounded by sediments with low permeability, sediments with poor groundwater quality, rock, and structural faults. In some areas the sediments of the Subbasin are continuous with adjacent subbasins. Specific Subbasin lateral boundaries include the following:

- The western boundary of the Subbasin is defined by the contact between the sediments in the Subbasin and the sediments of the Santa Lucia Range. An additional section of the western boundary is defined by the San Marcos-Rinconada fault system which separates the Paso Robles Subbasin from the Atascadero Subbasin.
- The northern boundary of the Subbasin is defined by the county line between San Luis Obispo County and Monterey County. This boundary is not defined by a physical barrier to groundwater flow; water-bearing sediments are continuous with the Salinas Valley Upper Valley Subbasin in Monterey County.
- The eastern boundary of the Subbasin is defined by the contact between the sediments in the Subbasin and the sediments of the Temblor Range. The San Andreas Fault forms the northeastern Subbasin boundary and is approximately parallel to the boundary further south.
- The southern boundary of the Subbasin is defined by the contact between the sediments in the Subbasin and the sediments of the La Panza Range. To the southeast, a watershed divide separates the Subbasin from the adjacent Carrizo Plain Basin; sedimentary layers are likely continuous across this divide.

The bottom of the Subbasin is generally defined as the base of the Paso Robles Formation, which is an irregular surface formed as the result of folding, faulting, and erosion (Fugro, 2002). The Subbasin boundary and bottom are not considered absolute barriers to flow because some of the geologic units underlying the Paso Robles Formation produce sufficient quantities of water, but the water is generally of poor quality and it is therefore not considered part of the Subbasin.

Figure 4-2 shows the lateral boundaries of the Subbasin and the approximate depth to the bottom of Paso Robles Formation in areas where it is saturated. The Paso Robles Formation is either not present or not saturated east of the San Juan fault system and there is very little well data in this portion of the subbasin.

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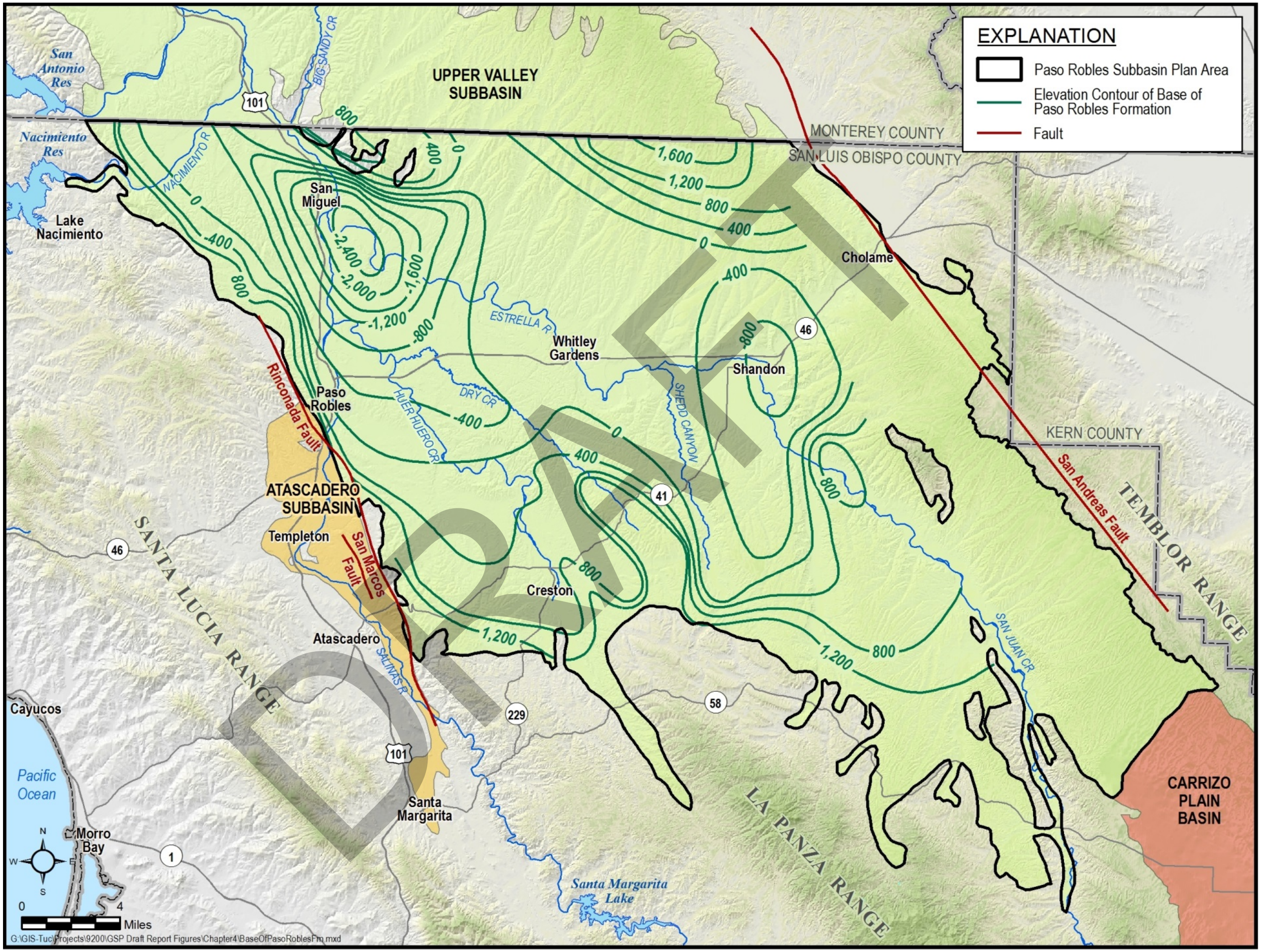

Figure 4-2. Base of Subbasin as Defined by the Base of the Paso Robles Formation

4.2 Soils Infiltration Potential

Saturated hydraulic conductivity of surficial soils is a good indicator of the soil's infiltration potential. Soil data from the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic Database (SSURGO) (USDA NRCS, 2007) is shown by the four hydrologic groups on Figure 4-3. The soil hydrologic group is an assessment of soil infiltration rates that is determined by the water transmitting properties of the soil, which includes 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; soil stypically have greater than 40 percent clay, less than 50 percent sand

The hydrologic group of the soil generally correlates with the hydraulic conductivity of underlying geologic units, with lower soil hydraulic conductivity zones correlating to areas underlain by clayey portions of the Paso Robles Formation. The higher soil hydraulic conductivity zones correspond to areas underlain by alluvium or areas of coarser sediments within the Paso Robles Formation.

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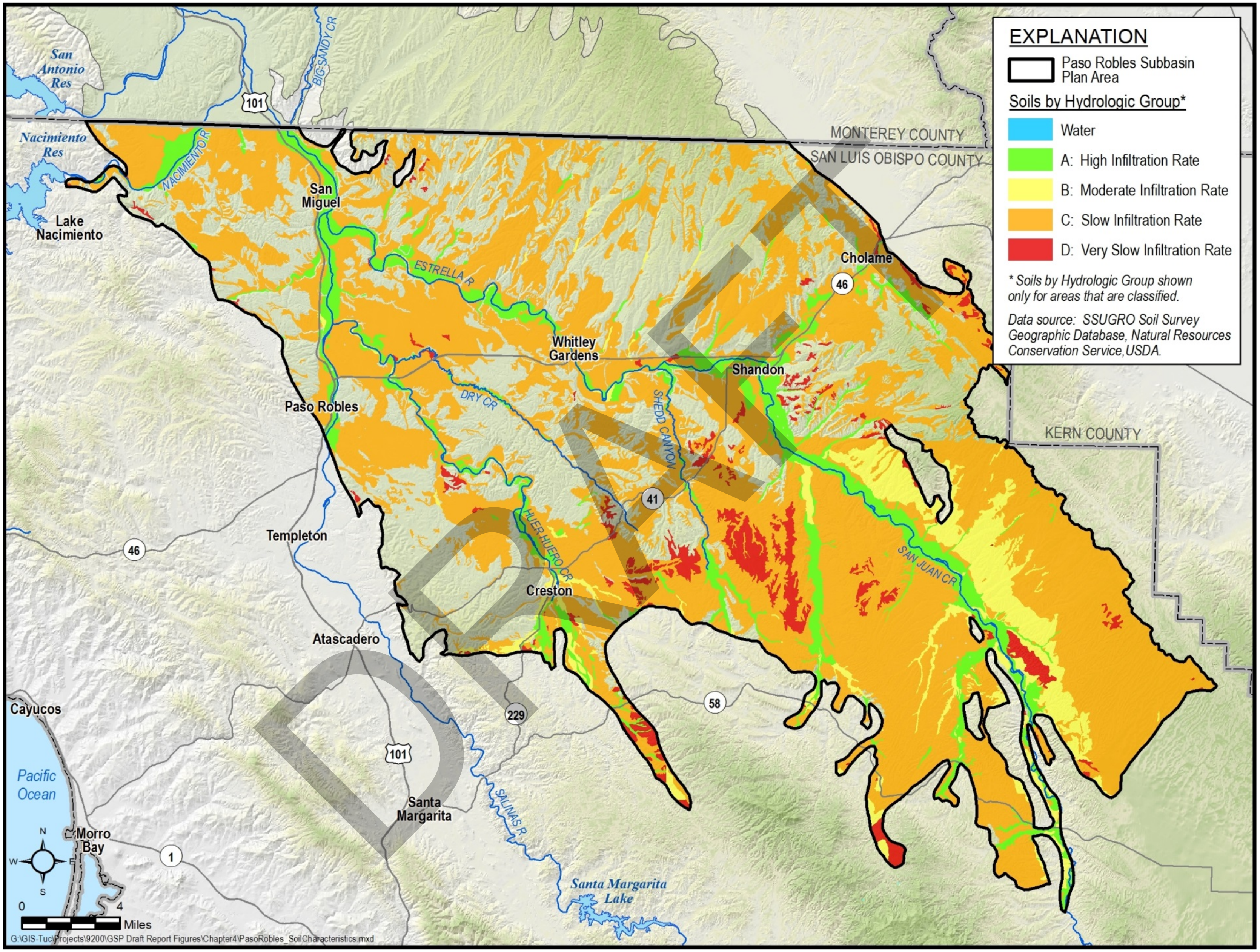

Figure 4-3. Paso Robles Subbasin Soil Characteristics

4.3 Regional Geology

This section provides a description of the geologic formations in the Subbasin. These descriptions are summarized from previously published reports by Fugro (2002 and 2005). Figure 4-4 shows the surficial geology and geologic structures of the Subbasin (County of SLO, 2007). Figure 4-5 provides the location of the geologic cross-sections shown on Figure 4-6 through Figure 4-10. The selected geologic cross-sections illustrate the relationship of the geologic formations that constitute the Subbasin and the geologic formations that underlie and surround the subbasin. The cross-sections are from different reports so the format differs but the units are consistent. Figure 4-6 through Figure 4-8 are from the *Paso Robles Groundwater Basin Study* (Fugro, 2002); Figure 4-9 and Figure 4-10 are from the *Paso Robles Groundwater Basin Study, Phase II: Numerical Model Development, Calibration, and Application* (Fugro, 2005).

