Chapter 6
Groundwater Resources

This chapter presents the existing conditions of groundwater resources within the area of analysis and discusses potential effects of the proposed alternatives on groundwater levels, land subsidence, and groundwater quality.

6.1 Affected Environment

This section presents the area of analysis, describes the regulatory setting pertaining to groundwater resources in the area of analysis, and describes the existing hydrologic and groundwater characteristics in the area of analysis.

6.1.1 Area of Analysis

The area of analysis consists of the following groundwater basins/subbasins which are subdivided by hydrologic regions as defined by the California Department of Water Resources (DWR):

- Sacramento River Hydrologic Region: Redding Area Groundwater Basin; Sacramento Valley Groundwater Basin (in the north of the Sacramento-San Joaquin River Delta [Delta] geographic region)
- San Joaquin River Hydrologic Region: San Joaquin Valley Groundwater Basin (Northern Potion) (generally in the south of Delta geographic region)
- Tulare Lake Hydrologic Region: San Joaquin Valley Groundwater Basin (Southern Portion); Panoche Valley Groundwater Basin (in the south of the Delta geographic region)
- San Francisco Bay/Central Coast Hydrologic Region: Santa Clara Valley Groundwater Basin; Bitter Water Valley Groundwater Basin; Gilroy-Hollister Valley Groundwater Basin; San Benito Valley Groundwater Basin, Pajaro Valley Groundwater Basin (generally in the south of the Delta geographic region)

Figure 6-1 shows the area of analysis and the groundwater basins subdivided by the hydrologic region.

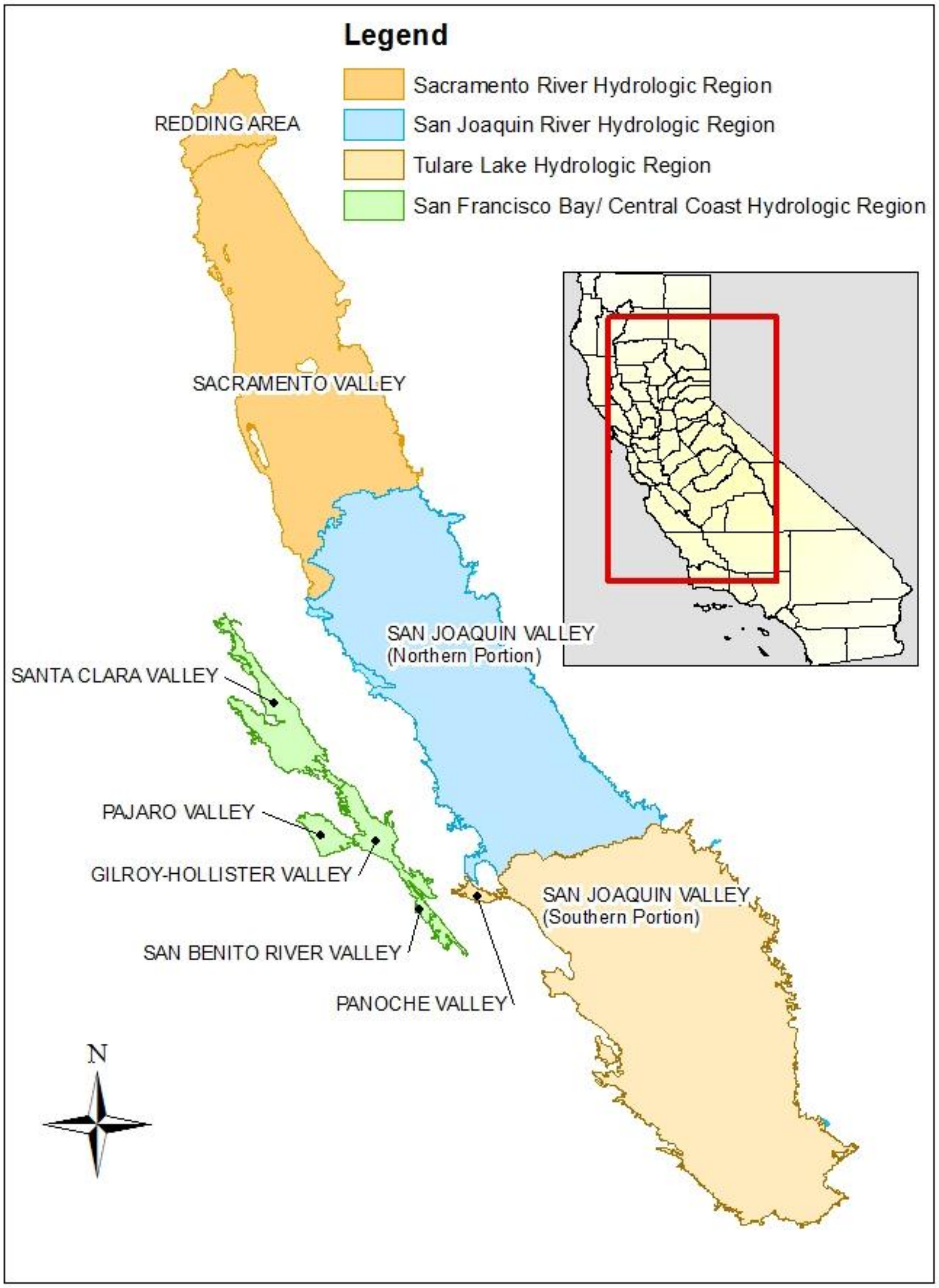


Figure 6-1. Groundwater Basins within the Area of Analysis

6.1.2 Regulatory Setting

This section describes the applicable laws, rules, regulations and policies relating to groundwater resources.

6.1.2.1 Federal Regulations

The Bureau of Reclamation (Reclamation) approves water transfers consistent with provisions of the Central Valley Project Improvement Act (CVPIA) and State of

California (State) law that protect against injury to third parties. According to the CVPIA Section 3405, the following principles must be satisfied for any transfer:

- Transfer may not violate the provisions of Federal or State law;
- Transfer may not cause significant adverse effects on Reclamation's ability to deliver Central Valley Project (CVP) water to its contractors or other legal user;
- Transfer will be limited to water that would be consumptively used or irretrievably lost to beneficial use;
- Transfers cannot exceed the average annual quantity of water under contract actually delivered; and
- Transfer will not adversely affect water supplies for fish and wildlife purposes.

Reclamation will not approve a water transfer if these basic principles are not satisfied and will issue its decision regarding potential CVP transfers in coordination with the United States (U.S.) Fish and Wildlife Service, contingent upon the evaluation of impacts on fish and wildlife.

6.1.2.2 State Regulations

All water use in California is subject to constitutional provisions that prohibit waste and unreasonable use of water (State Water Resources Control Board [SWRCB] n.d.). In general, groundwater is subject to a number of provisions in the California Water Code (Water Code). Some of these provisions are listed below:

Water Code (Section 10750) or Assembly Bill 3030 Assembly Bill 3030 (AB 3030), commonly referred to as the Groundwater Management Act, permits local agencies to develop Groundwater Management Plans (GMPs) that cover certain aspects of management. Subsequent legislation has amended this chapter to make the adoption of a management program mandatory if an agency is to receive public funding for groundwater projects, creating an incentive for the development and implementation of plans.