4.3.1 Regional Geologic Structures

The base of the Subbasin is locally divided by two semi-parallel bedrock ridges: the San Miguel Dome and the Creston Anticlinorium (Figure 4-4). These two bedrock ridges are often not exposed at the ground surface, but are apparent in the subsurface cross-sections. The subsurface expression of the bedrock is illustrated on the cross-sections shown on Figure 4-6, which shows the Creston Anticlinorium, and Figure 4-8 which shows the San Miguel Dome. Between the San Miguel Dome and Creston Anticlinorium, there is no clear bedrock ridge as shown on Figure 4-7. This gap allows for sediments on the east side of the ridges near Shandon to continue and be connected with sediments on the west side of the ridges.

The deepest portion of the Subbasin is west of the San Miguel Dome and north of Paso Robles, with over 3,000 feet of sediments (Fugro, 2005). This deep trough extends through the Paso Robles area and shallows progressively to the south. As shown on Figure 4-6, the sediments are generally relatively thin on the order of a few hundred feet in the Creston area. East of the San Miguel Dome and near the community of Shandon the Paso Robles Formation is over 2,000 feet thick.

The faults within and along the borders of the Subbasin boundaries are shown on Figure 4-6. The predominant fault near the eastern side of the Subbasin is the San Andreas Fault. The predominant fault near the western side of the Subbasin is the San Marcos-Rinconada fault system. Within the Subbasin and sub-parallel to the San Andreas Fault are the Red Hill, San Juan, and White Canyon faults. It is unknown to what degree these faults are barriers to groundwater flow. In the center of the Subbasin are the King City fault and various unnamed faults. It is unknown to what degree these internal faults are barriers to groundwater flow. These faults could create compartments in the sediments and limit the ability of groundwater to move within the Subbasin.

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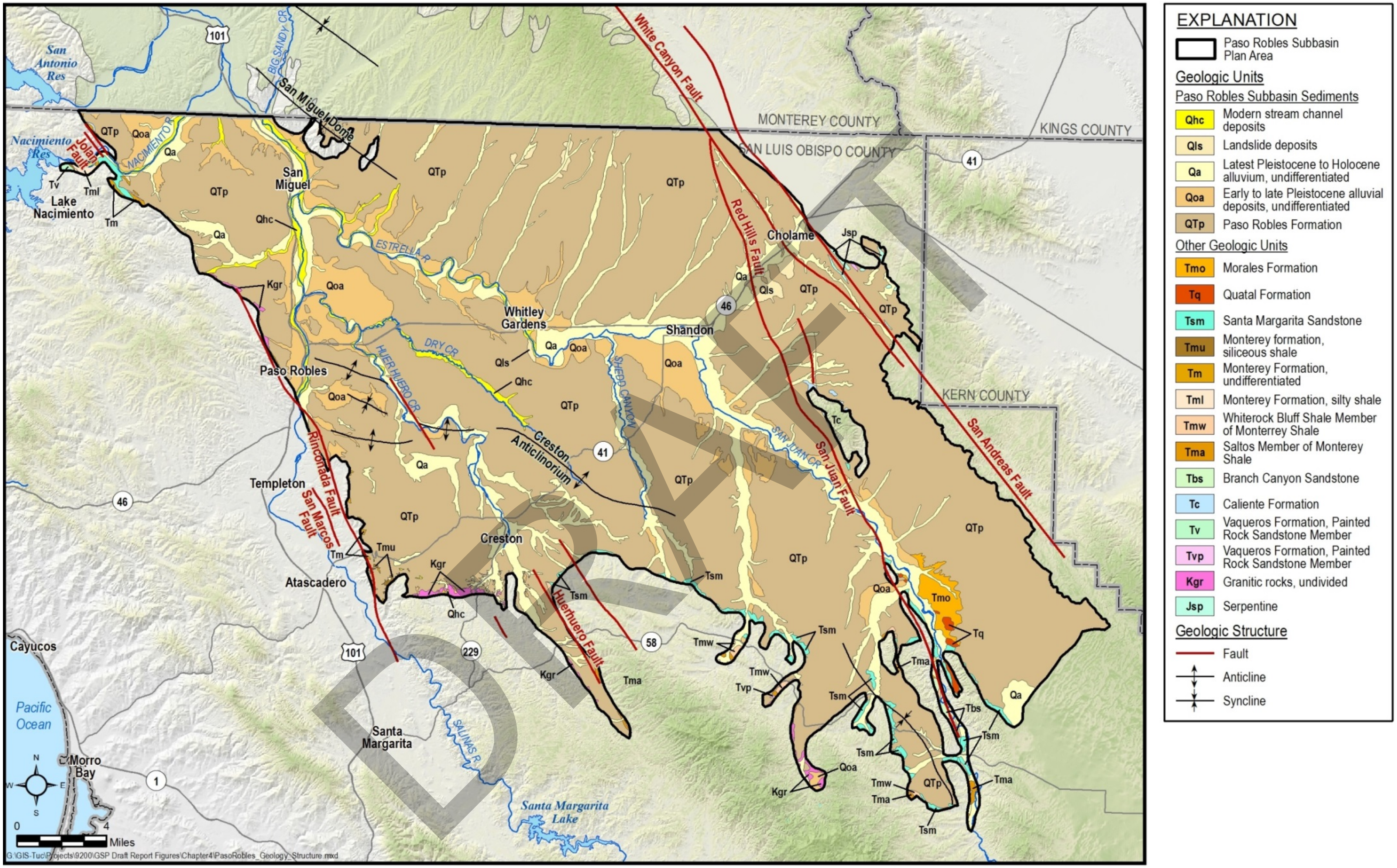

Figure 4-4. Surficial Geology and Geologic Structures

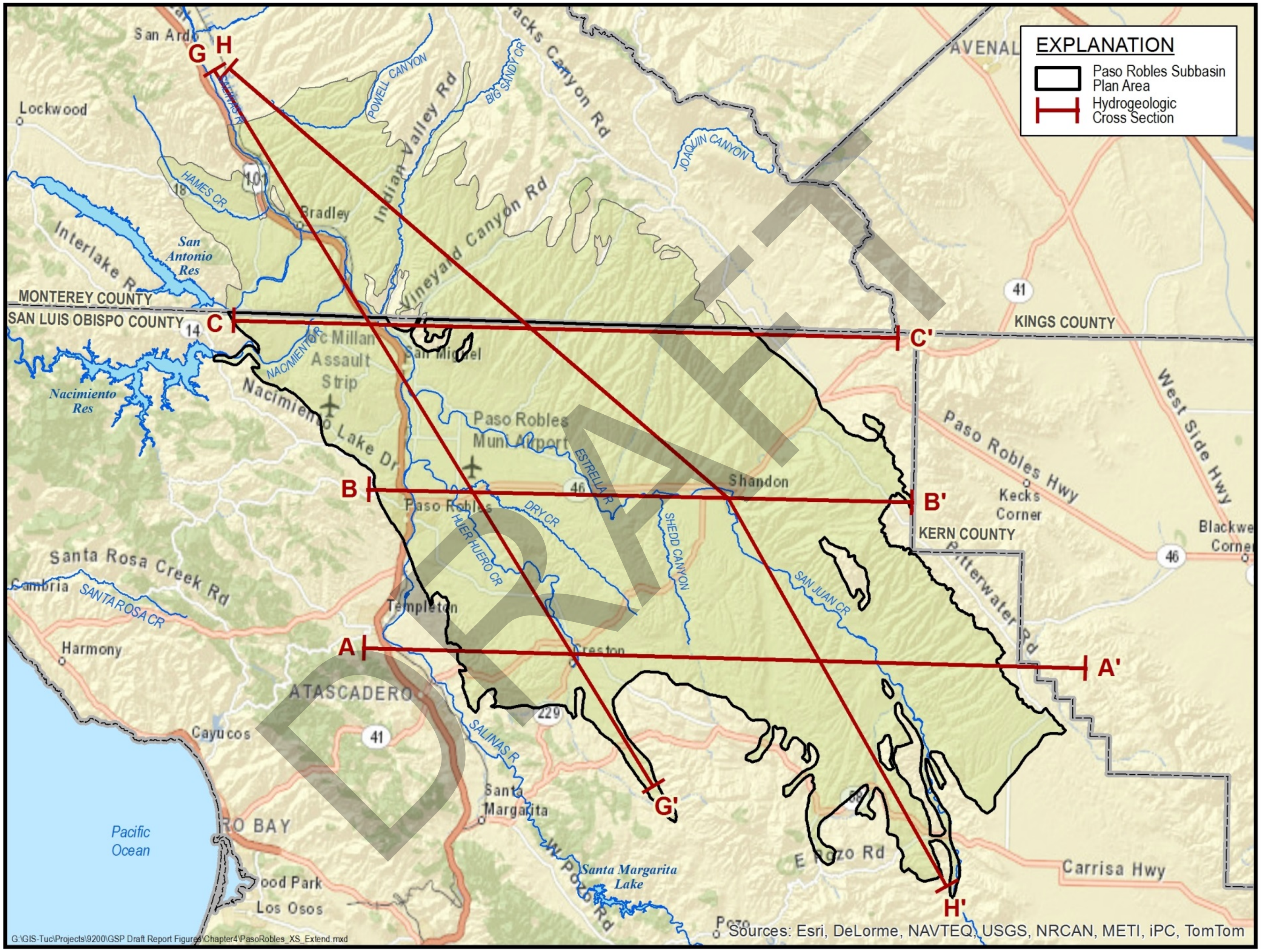

Figure 4-5. Cross Sections Locations

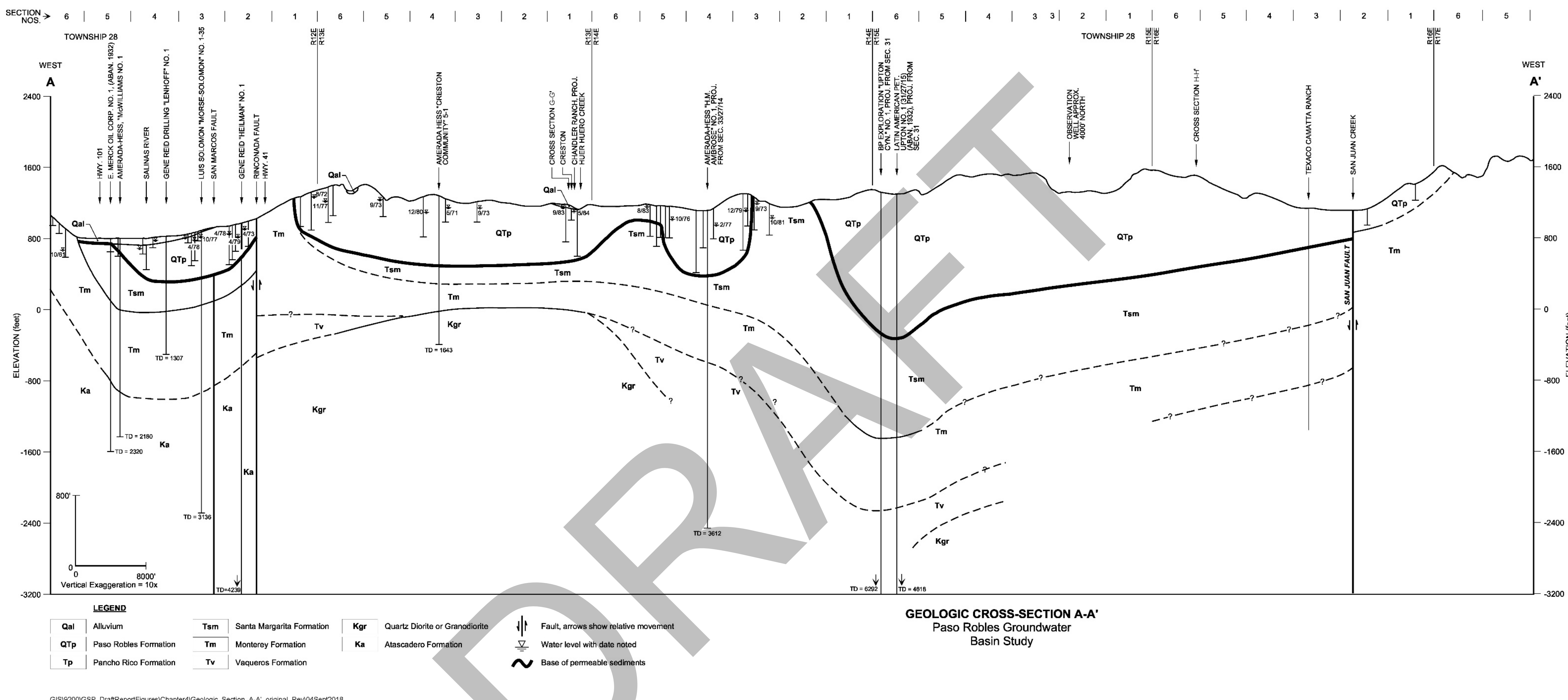

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Figure 4-6. Geologic Section A-A′

Source: Modified from Fugro (2002)

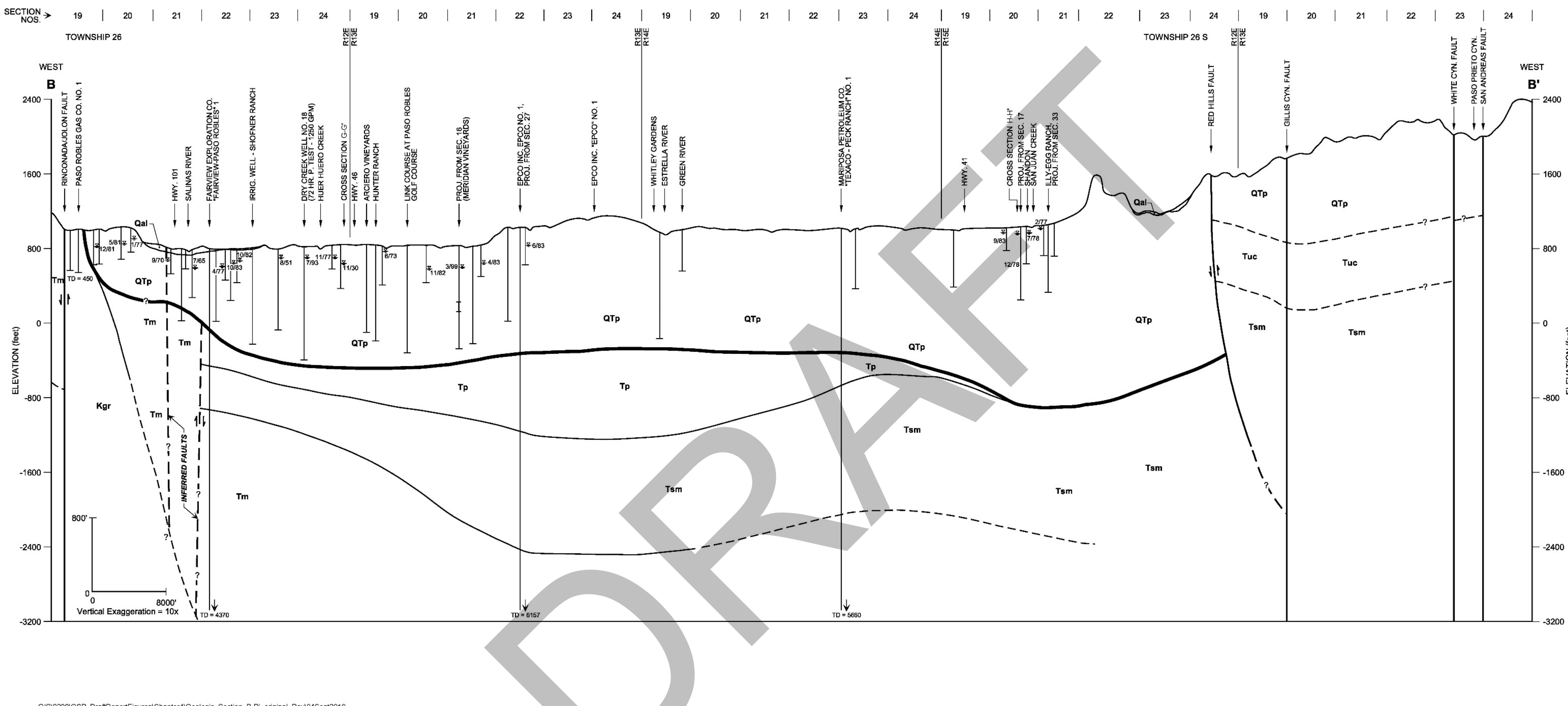

Figure 4-7. Geologic Section B-B'

Source: Modified from Fugro (2002)

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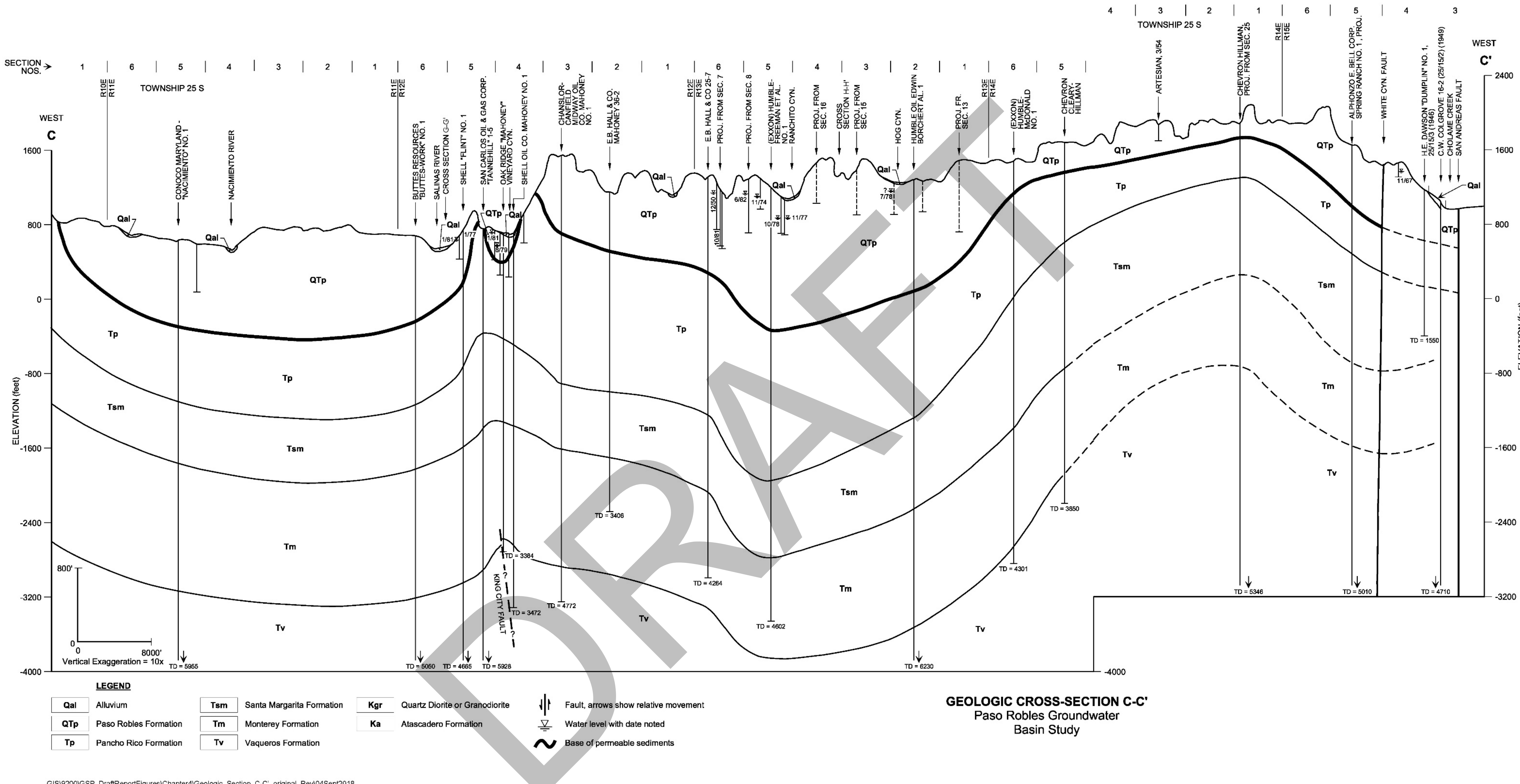

Figure 4-8. Geologic Section C-C′

Source: Modified from Fugro (2002)

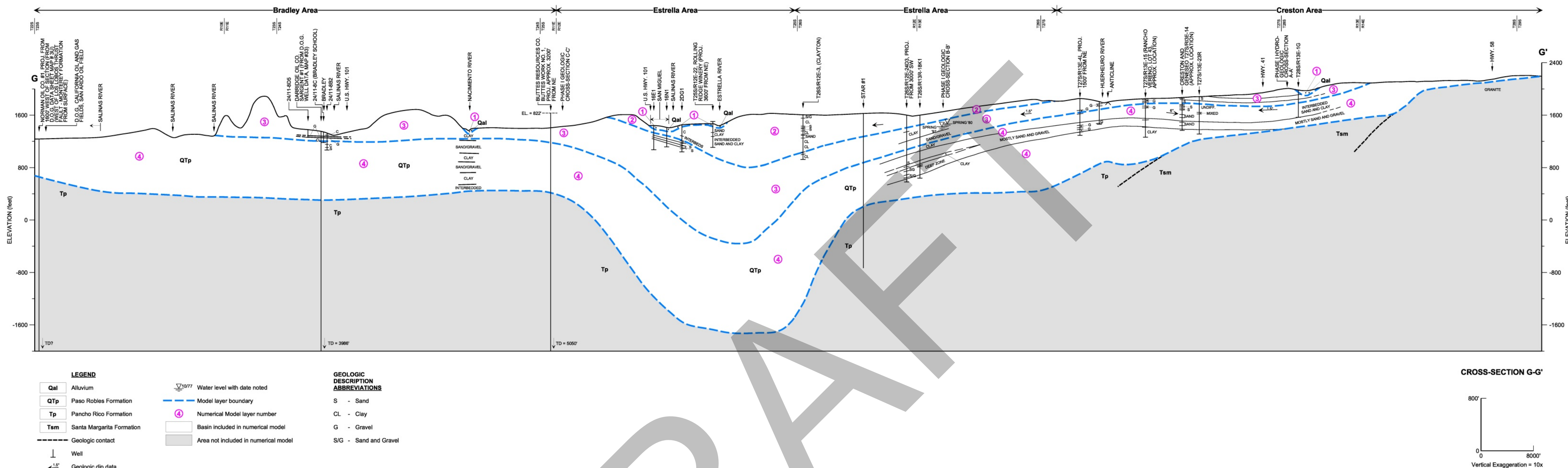

Figure 4-9. Geologic Section G-G′

Source: Modified from Fugro (2005)