Water Code (Section 10753.7) or Senate Bill 1938 Senate Bill 1938 (SB 1938), requires local agencies seeking State funds for groundwater well construction or groundwater quality projects to have the following: 1) a developed and implemented GMP that includes basin management objectives[1] (BMOs) and addresses the monitoring and management of groundwater levels, groundwater quality degradation, inelastic land subsidence, and surface water/ groundwater interaction; 2) a plan addressing cooperation and working relationships with other public entities; 3) a map showing the groundwater subbasin the project is in, neighboring local agencies, and the area subject to the GMP; 4)

[1] BMOs are management objectives that define the acceptable range of groundwater levels, groundwater quality, and inelastic land subsidence that can occur in a local area without causing significant adverse impacts.

protocols for the monitoring of groundwater levels, groundwater quality, inelastic land subsidence, and groundwater/surface water interaction; and 5) GMPs with the components listed above for local agencies outside the groundwater subbasins delineated by DWR Groundwater Bulletin 118, published in 2003 (DWR 2003).

Water Code (Section 10920-10936 and 12924) or SB X7 6 SB X7 6 established a voluntary statewide groundwater monitoring program and requires that groundwater data collected be made readily available to the public. The bill requires DWR to: 1) develop a statewide groundwater level monitoring program to track seasonal and long-term trends in groundwater elevation; 2) conduct an investigation of the State's groundwater basins delineated by DWR Bulletin 118 and report its findings to the Governor and Legislature no later than January 1, 2012 and thereafter in years ending in five or zero; and 3) work cooperatively with local Monitoring Entities to regularly and systematically monitor groundwater elevation to demonstrate seasonal and long-term trends. AB 1152 (Amendment to Water Code Section 10927, 10932, and 10933), allows local Monitoring Entities to propose alternate monitoring techniques for basins meeting certain conditions and requires submittal of a monitoring plan to DWR for evaluation.

Water Code (Section 10927, 10933, 12924, 10750.1 and 10720) or SB 1168 SB 1168 requires the establishment of Groundwater Sustainability Agencies (GSA) and adoption of Groundwater Sustainability Plans (GSP). GSAs must be formed by June 30, 2017. GSAs are new entities that consist of local agency(ies) and include new authority to: 1) investigate and determine the sustainable yield of a groundwater basin; 2) regulate groundwater extractions; 3) impose fees for groundwater management; 4) require registration of groundwater extraction facilities; 5) require groundwater extraction facilities to use flow measurement devices; and 6) enforce the terms of a GSP.

GSPs for groundwater basins designated by DWR as high- and medium-priority with critical overdraft conditions (per SB X7 6) are required to be developed by January 31, 2020. GSPs for the remaining high- and medium-priority groundwater basins are to be developed by January 31, 2022. GSPs are encouraged to be developed for groundwater basins prioritized as low- or very low-priority (Pavley 2014a). All high- and medium-priority basins must achieve sustainability within 20 years of adopting a GSP.

Water Code (Section 10729, 10730, 10732, 10733 and 10735) or AB 1739 AB 1739 establishes the following: 1) provides the specific authorities to a GSA (as defined by SB 1168); 2) requires DWR to publish best management practices for the sustainable management of groundwater by January 1, 2017; and 3) requires DWR to estimate and report the amount of water available for groundwater replenishment by December 31, 2016. The bill authorizes DWR to approve and periodically review all GSPs (Dickinson 2014).

The bill authorizes the SWRCB to: 1) conduct inspections and obtain an inspection warrant; 2) designate a groundwater basin as a probationary groundwater basin; 3) develop interim plans for probationary groundwater basins in consultation with DWR if the local agency fails to remedy a deficiency resulting in the designation of probationary;

and 4) issue cease and desist orders or violations of restrictions, limitations, orders, or regulations issued under AB 1739 (Dickinson 2014).

Water Code (Section 10735.2 and 10735.8) or SB 1319 SB 1319 would authorize the SWRCB to designate high- and medium-priority basins (defined by SB 1168) as a probationary basin after January 31, 2025. This bill allows the SWRCB to develop interim management plans that may override a local agency. However, if the appointed GSA can demonstrate compliance with sustainability goals for the basin, then the SWRCB has to exclude the groundwater basin or a portion of the groundwater basin from probationary status (Pavley 2014b).

Other Groundwater Regulations Groundwater quality issues are monitored through a number of different legislative acts and are the responsibility of several different State agencies including:

- SWRCB and nine Regional Water Quality Control Boards – responsible for protecting water quality for present and future beneficial use;
- SWRCB Division of Drinking Water (DDW, formerly California Department of Public Health) - responsible for drinking water supplies and standards;
- California Department of Toxic Substances Control - responsible for protecting public health from improper handling, storage, transport, and disposal of hazardous materials;
- California Department of Pesticide Regulation - responsible for preventing pesticide pollution of groundwater;
- California Integrated Waste Management Board - oversees non-hazardous solid waste disposal, and
- California Department of Conservation - responsible for preventing groundwater contamination due to oil, gas, and geothermal drilling and related activities.

6.1.2.3 Regional/Local

Local groundwater management plans and county ordinances vary by authority/agency and region, but typically involve provisions to limit or prevent groundwater overdraft, regulate transfers, and protect groundwater quality.

AB 3030, the Groundwater Management Act, encourages local water agencies to establish local GMPs. The Groundwater Management Act lists 12 elements that should be included within the plans to ensure efficient groundwater use, good groundwater quality, and safe production of water. Table 6-1 lists the current GMPs that apply to CVP contractors subject to the Municipal and Industrial Water Shortage Policy (M&I WSP).