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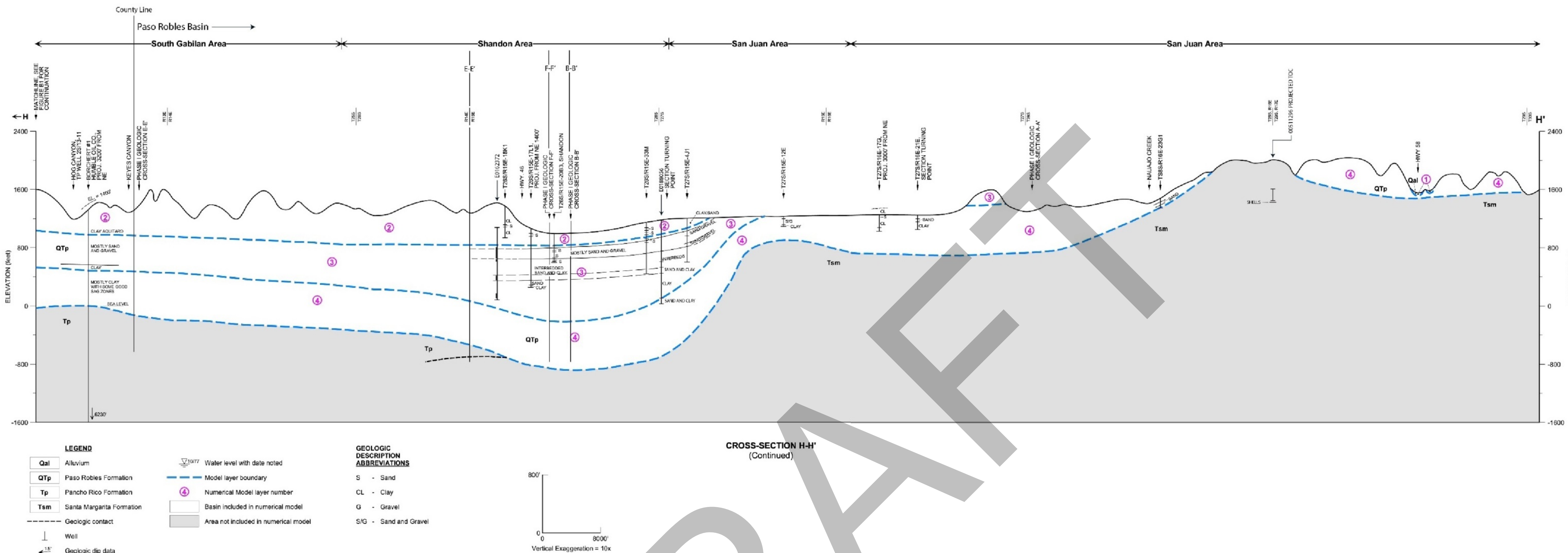

Figure 4-10. Geologic Section H-H'

Source: Modified from Fugro (2005)

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4.3.2 Geologic Formations Within the Subbasin

The main criteria used by previous authors for defining which geologic formations constitute the groundwater basin are:

1. The formation must have sufficient permeability and storage potential for the movement and storage of groundwater such that wells can reliably produce more than 50 gallons per minute (gpm) on a long-term basis, and
2. The groundwater produced from the geologic formation must be of generally acceptable quality (Fugro, 2002). DWR (1979) classifies groundwater with a conductivity of 3,000 micromhos/centimeter or less as fresh, and therefore of acceptable quality.

The only two geologic formations that reliably meet these two criteria are the Quaternary-age alluvial deposits and the Tertiary-age Paso Robles Formation. Therefore, these are the only two formations that constitute the Subbasin. A general discussion of these two formations is presented below.

Alluvium

Alluvium occurs beneath the flood plains of the rivers and streams within the Subbasin. Figure 4-4 shows the location of the alluvial deposits, labeled as Quaternary alluvium, identified as Qa. These deposits are typically no more than 100 feet thick and comprise coarse sand and gravel with some fine-grained deposits. The alluvium is generally coarser than the Paso Robles Formation, with higher permeability that results in well production capability that often exceeds 1,000 gpm.

Paso Robles Formation

The largest volume of sediments in the Subbasin are in the Paso Robles Formation. This formation has sedimentary layers up to 3,000 feet thick in the northern part of the Estrella area and up to 2,000 feet near Shandon. Figure 4-4 shows the location of the Paso Robles Formation deposits, identified as QTp. Throughout most of the Subbasin the Paso Robles Formation sediments have a thickness of 700 to 1,200 feet.

The Paso Robles Formation is derived from erosion of nearby mountain ranges. Sediment size decreases from the east and the west, becoming finer towards the center of the Subbasin, indicating sediment source areas are both to the east and west. The Paso Robles Formation is a Plio-Pleistocene, predominantly non-marine geologic unit comprising relatively thin, often discontinuous sand and gravel layers interbedded with

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thicker layers of silt and clay. The formation was deposited in alluvial fan, flood plain, and lake depositional environments. The formation is typically unconsolidated and generally poorly sorted. The sand and gravel beds in the Paso Robles Formation have a high percentage of eroded Monterey shale and have lower permeability compared to the overlying alluvial unit. The formation also contains minor amounts of gypsum and woody coal.

Poor quality groundwater with elevated concentrations of iron, manganese, and in some cases hydrogen sulfide odor have been observed within deeper portions of the Paso Robles Formation in some areas.

4.3.3 Geologic Formations Surrounding the Subbasin

Underlying and surrounding the Subbasin are older geologic formations that either typically have low well yields or have poor quality water. In general, the geologic units underlying the Subbasin include:

1. Tertiary-age or older consolidated sedimentary beds;
2. Cretaceous-age metamorphic rocks; and
3. Granitic rock.

Figure 4-11 shows the location of oil and gas exploration wells drilled in the Subbasin. These oil and gas wells help identify the depth and extent of the geologic formations that surround and underlie the Subbasin.

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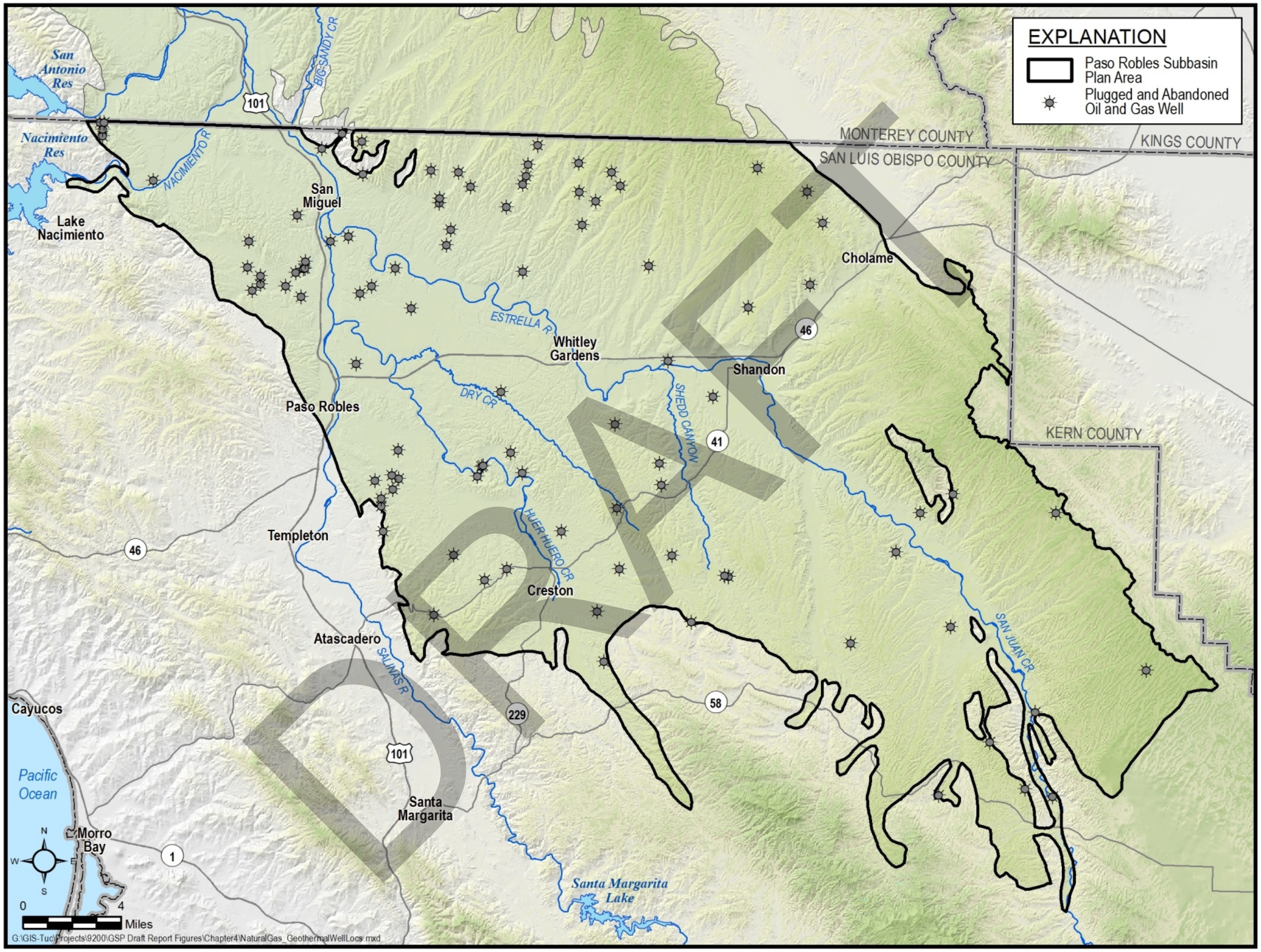

Figure 4-11. Natural Gas Exploration Well Locations and Geothermal Wells

PANCHO RICO FORMATION

The Pancho Rico Formation (Tp) is a Pliocene-age marine deposit found mostly in the northern portion of the study area. In places it appears to be time-correlative to the Paso Robles Formation, and may be in lateral contact as a facies change. The unit predominantly consists of fine-grained sediments up to 1,400 feet thick that yield low quantities of water. The Pancho Rico Formation additionally has poor water quality associated with tar sands that are present at the bottom of this formation (State Division of Mines, 1974).

SANTA MARGARITA FORMATION

The Santa Margarita Formation (Tsm) is an upper Miocene-age marine deposit, consisting of a white, fine-grained sandstone and siltstone with a thickness of up to 1,400 feet. The unit is found beneath most of the Subbasin. The Santa Margarita Formation is relatively permeable, but is not considered part of the Subbasin because the water quality is usually very poor. The geothermal waters contained in the Santa Margarita Formation in this area are often highly mineralized and characterized by elevated boron concentrations that restrict agricultural uses.

MONTEREY FORMATION

The Miocene-age Monterey Formation (Tm) consists of interbedded argillaceous and siliceous shale, sandstone, siltstone, and diatomite. The unit is as great as 2,000 feet thick in the study area, and is often highly deformed. Wells in the Monterey Formation are generally of too low yield to consider the Monterey Formation part of the Subbasin; although isolated areas in the Monterey Formation can yield more than 50 gpm. Additionally, groundwater produced from the Monterey Formation often has high concentrations of hydrogen sulfide, total organic carbon, manganese, and iron.

VAQUEROS FORMATION

The marine Oligocene-age Vaqueros Formation (Tv) is a highly cemented fossiliferous sandstone that reaches a thickness up to 200 feet. Springs in the Vaqueros Formation with flows up to 25 gpm are common in canyons on the western and southern sides of the study area. Most water wells tapping this formation produce less than 20 gpm. Generally, the quality of water in this unit is good, though hard due to the calcareous cement within the rock.

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METAMORPHIC AND GRANITIC ROCKS

The southern and western edges of the Subbasin are bordered by Cretaceous-age metamorphic and granitic rock. The metamorphic rock units include the Franciscan, Toro, and Atascadero Formations. The Franciscan consists of discontinuous outcrops of shale, chert, metavolcanics, graywacke, and blue schist, with or without serpentinite. The Toro Formation (Kt) is a highly consolidated claystone and shale that does not typically yield significant water to wells. The Atascadero Formation (Ka) is highly consolidated, but does have some sandstone beds that yield limited amounts of water to wells.

The granitic rock unit (Kgr) lies east of the Rinconada fault system, south of Creston, east of Atascadero, and in the area northwest of the City of Paso Robles. The granitic rocks are often capped by a layer of granular decomposed granite that may be weathered to clay. This decomposed granite may be up to 80 feet in thick and may contain limited amounts of groundwater.

4.4 PRINCIPAL AQUIFERS AND AQUITARDS

Water-bearing sand and gravel beds that may be laterally and vertically discontinuous are generally grouped together into zones that are referred to as aquifers. The aquifers can be vertically separated by fine-grained zones that can impede movement of groundwater between aquifers. Two aquifers exist in the Subbasin:

- A relatively continuous aquifer comprising alluvial sediments that underlie streams;
- An interbedded and discontinuous aquifer comprising sand and gravel lenses in the Paso Robles Formation.

Figure 4-4 shows the location of geologic sections that were used to depict the aquifers in the subsurface. Figure 4-12 through Figure 4-15 show the aquifers and model layers in profile, which are interpreted from the geologic logs, geophysical logs, groundwater levels, and water quality (Fugro, 2002 and 2005). For the GSP several additional well logs were added to the sections to refine the extent of the aquifers. These logs have been labeled with the state well inventory number (e.g. E0188061). Appendix 4A contains the well logs used to update the sections.

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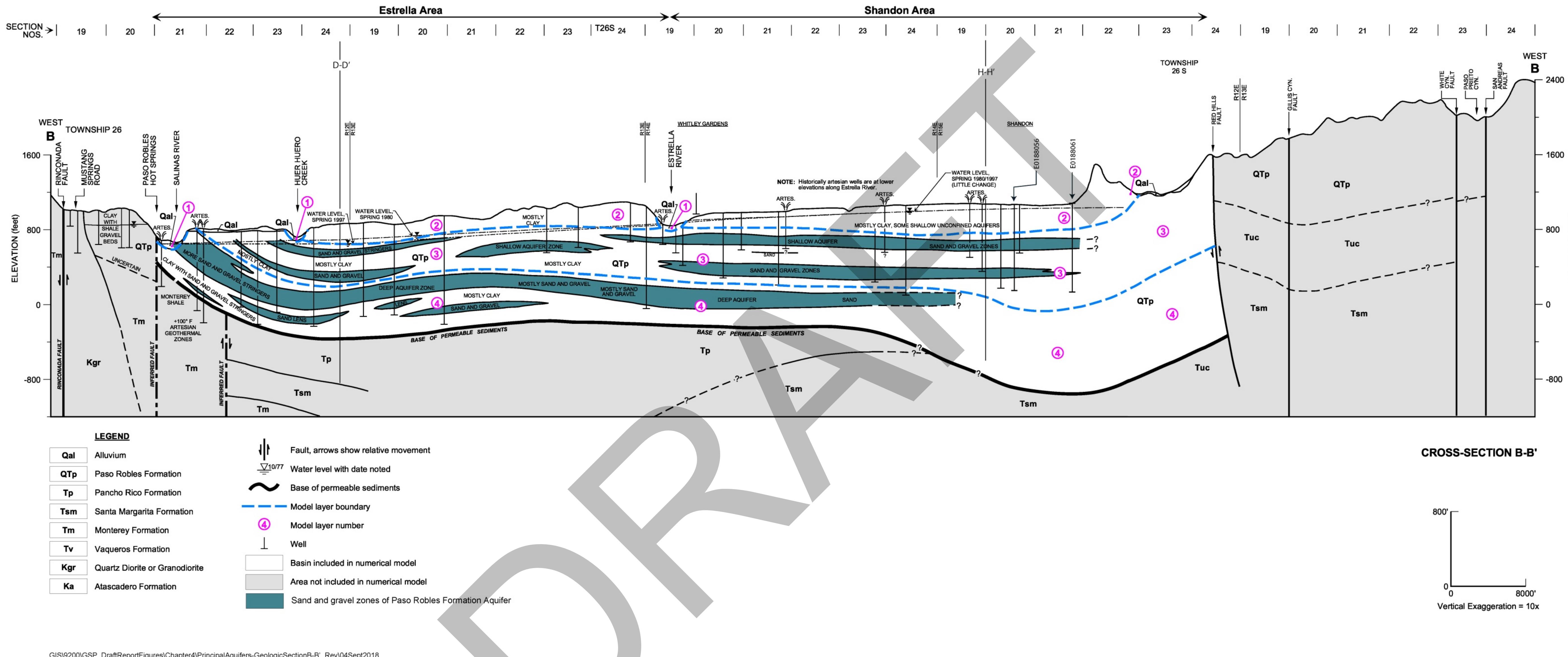

Figure 4-12. Aquifers - Geologic Section B-B′

Source: Modified from Fugro (2005)

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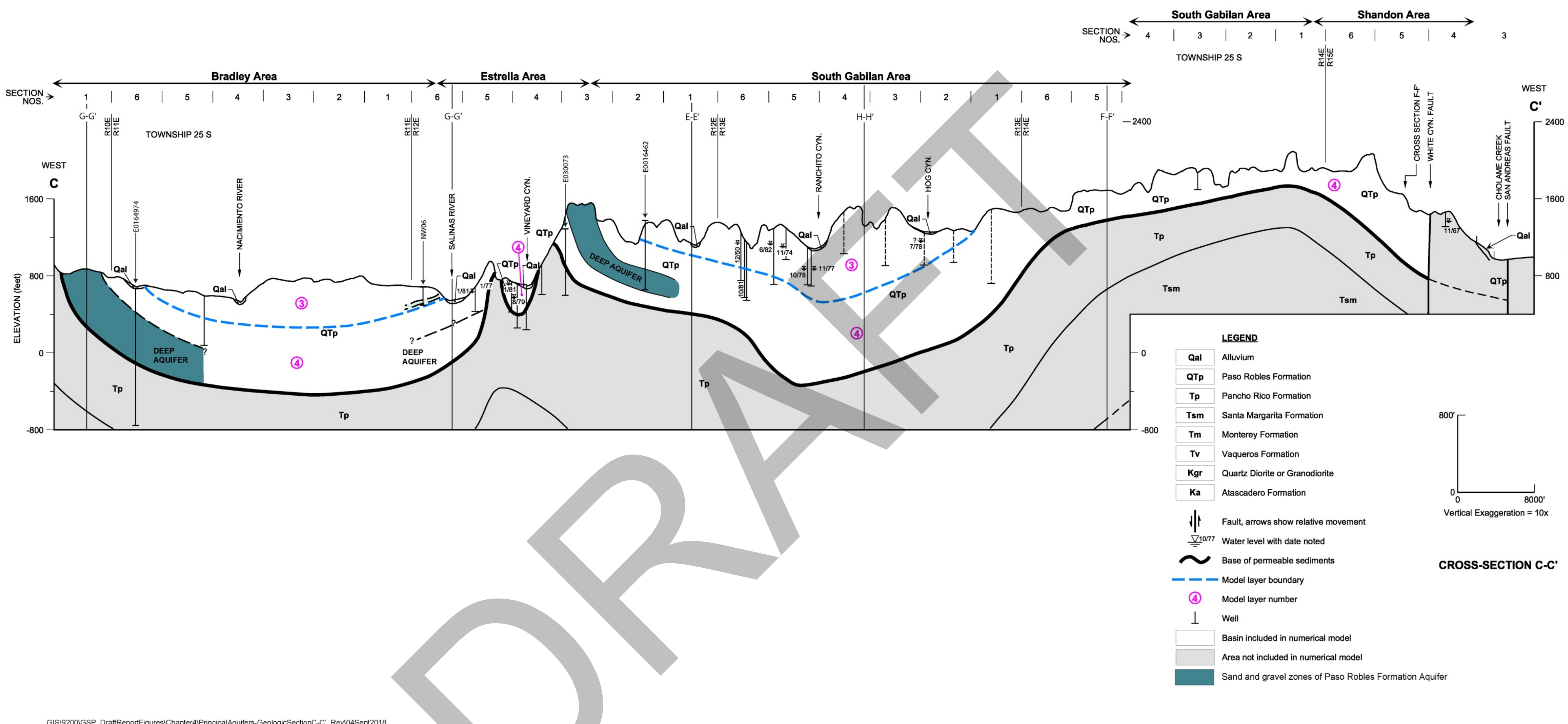

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Figure 4-13. Aquifers - Geologic Section C-C′

Source: Modified from Fugro (2005)