Table 6-1. Local Groundwater Management Plans and Ordinances

Hydrologic Region	Groundwater Basins	Groundwater Management Plans, (GMPs or GWMPs), Agreements and County Ordinances
Sacramento River Hydrologic Region	Redding Area	• Coordinated GMP for the Redding Groundwater Basin
	Sacramento Valley	• Coordinated AB 3030 GMP (Tehama County Flood Control & Water Conservation District) • Glenn County GMP • Colusa County GMP • Dunnigan Water District GMP • Sacramento Groundwater Authority GMP • Sacramento County WA GMP • Central Sacramento County GMP • GWMP of Feather Water District • Martis Valley GWMP • Western Placer County GWMP
San Joaquin River/Tulare Lake Hydrologic Region	San Joaquin Valley	• Tracy Regional GMP • GMP for the Northern Agencies in the Delta-Mendota Canal Service Area and a Portion of San Joaquin County • Amended GMP for James Irrigation District • Westlands Water District GMP • GMP for Orange Cove Irrigation District, Tri Valley Water District, Hills Valley Irrigation
San Francisco Bay/Central Coast Hydrologic Region	Santa Clara Valley	• South East Bay Plain Basin GMP • Santa Clara Valley Water District (SCVWD) GMP
	Gilroy-Hollister Valley Groundwater	• Final Program-Environmental Impact Report-GMP Update for the San Benito County Portion of the Gilroy-Hollister Valley Groundwater Basin • Revised Basin Management Plan

Source: DWR 2008b

6.1.3 Existing Conditions

6.1.3.1 Sacramento River Hydrologic Region

Redding Area Groundwater Basin The Redding Area Groundwater Basin is in the northernmost part of the Central Valley. Underlying Tehama and Shasta Counties, it is bordered by the Klamath Mountains to the north, the Coast Range to the west, and the Cascade Mountains to the east. Red Bluff Arch separates the Redding Area Groundwater Basin from the Sacramento Valley Groundwater Basin to the south. DWR Bulletin 118 subdivides the Redding Area Groundwater Basin into six subbasins (DWR 2003). Figure 6-2 shows the Redding Area Groundwater Basin and subbasins. The following section provides information on geology, hydrogeology, hydrology, groundwater production, groundwater levels and storage, land subsidence, and groundwater quality.

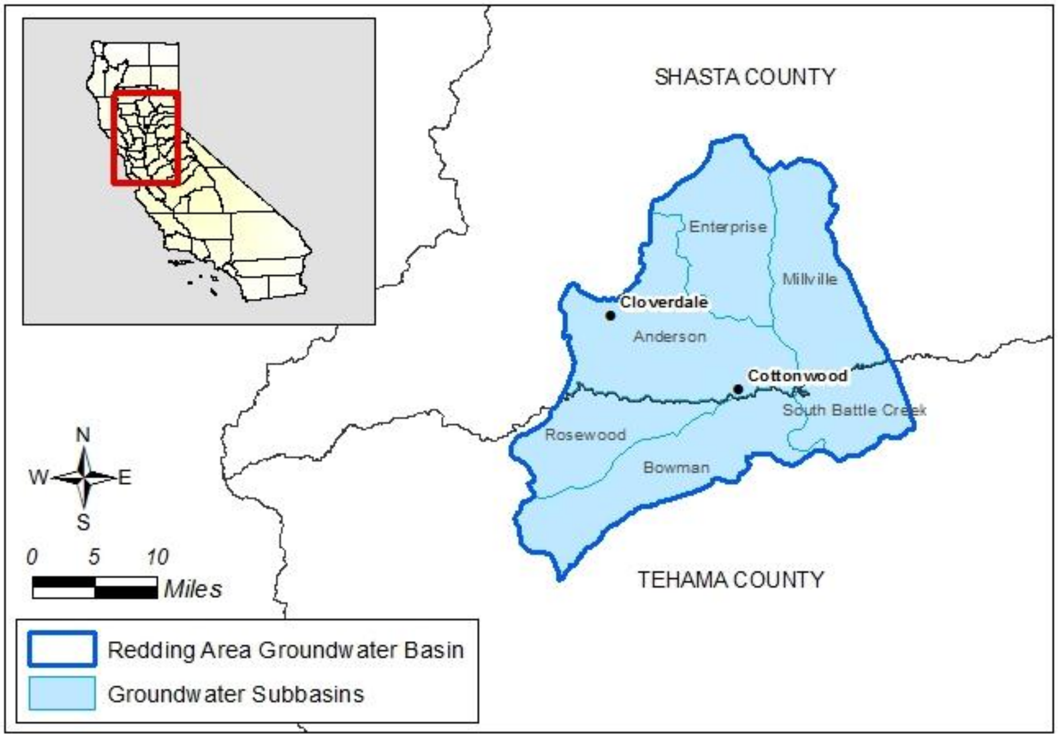


Figure 6-2. Redding Area Groundwater Basin and Subbasins

Geology, Hydrogeology, and Hydrology The Redding Area Groundwater Basin consists of a sediment-filled, southward plunging symmetrical trough (Shasta County Water Agency 2007). Concurrent deposition of material from the Coast Range and the Cascade Range resulted in two different formations, which are the principal freshwater-bearing formations in the basin. Geology of the Redding Area Groundwater Basin is similar to the geology in the northern portion of the Sacramento Valley Groundwater Basin (shown in Figure 6-6). The Tuscan Formation in the east is derived from the Cascade Range volcanic sediments, and the Tehama Formation in the western and northwest portion of the basin is derived from Coast Range sediments. These formations are up to 2,000 feet thick near the confluence of the Sacramento River and Cottonwood Creek. The Tuscan Formation is generally more permeable and productive than the Tehama Formation (Shasta County Water Agency 2007).

As illustrated in Figure 6-3, groundwater in the Redding Area Groundwater Basin generally flows southeasterly on the west side of the basin and southwesterly on the east side, toward the Sacramento River. The Sacramento River is the main drain for the basin (DWR Northern District 2002). The Shasta County Water Resources Master Plan Phase 1 Report estimated the total annual groundwater discharge to rivers and streams at about 266 thousand acre-feet (TAF), and seepage from streams and canals into groundwater at 59 and 44 TAF, respectively (CH2MHill 1997). Groundwater is typically unconfined to semi-confined in the shallow aquifer system and confined where deeper aquifers are present. Surface water and groundwater interact in many areas in the Redding Area

Groundwater Basin. The principal surface water features in the Redding Area Groundwater Basin are the Sacramento River and its tributaries: Battle Creek, Cow Creek, Little Cow Creek, Clear Creek, Dry Creek, and Cottonwood Creek.