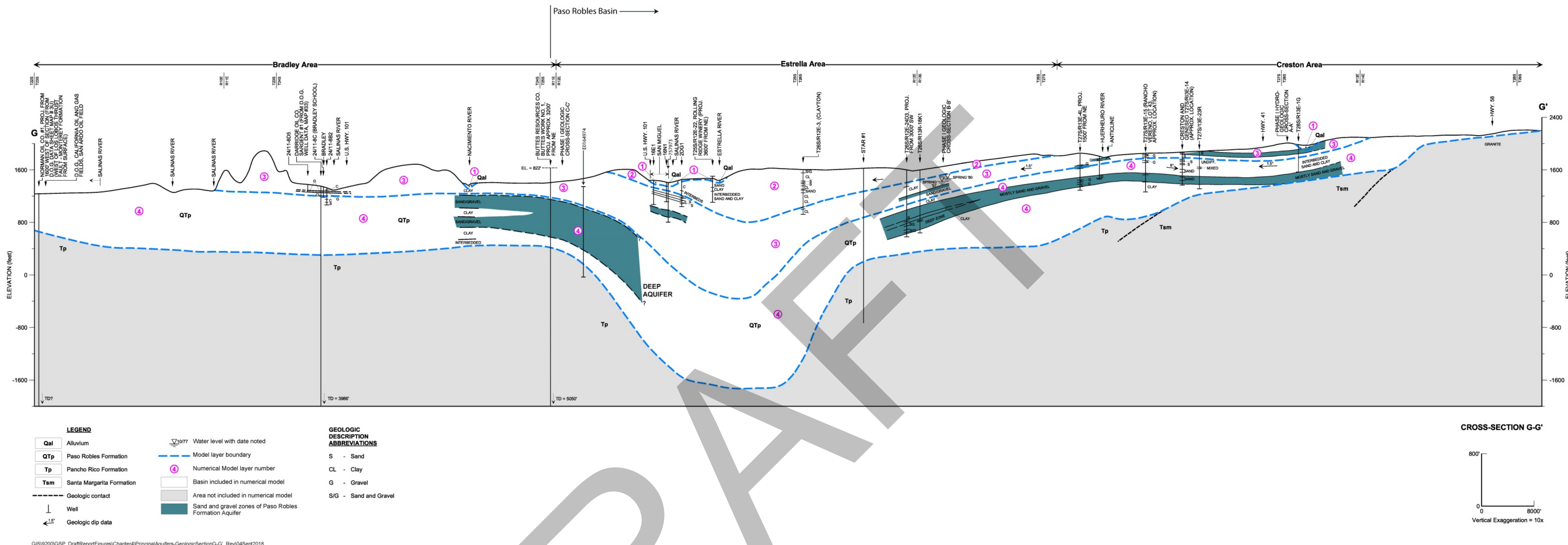

Figure 4-14. Aquifers - Geologic Section G-G'

Source: Modified from Fugro (2005)

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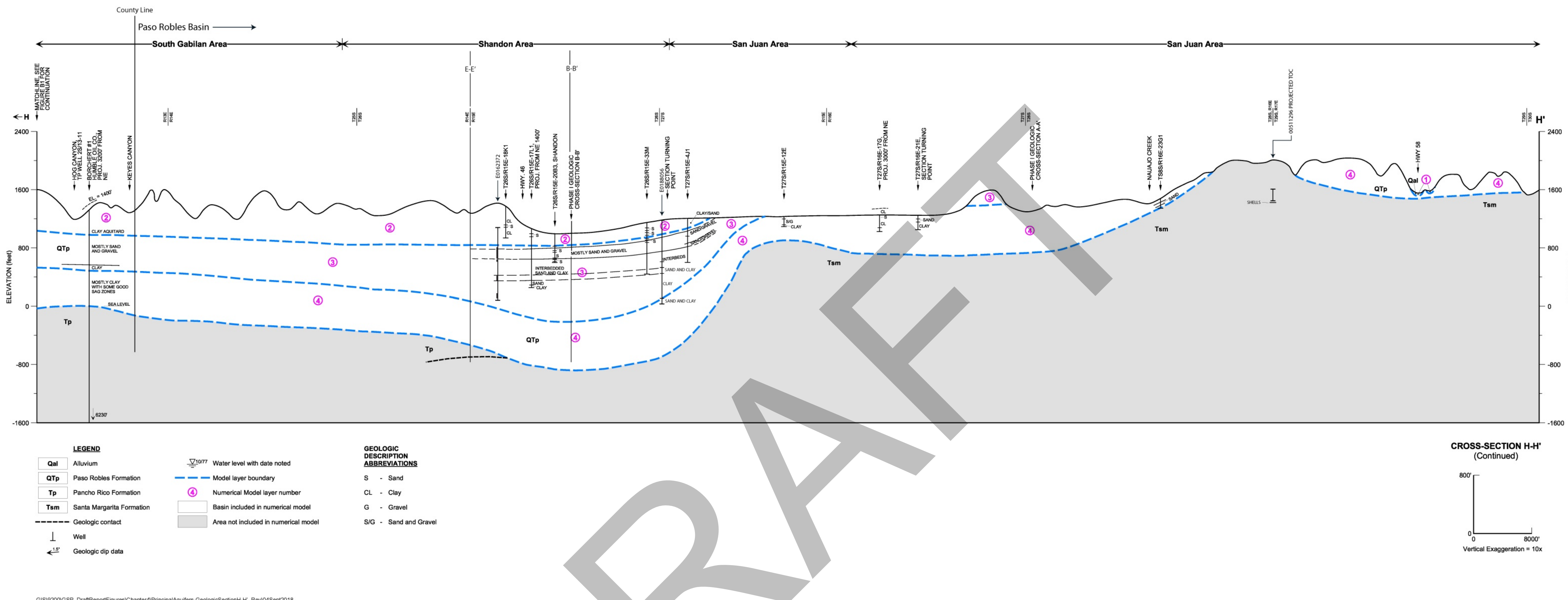

Figure 4-15. Aquifers - Geologic Section H-H'

Source: Modified from Fugro (2005)

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4.4.1 ALLUVIAL AQUIFER

The unconfined Alluvial Aquifer is generally composed of saturated coarse-grained sediments and occurs along Huer Huero Creek, the Salinas River, and the Estrella River; the extent of this aquifer is shown on Figure 4-4. The alluvial aquifer varies in thickness, but is generally about 100 feet thick. The Alluvial Aquifer is highly permeable. Wells screened in the alluvial aquifer can yield up to a 1,000 gpm (Fugro, 2005).

4.4.2 PASO ROBLES FORMATION AQUIFER

Geologic information reported in Fugro (2002) suggests that the sand and gravel zones that constitute the Paso Robles Formation Aquifer are generally thin, discontinuous, and are usually separated vertically by relatively thick zones of silts and clays. Figure 4-4 shows the extent of the Paso Robles Formation in the Subbasin. In general, the sand and gravel zones occur throughout the Paso Robles Formation, although they may be locally discontinuous or absent in some areas. As shown on Figure 4-14, near Creston the shallow sand and gravel zones appear to be disconnected from other parts of the Paso Robles aquifer by faults and structural folds. The shallow aquifer zone near Creston may be an isolated aquifer area.

4.4.3 AQUIFER PROPERTIES

Data reported in Fugro (2002) were reviewed to estimate representative aquifer hydraulic properties. Most aquifer tests have been conducted in the Estrella and Creston areas. Estimated aquifer properties are summarized in Table 4-1.

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Table 4-1. Paso Robles Subbasin Aquifer Hydrogeologic Properties

Well Location	Test Duration (hours)	Flow (gpm)	Well Depth (feet)	Perforated Interval	Transmissivity (gpd/ft)	Q/s (gpm/ft)	Hydraulic Conductivity (ft/day)
Alluvial Aquifer							
28S/13E-36	24	367	70	40	186,300	68	620
Paso Robles Formation Aquifer							
27S/12E-09	72	300	450	170	8,800	4.9	6.9
26S/12E-22	12	220	430	100	900	1.2	1.2
25S/11E-24	12	150	350	90	800	0.62	1.2
27S/12E-18	8	140	225	35	4,100	3	15.7
26S/12E-20	48	115	400	50	7,600	10	20
26S/12E-36	24	400	660	280	8,800	5.1	4.2
26S/12E-35	18	690	830	370	7,900	4.9	2.9
27S/14E-18	24	600	740	220	6,100	5.5	3.7
26S/13E-16	24	200	820	350	3,100	2.63	1.2
26S/12E-25	24	500	730	340	5,700	3.6	2.2
25S/13E-30	24	600	720	260	6,900	79	3.5
26S/13E-7	24	600	825	380	3,200	3	1.1
26S/13E-7	24	600	990	610	5,000	4.2	1.1
24S/11E-34	24	850	612	100	2,805	4.5	3.8

Source: Fugro, 2002

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Based on limited aquifer property data available for the Alluvial Aquifer, the transmissivity may be in the range of 150,000 to 200,000 gallons per day per foot (gpd/ft); or between 20,000 and 27,000 square feet per day (ft^2/day). Hydraulic conductivity of the Alluvial Aquifer may be over 500 feet per day (ft/d).

The estimated transmissivity of the Paso Robles Formation Aquifer ranges between 800 gpd/ft and about 9,000 gpd/ft; or between 100 and 1,200 ft^2/day. The geometric mean of the tabulated transmissivity values for the shallow aquifer zone is about 3,500 gpd/ft, or 470 ft^2/day.

The estimated hydraulic conductivity of the Paso Robles Formation Aquifer ranges from about 1 ft/d to about 20 ft/d. The geometric mean of the tabulated hydraulic conductivity values for the Paso Robles Formation Aquifer is 5 ft/d.

Limited data exist to assess the confined storage properties, such as storativity, of the Paso Robles Formation aquifer (Fugro, 2002). Table 4-2 summarizes reported estimates of specific yield for unconfined portions of the aquifers. Average specific yield was estimated by analyzing 10 to 20 of the deepest well completion logs for each area. Each lithologic interval was assigned a specific yield by comparison of the formation description with published estimates based on extensive field and laboratory investigations conducted in southern coastal basins by the DWR and modified for the Paso Robles Formation (DWR, 1958). The assigned specific yield was then weighted according to the thickness of each bed and averaged over the entire depth of the well (Fugro, 2002). Results of this analysis suggested that a representative average value for specific yield for the Paso Robles Formation in the Subbasin was 0.09. This specific yield may be low. Average specific yields for unconsolidated sand and gravel sedimentary aquifers are commonly between 0.1 and 0.3 (Driscoll, 1986).

Table 4-2. Paso Robles Subbasin Specific Yield Estimates

Area	Number of Wells Used to Calculate	Average Estimated Specific Yield
Creston Area	47	0.09
Estrella	20	Not provided
San Juan	5	0.10
Shandon	20	0.08
North and South Gabilan	20	0.09
Basin Wide Average		**0.09**

Estimates of vertical hydraulic conductivity for each of the aquifers were not in reports from previous studies for the Subbasin. Estimates of vertical hydraulic conductivity incorporated into the basin-wide groundwater model are discussed in an appendix to Chapter 6.

4.4.4 Confining Beds and Geologic Structures

There is limited information regarding the continuity of stratigraphic features in the Subbasin that restrict groundwater flow within the Subbasin. Conceptually, the presence of laterally continuous zones of fine-grained strata within the Paso Robles Formation can restrict vertical movement of groundwater. These fine-grained zones are generally shown on the sections on Figure 4-12 through Figure 4-15. These figures show that the fine-grained strata are likely more continuous than the sand and gravel layers. These fine-grained zones act as confining beds, and are the cause of the artesian wells that were historically reported in the Subbasin. Fine-grained layers that limit vertical movement of groundwater appear to be more prevalent in the Estrella and Creston areas than in the eastern portion of the Shandon area. This may indicate that infiltration and recharge is more limited to the west.

There is some anecdotal evidence that subsurface geologic structures such as folds and faults may affect groundwater flow in the Subbasin. Additional investigations would be needed to characterize the effect of structures on groundwater flow.

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4.5 PRIMARY USERS OF GROUNDWATER

The primary groundwater users in the Subbasin include municipal, agricultural, rural residential, small community water systems, and small commercial entities. Municipal, domestic, and agricultural demands in the Subbasin currently rely almost entirely on groundwater. The municipal sector pumps primarily from the Paso Robles Aquifer. The agriculture sector uses groundwater from the Alluvial Aquifer and the Paso Robles Aquifer.

4.6 GENERAL WATER QUALITY

This section presents a general discussion of the natural groundwater quality in the Subbasin, focusing on general minerals. The general water quality of the Subbasin described in this section is a summary of results in the Fugro 2002 report. A more complete discussion of the distribution and concentrations of specific constituents is presented in Chapter 5: Current Conditions.