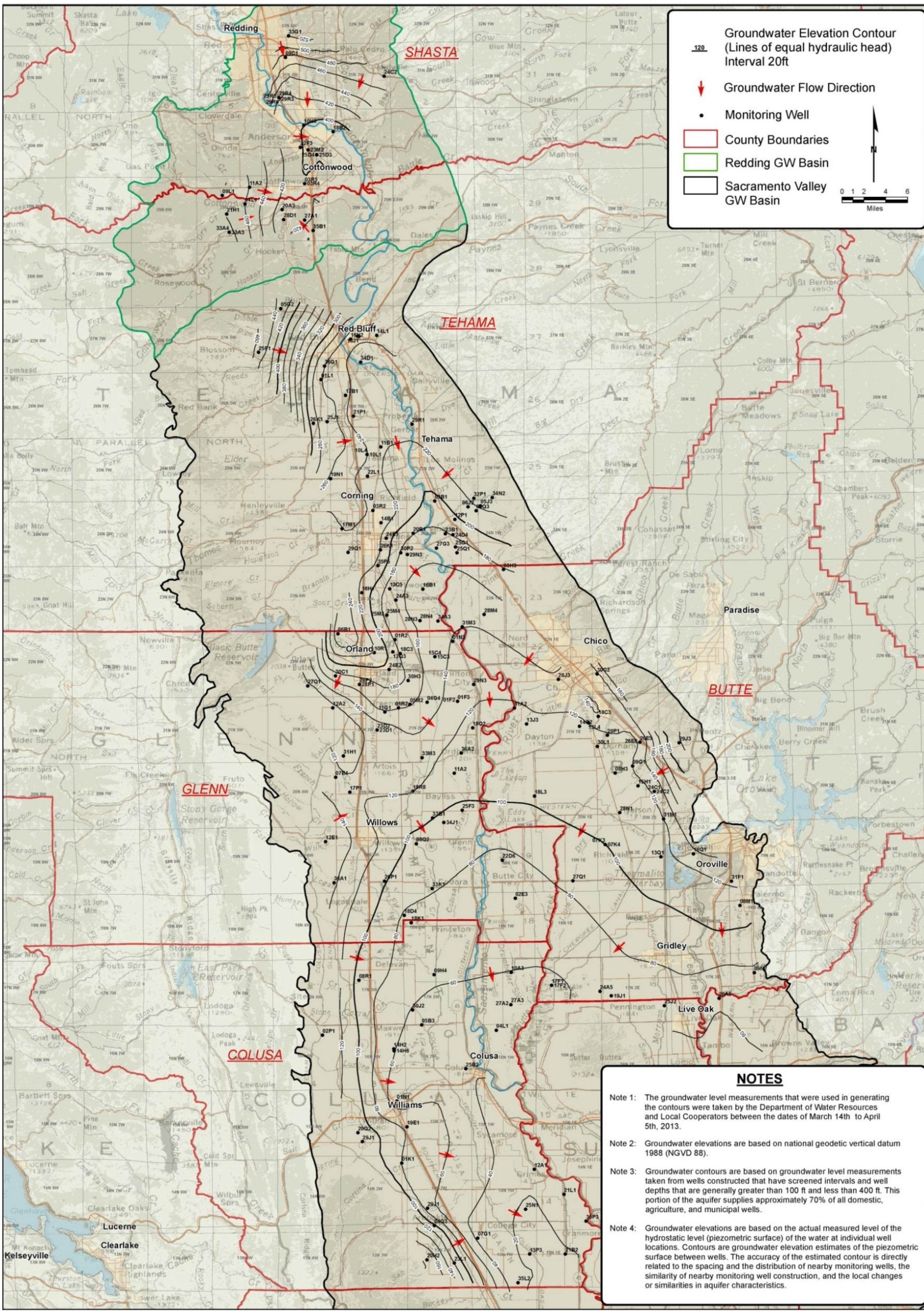
Groundwater Production, Levels and Storage The Redding Area Groundwater Basin water resources management plan estimates the watersheds overlying the Redding Basin yield an average of 850 TAF of annual runoff (CH2M HILL 2003). Applied irrigation water (from all sources) totals approximately 270 TAF annually in the Redding Area Groundwater Basin (CH2M HILL 1997). It has been estimated that approximately 55 TAF per year of water is pumped from M&I and agricultural production wells (CH2M HILL 2003). This magnitude of pumping represents approximately six percent of the average annual runoff.

Figure 6-3 shows spring 2013 groundwater elevation contours within the Redding Area Groundwater Basin. The storage capacity for the entire Redding Area Groundwater Basin is estimated to be 5.5 million acre-feet (AF) for 200 feet of saturated thickness over an area of approximately 510 square miles (Pierce 1983 as cited in DWR 2003).

Groundwater-Related Land Subsidence Land subsidence has not been monitored in the Redding Area Groundwater Basin. However, there would be potential for subsidence in some areas of the basin if groundwater levels decline below historic low levels. The groundwater basin west of the Sacramento River is composed of the Tehama Formation; this formation has exhibited subsidence in Yolo County and because of the similar hydrogeologic characteristics, the Redding Area Groundwater Basin could be susceptible to land subsidence.

Groundwater Quality Groundwater in the Redding Area Groundwater Basin is typically of good quality, as evidenced by its low total dissolved solids (TDS) concentrations, which range from 70 to 360 milligrams per liter (mg/L). Areas of high salinity (poor water quality), are generally found on the western basin margins, where the groundwater is derived from marine sedimentary rock. Elevated levels of iron, manganese, nitrate, and high TDS have been detected in some areas. Localized high concentrations of boron have been detected in the southern portion of the basin (DWR Northern District 2002).

Sacramento Valley Groundwater Basin The Sacramento Valley Groundwater Basin includes portions of Butte, Colusa, Glenn, Placer, Sacramento, Sutter, Solano, Tehama, Yuba, and Yolo counties. The Sacramento Valley Groundwater Basin is bordered by the Red Bluff Arch to the north, the Coast Range to the west, the Sierra Nevada to the east, and the San Joaquin Valley to the south. Bulletin 118 further divides the Sacramento Valley Groundwater Basin into subbasins (DWR 2003). Figure 6-4 shows the Sacramento Valley Groundwater Basin and subbasins. The following section provides information on geology, hydrogeology, hydrology, groundwater production, groundwater levels and storage, land subsidence, and groundwater quality.



Source: DWR 2013

Figure 6-3. Redding Area and Northern Sacramento Valley Spring 2013 Groundwater Elevation Contours

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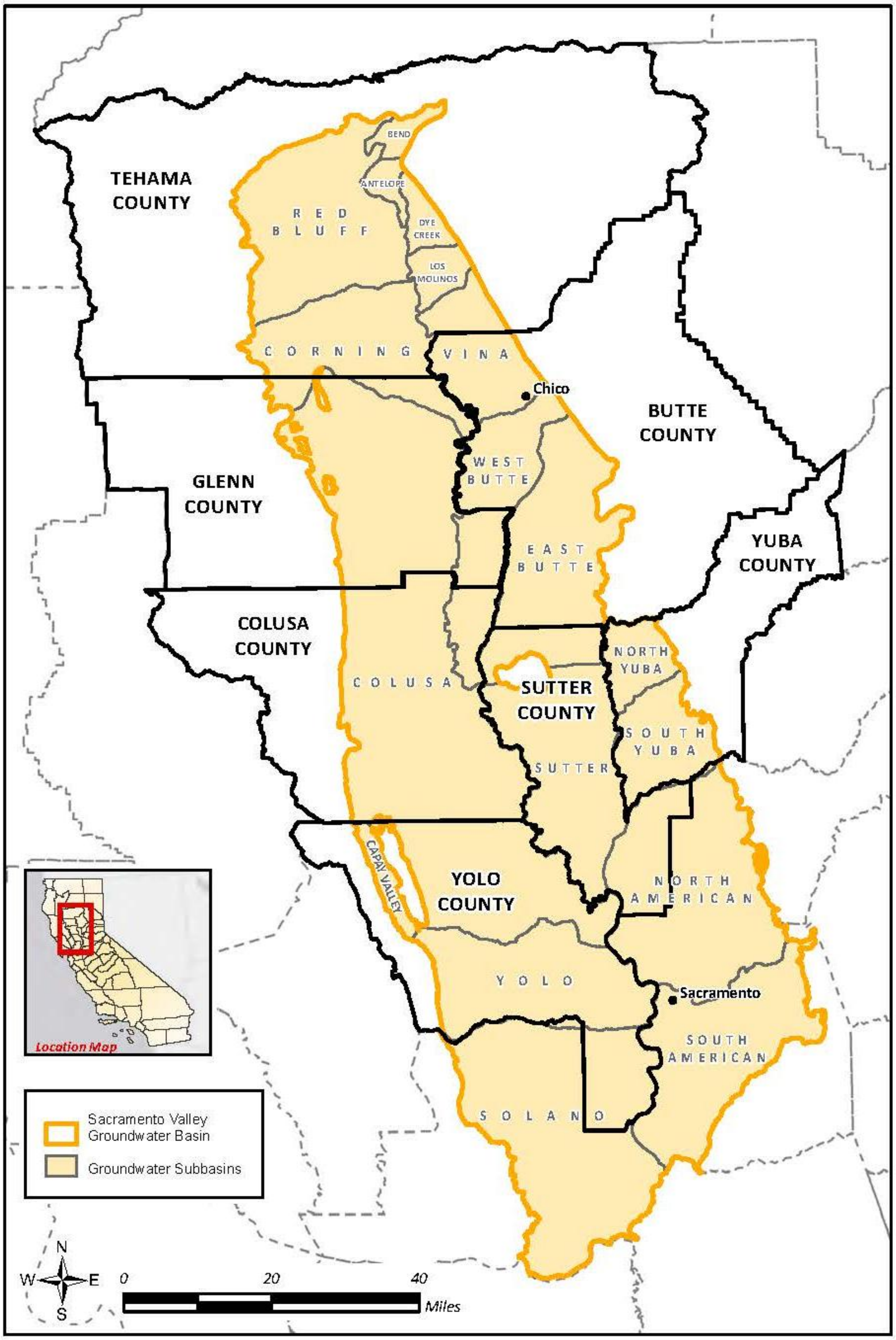


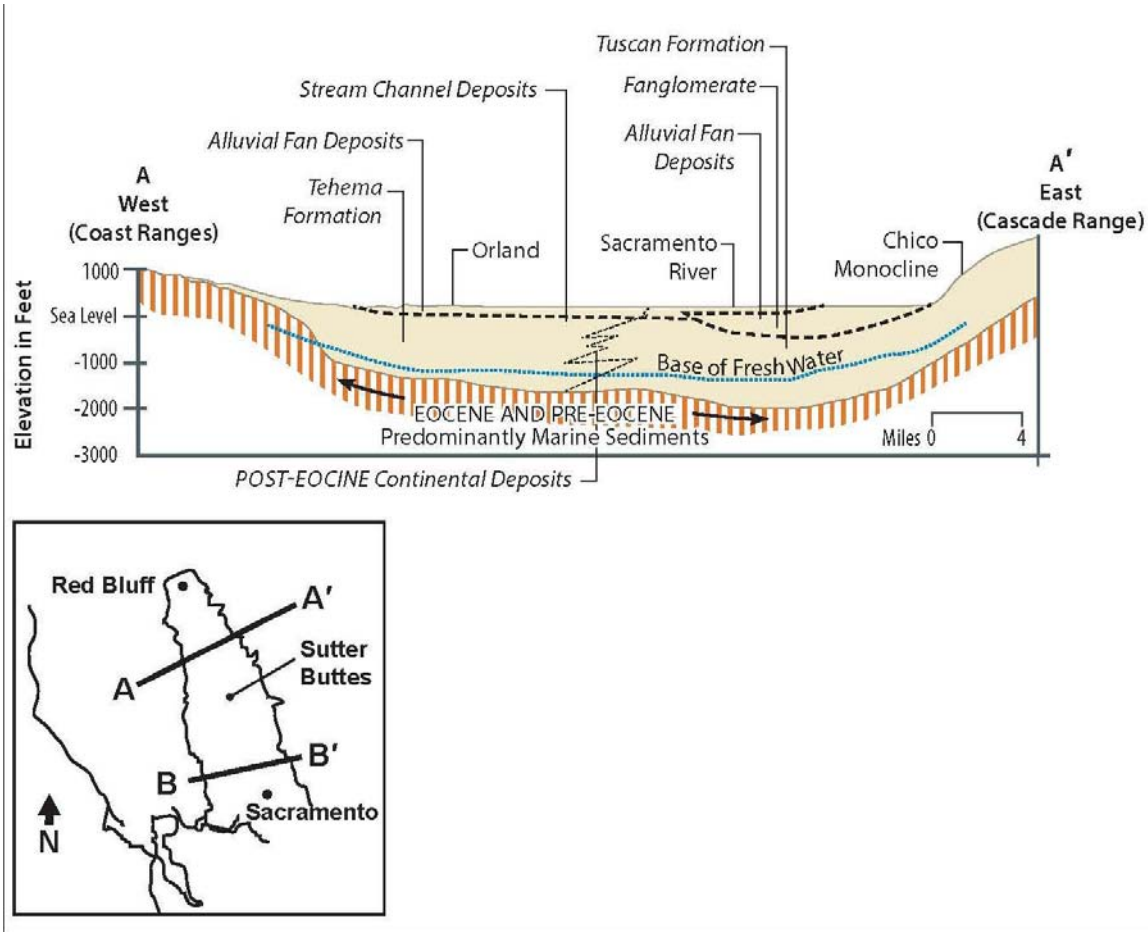
Figure 6-4. Sacramento Valley Groundwater Basin

Geology, Hydrogeology, and Hydrology The Sacramento Valley Groundwater Basin is a north-northwest trending asymmetrical trough filled with both marine and continental rocks and sediment. On the eastern side, the basin overlies basement rock that rises relatively gently to the Sierra Nevada, while on the western side the underlying basement rock rises more steeply to form the Coast Range. Overlying the basement rock are marine sandstone, shale, and conglomerate rocks, which generally contain brackish or saline water (DWR 1978). The freshwater-bearing formation in the valley is comprised of sedimentary and volcanic rocks that have the ability to absorb, transmit and yield fresh water. The depth below ground surface (bgs) to the base of freshwater is approximately 1,150 feet in the northern portion of the Sacramento Valley and approximately 1,600 feet in the southern portion of the Sacramento valley (DWR 1978).

Along the eastern and northeastern portion of the basin are the Tuscan and Mehrten formations, derived from the Cascade and Sierra Nevada ranges. The Tehama Formation in the western portion of the basin is derived from Coast Range sediments. In most of the Sacramento Valley Groundwater Basin, the Tuscan, Mehrten, and Tehama formations are overlain by relatively thin alluvial deposits.