Groundwater in the Subbasin is generally suitable for drinking and agricultural uses. The two main water types found in the Subbasin are calcium bicarbonate and sodium bicarbonate. Calcium-bicarbonate type is the most prominent and is found in the Creston and San Juan areas. Sodium-bicarbonate is the second most dominant water type and is found in the Estrella and Shandon areas. Minor areas of sodium-chloride type water can be found in the eastern portion of the Subbasin and near Cholame Valley. In the northwest portion of the Subbasin, magnesium bicarbonate waters are found in the San Miguel area and a mixed water type is seen in the Bradley area. A summary of general water quality as indicated by average total dissolved solids (TDS), chloride (Cl), and nitrate (NO3) concentrations in groundwater is provided in Table 4-4 (Fugro 2002).

Table 4-3. Summary of General Water Quality by Area

Area	TDS (ppm)			Cl (ppm)			NO3 (ppm)		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Creston	490	190	1620	112	25	508	16	2	41
San Juan	753	160	2170	162	13	699	18	ND[1]	56
Shandon	606	270	1610	110	31	451	13	5.6	35
Estrella	624	350	1270	126	32	572	9	ND	30
Bradley	897	400	1280	131	40	400	14	ND	55
Gabilan	745	370	1320	87	38	209	39	11	71

[1]ND = Non-detect. For the purpose of computing an average, half the detection limit was used.

4.7 Groundwater Recharge and Discharge Areas

Areas of significant, natural, areal recharge and discharge within the Paso Robles Subbasin are discussed below. Quantitative information about all natural and anthropogenic recharge and discharge is provided in Chapter 6: Water Budgets.

4.7.1 Groundwater Recharge Areas Inside The Subbasin

In general, natural areal recharge occurs via the following processes:

1. Distributed areal infiltration of precipitation, and
2. Infiltration of surface water from streams and creeks.

Figure 4-16 is a map that ranks soil suitability to accommodate groundwater recharge based on five major factors that affect recharge potential, including: deep percolation, root zone residence time, topography, chemical limitations, and soil surface condition. The map[1] was developed by the California Soil Resource Lab at UC Davis and the University of California Agricultural and Natural Resources Department.

Areas with excellent recharge properties are shown in green. Areas with poor recharge properties are shown in red. Not all land is classified, but this map provides good guidance on where natural recharge likely occurs.

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[1] Figure 4-16 shows the Soil Agricultural Groundwater Banking Index (SAGBI) map for the Paso Robles Subbasin. While the UC Davis database title SAGBI includes the term “banking”, its use in this section is strictly as a dataset for evaluating recharge potential in the basin.

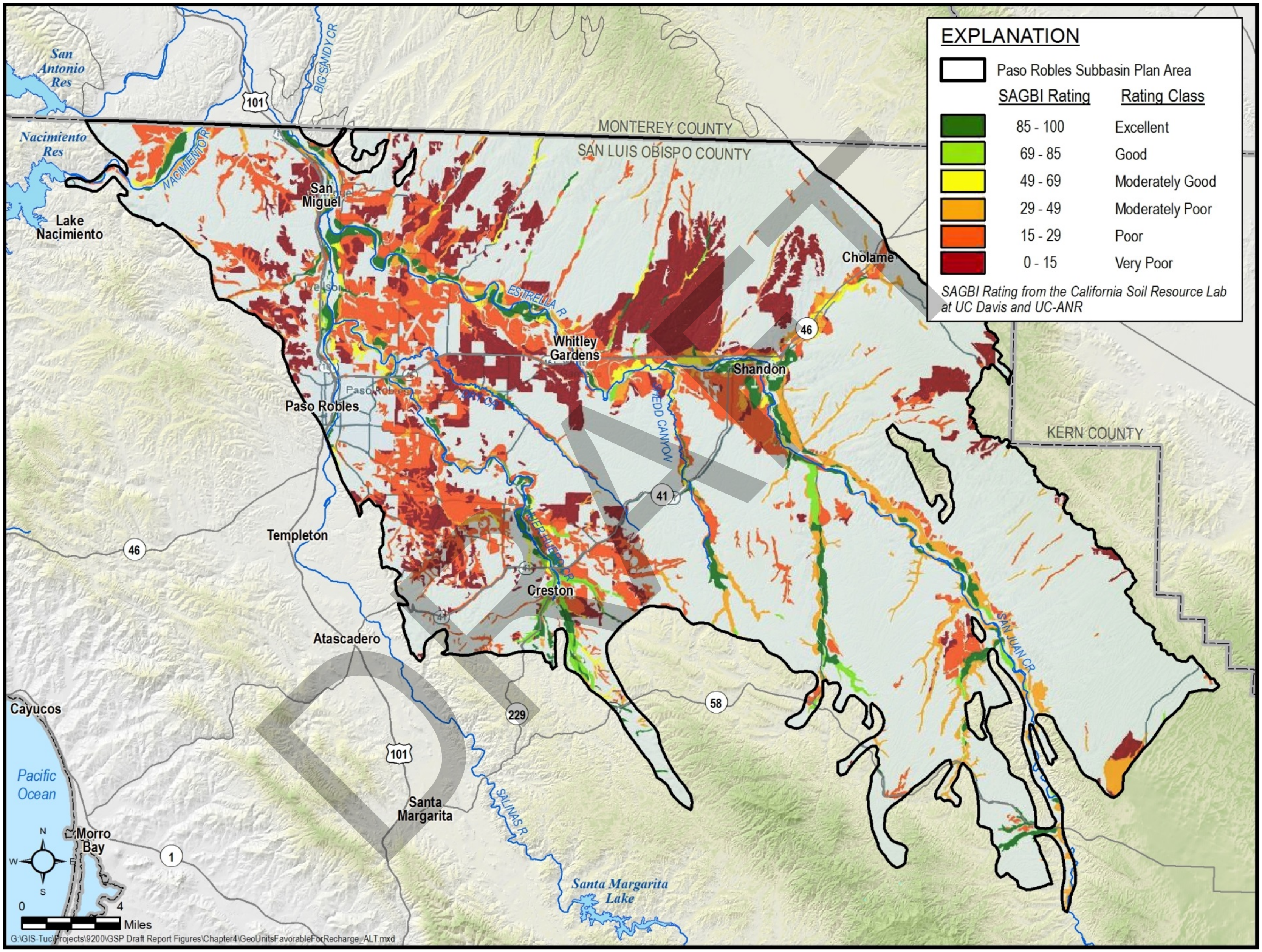

Figure 4-16. Potential Recharge Areas

4.7.2 GROUNDWATER DISCHARGE AREAS INSIDE THE SUBBASIN

Natural groundwater discharge areas within the Plan area include springs and seeps, groundwater discharge to surface water bodies, and evapotranspiration (ET) by phreatophytes. Springs and seeps identified in the National Hydrology Dataset (NHD), and shown on Figure 4-17, tend to be located in the foothills of the Santa Lucia and Temblor mountain ranges. Based on the elevation of mapped springs and seeps, it is likely that these discharge groundwater from shallow, and possibly perched aquifer units. Groundwater discharge to streams – primarily, the Salinas River and Estrella River – has not been mapped to date. Instead, areas of potential groundwater discharge to streams are identified using the groundwater flow model. Orange areas on Figure 4-17 represent streams in the model where simulated average groundwater discharge to the stream reach is at least 10 acre-feet per year. In contrast to mapped springs and seeps, which are derived from groundwater in the Paso Robles Formation, groundwater discharge to streams is derived from the Alluvium.

Figure 4-18 shows the distribution of potential groundwater-dependent ecosystems (GDEs) and Natural Communities Commonly Associated with Groundwater (NCCAG) within the Plan area. In areas where the water table is sufficiently high, groundwater discharge may occur as ET from phreatophyte vegetation within these GDEs. Appendix 4B describes methods used to determine the extent and type of potential GDEs. Figure 4-18 shows only potential GDEs. There has been no verification that the locations shown on this map constitute groundwater dependent ecosystems. Additional field reconnaissance is necessary to verify the existence of these potential GDEs.

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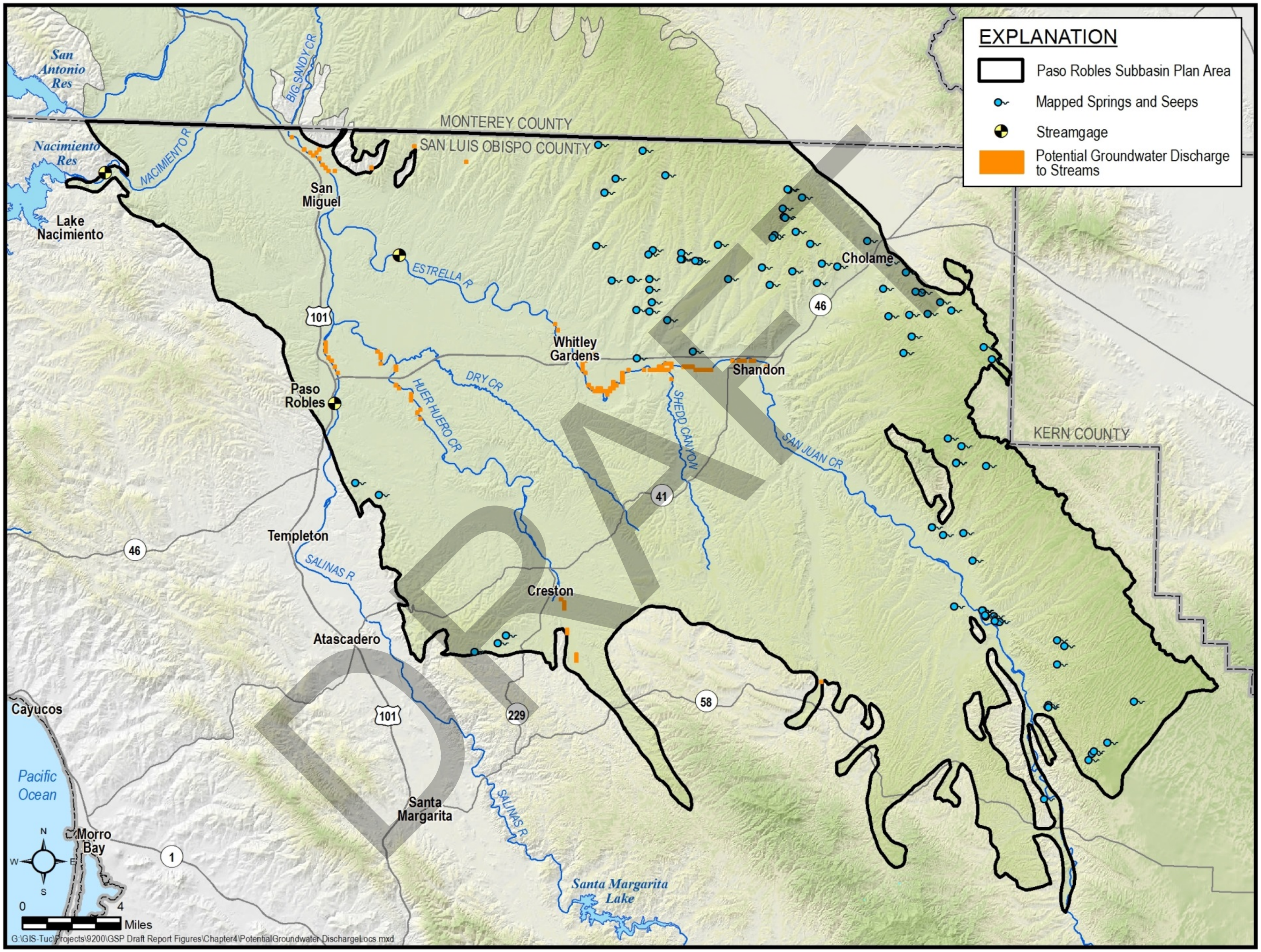