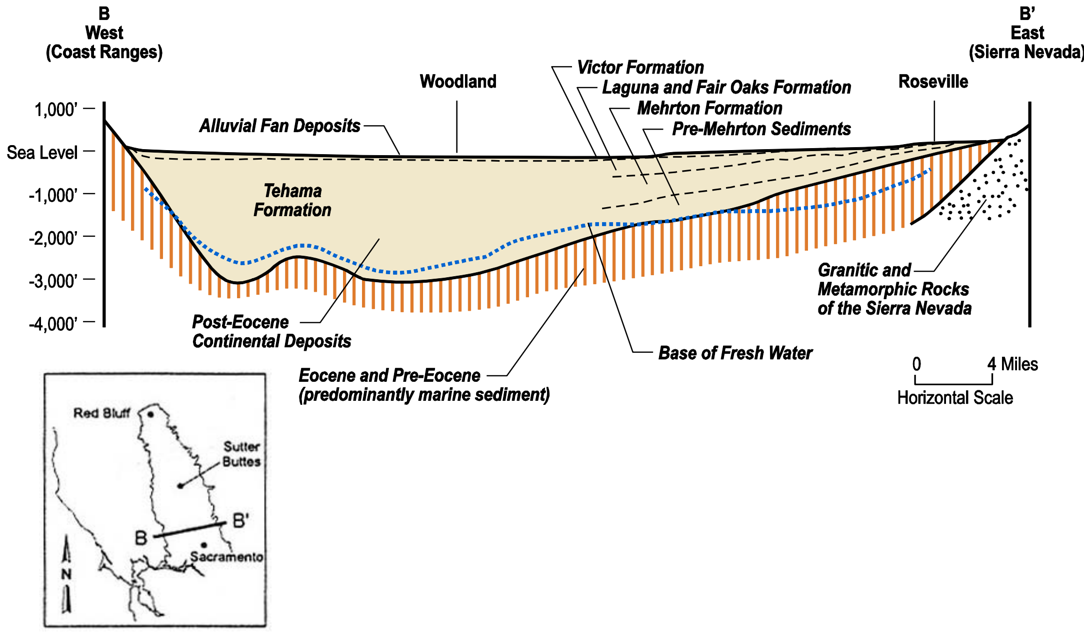
Freshwater is present primarily in the Laguna, Mehrten, Tehama, and Tuscan formations and in alluvial deposits that overly the deeper Eocene and Pre-Eocene marine deposits. Figure 6-5 and Figure 6-6 are generalized cross sections for the northern and southern portions of the Sacramento Valley Groundwater Basin, respectively. Groundwater users in the basin pump primarily from aquifers above the marine deposits.

Groundwater is recharged by deep percolation from rainfall infiltration, leakage from streambeds, lateral inflow along the basin boundaries, and landscape processes, including irrigation. A significant source of recharge has become deep percolation of irrigation water below crop roots, sometimes referred to as recharge from excess applied irrigation water. Of the average 13.3 million AF of groundwater recharged annually from 1962 to 2003, approximately 19 percent was from streamflow leakage and 79 percent was from the landscape processes, including recharge from excess applied irrigation water and from precipitation (Faunt 2009). Net recharge from landscape processes within the Sacramento Valley has been estimated to be 2.9 million AF (Faunt 2009).



Source: DWR Northern District 2002

Figure 6-5. North Geologic Cross Section of the Sacramento Valley Groundwater Basin



Source: DWR Northern District 2002

Figure 6-6. South Geologic Cross Section of the Sacramento Valley Groundwater Basin

Average annual precipitation in the Sacramento Valley Groundwater Basin ranges from 13 to 26 inches, with the higher precipitation of 46 inches occurring along the eastern and northern edges of the basin. Typically, 85 percent of the basin's precipitation occurs from November to April, half of it during December through February in average years (Faunt 2009).

The main surface water feature in the Sacramento Valley Groundwater Basin is the Sacramento River which flows from north to south through the basin. The Sacramento River has several major tributaries draining the Sierra Nevada, including the Feather, Yuba, and American Rivers. Stony, Cache, and Putah Creeks drain the Coast Range and are the main west side tributaries of the Sacramento River. Surface water and groundwater interact on a regional basis, and gains and losses to groundwater vary spatially and temporally.

Groundwater Production, Levels, and Storage Groundwater pumping can be generally grouped into agricultural and urban, which includes M&I sources. Agricultural groundwater pumping supplies water for the crops grown in the basin. Truck, field, orchard, and rice crops are grown on approximately 2.1 million acres. Rice represents about 23 percent of the total acreage (DWR 2003 as cited in Faunt 2009). The water supply for growing rice relies on a combination of surface water and groundwater. Groundwater accounts for less than 30 percent of the annual supply used for agricultural and urban purposes in the Sacramento Valley (Faunt 2009). Urban pumping in the Sacramento Valley increased from approximately 250 TAF annually in 1961 to more than 800 TAF annually in 2003 (Faunt 2009).

DWR and other monitoring entities, as defined by SB X7 6 extensively monitor groundwater levels in the basin. The total depth of monitoring wells range from 18 to 1,380 feet bgs within the Sacramento Valley Groundwater Basin.

Figure 6-7 and Figure 6-8 show the location and groundwater elevation of select monitoring wells that portray the local groundwater elevations within the Sacramento Valley Groundwater Basin. Water levels at well 21N03W33A004M generally declined during the 1970s and prior to import of surface water conveyed by the Tehama-Colusa Canal. During the 1980s, groundwater levels recovered due to import and use of surface water supply and because of the 1982 to 1984 wet water years (DWR 2014). Groundwater levels in well 15N03W01N001M (which is surrounded by agricultural lands) declined until 1977 and then recovered during the wet years from 1982 to 1984. After the 2008 to 2009 drought, water levels declined to historical lows. Water levels recovered quickly during 2010 and 2011 (DWR 2014). Even though groundwater levels at wells 21N03W33A004M and 15N03W01N001M are generally showing a declining trend, groundwater levels in other wells in the basin have remained steady, declining moderately during extended droughts and recovering to pre-drought levels after subsequent wet periods (See Figure 6-7 and Figure 6-8 for Groundwater Elevations within the Sacramento Valley Groundwater Basin).

Figure 6-3 shows spring 2013 groundwater elevation contours within the northern Sacramento Valley Groundwater Basin. In general, groundwater flows inward from the edges of the basin and south, parallel to the Sacramento River. In some areas there are groundwater depressions associated with pumping that influence local groundwater gradients and flow direction. Prior to the completion of CVP facilities in the area (1964-1971), pumping along the west side of the basin caused groundwater levels to decline. Following construction of the CVP, the delivery of surface water and reduction in groundwater extraction resulted in a recovery to historic groundwater levels by the mid to late-1970s. Throughout the basin, individuals, counties, cities, and special legislative agencies manage and/or develop groundwater resources. Many agencies use groundwater to supplement surface water; therefore, groundwater production is closely linked to surface water availability. Climatic variations and the resulting surface water supply directly affect the demand and the amount of groundwater required to meet agricultural and urban water demands (Faunt 2009).