Figure 4-17. Potential Groundwater Discharge Areas

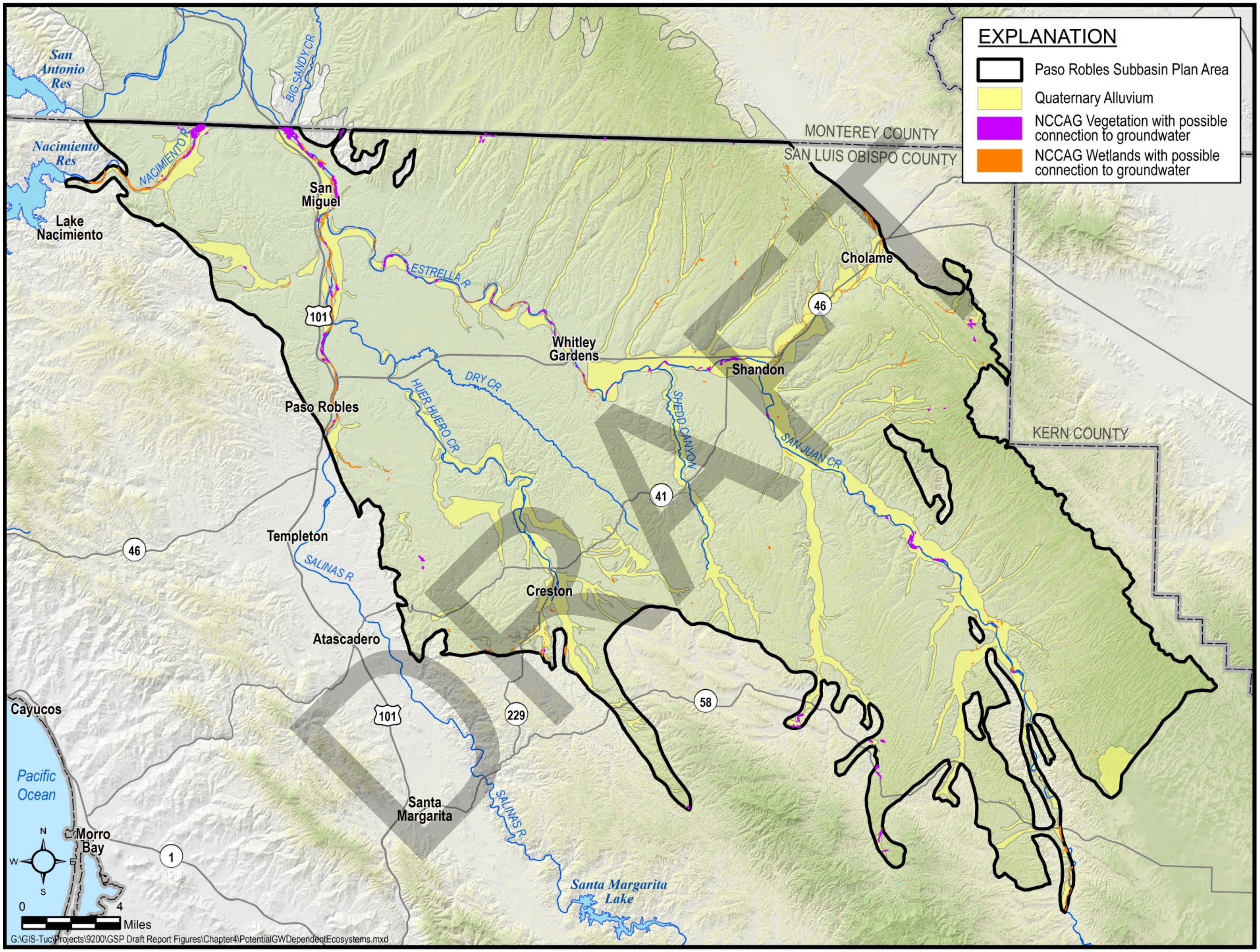

Figure 4-18. Potential Groundwater- Dependent Ecosystems

4.8 SURFACE WATER BODIES

Figure 4-19 shows the rivers in the Subbasin that are considered significant to the management of groundwater in the Subbasin. Significant streams in the Subbasin include the Salinas River, the Estrella River, Huer Huero Creek, San Juan Creek, Dry Creek, and Shedd Canyon. These rivers and creeks are ephemeral, and during most of the year the streams lose water to the shallow aquifers. A complete description and quantification of the stream/aquifer interaction is included in Chapters 5 and 6. There are no natural lakes in the Subbasin.

There are no reservoirs within the Subbasin; however, there are two reservoirs in the watershed. The Salinas Dam south of the Subbasin on the Salinas River forms Santa Margarita Lake. The Salinas Dam was constructed in the early 1940s as an emergency measure to provide adequate water supplies for Camp San Luis Obispo. The United States Army Corps of Engineers (USACE) now has jurisdiction over the dam and reservoir facilities. The City of San Luis Obispo has an agreement with USACE to divert the entire yield of Santa Margarita Reservoir for water supply. Nacimiento Reservoir lies just outside of the Subbasin to the northwest. The reservoir discharges to the Nacimiento River, which crosses the northwest corner of the Subbasin.

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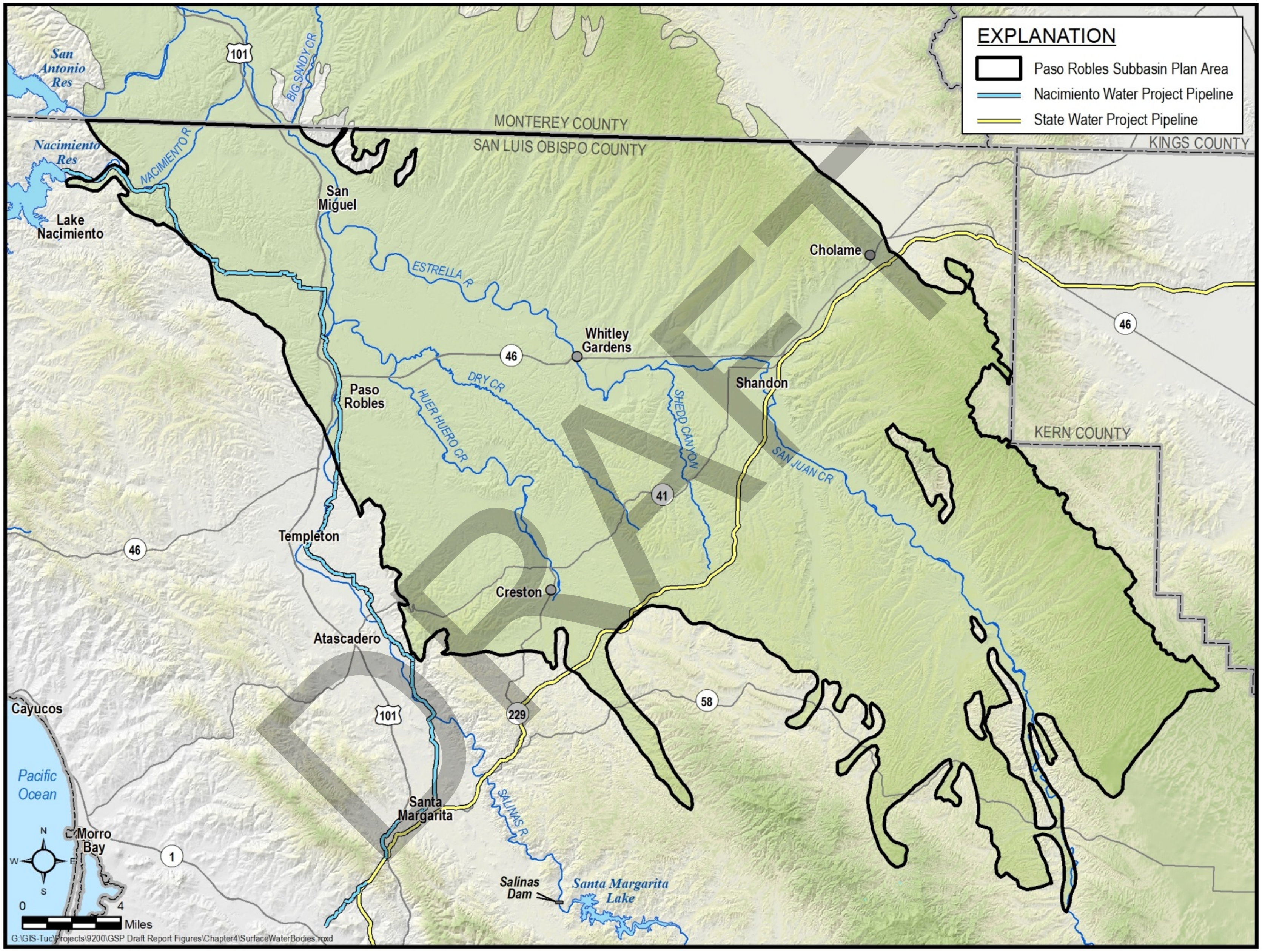

Figure 4-19. Surface Water Bodies

4.9 Data Gaps in the Hydrogeologic Conceptual Model

All hydrologic conceptual models contain a certain amount of uncertainty, and can be improved with additional data and analysis. The hydrogeologic conceptual model of the Paso Robles Subbasin could be improved with certain additional data and analyses. Several data gaps are identified below.

Aquifer Continuity

Aquifer continuity has a significant impact on how projects and management actions in one part of the Subbasin may influence sustainability in other parts of the Subbasin. As noted earlier, the Paso Robles aquifer comprises many discontinuous sand and gravel beds. However, Figure 4-12 shows a previous interpretation of a deep sand and gravel zone that is relatively continuous across the Subbasin. The continuity of this zone may prove to be important in how effective various projects and programs may promote sustainability. The extent and continuity of the Paso Robles Aquifer should be confirmed through existing or new well logs or other methods such as aerial geophysics. This is particularly important in the areas around Shandon and San Juan.

Fault Influence on Groundwater Flow

Southeast of the City of Paso Robles is an interbasin fault. It is unknown whether this fault and others are barriers to groundwater flow. If these interbasin faults are barriers to groundwater flow, they could compartmentalize the Subbasin and have a significant impact on where projects must be located in order to achieve sustainability. It may be possible to get a better understanding of the influence of these faults by performing aquifer tests and geophysical surveys in the vicinity of these faults.

Vertical Groundwater Gradients

There are no nested wells to demonstrate vertical hydraulic gradients. Demonstrating vertical gradients could be important to assess vertical flows between the Alluvium and the Paso Robles Aquifer as well as vertical flows within the Paso Robles Aquifer.

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