Figure 6-9 shows the simulated cumulative change in groundwater storage in the Sacramento Valley Groundwater Basin since 1962, along with the other major groundwater basins in the Central Valley of California. As shown in this figure, groundwater storage in the Sacramento Valley Groundwater Basin has been relatively constant over the long term. Storage tends to decrease during dry years and increase during wetter periods.

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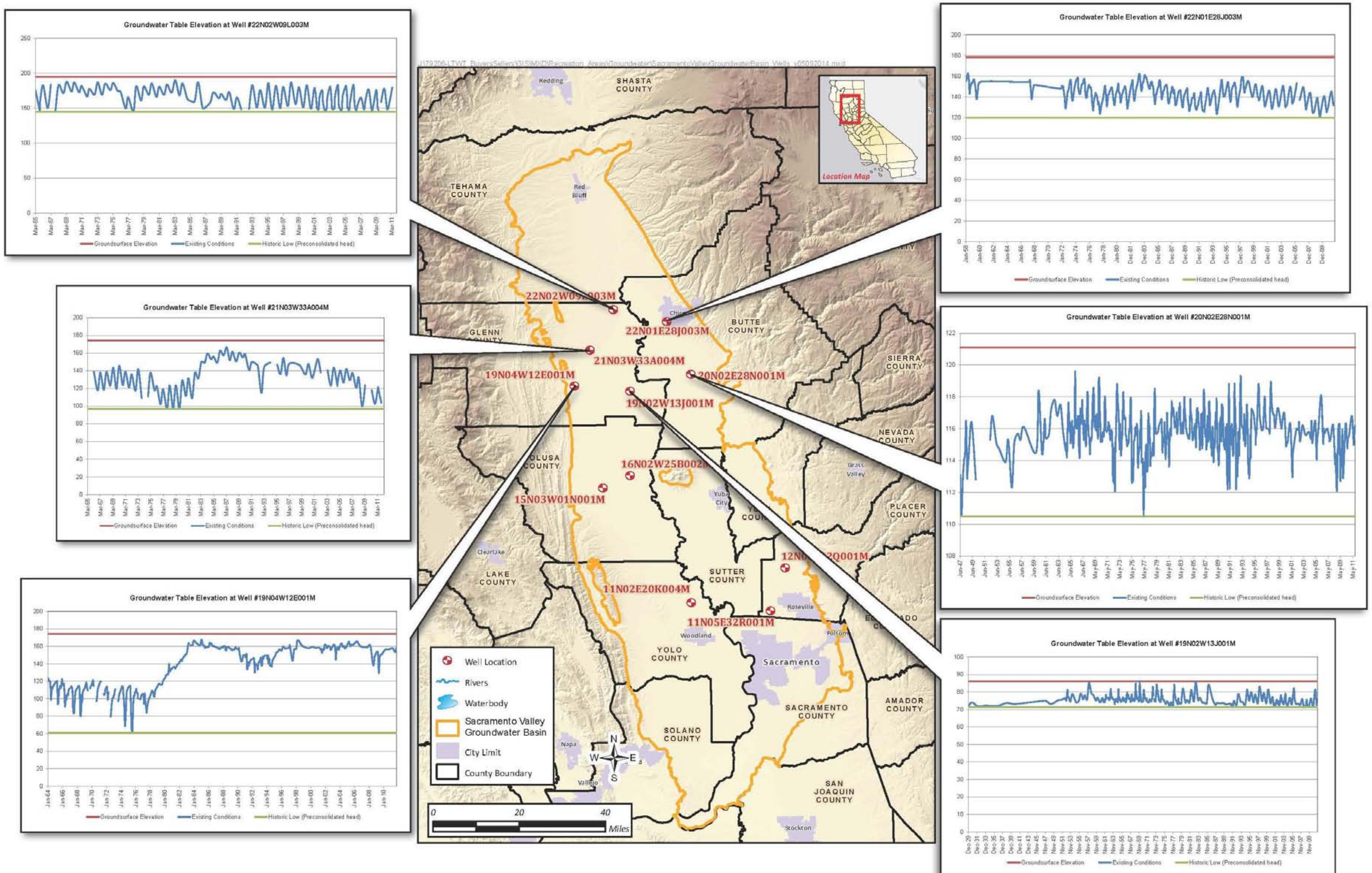

Figure 6-7. Sacramento Valley Groundwater Basin Historic Groundwater Elevations

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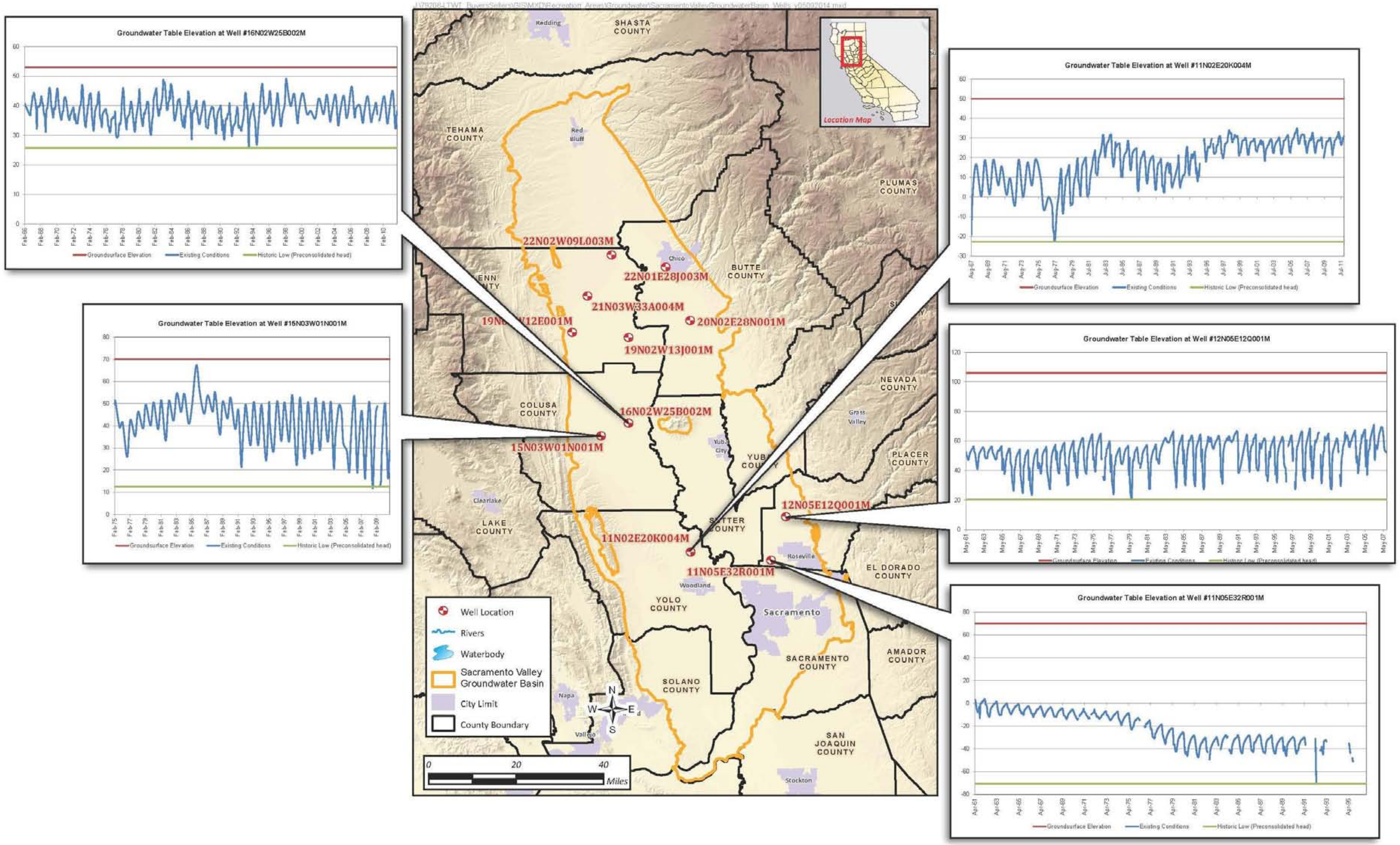

Figure 6-8. Sacramento Valley Groundwater Basin Historic Groundwater Elevations

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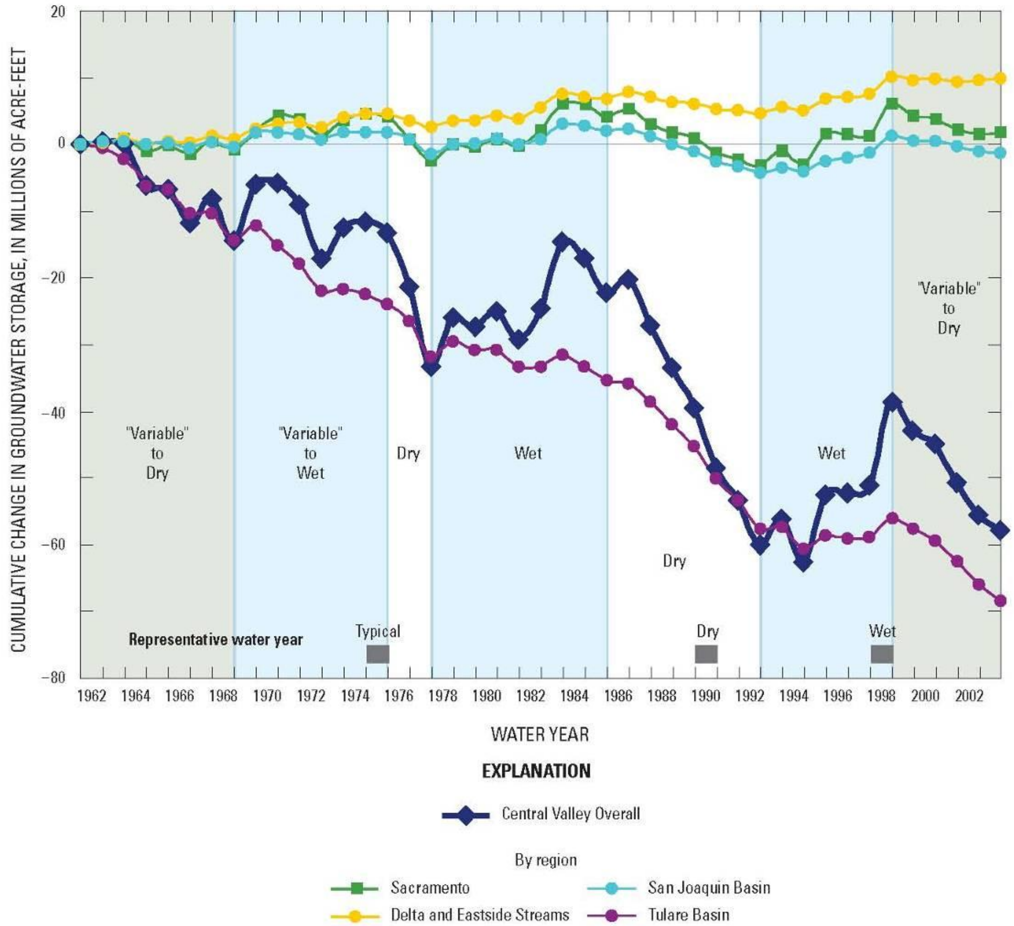

Source: Faunt 2009

Figure 6-9. Cumulative Annual Change in Storage, as simulated by the USGS's Central Valley Hydrologic Model

Groundwater-Related Land Subsidence This section discusses land subsidence due to changes in groundwater levels. Groundwater-related land subsidence is a process that causes the elevation of the ground surface to lower in response to groundwater pumping. Non-reversible (i.e., inelastic) land subsidence occurs where groundwater extraction lowers groundwater levels causing loss of pore pressure and subsequent consolidation of clay beds within a groundwater system. Subsidence is typically a slow process that occurs over a large area. Subsidence generally occurs in small increments during dry years when groundwater pumping lowers groundwater levels below historical lows.

Because of the slow rate of subsidence, the general appearance of the landscape may not change; however, subsidence can lead to problems with flood control and water distribution systems due to substantial changes in ground surface elevation. Subsidence can reduce the freeboard of levees, allowing water to over top them more easily. It also can change the slope, and even the direction of flow, in conveyance and drainage systems, including canals, sewers, and storm drains. Subsidence can also damage infrastructure, including building foundations and collapsed well casings.

There are several methods used to measure land subsidence. Global Positioning System (GPS) surveying is a method used for monitoring subsidence on a regional scale. DWR uses this method to monitor subsidence in the Tule Lake Basin, Glenn and Yolo counties, and the Sacramento-San Joaquin River Delta (Delta). The GPS network consists of 339 survey monuments spaced about seven kilometers apart and covers all or part of 10 counties within the Sacramento Valley Groundwater Basin (DWR 2008a). It extends from northern Sacramento County eastward to Reclamation’s Folsom Lake network, southwest to DWR’s Delta/Suisun Marsh network, and north to Reclamation’s Shasta Lake network. The land surface elevations will be re-surveyed every few years to track changes in elevation.

Vertical extensometers are a more site-specific method of measuring land subsidence. DWR’s subsidence monitoring program within the Sacramento Valley Groundwater Basin includes 11 extensometer stations that are located in Yolo (2), Sutter (1), Colusa (2), Butte (3), and Glenn (3) counties. Figure 6-10 shows the areas within the Sacramento Valley Groundwater Basin that have experienced subsidence due to significant declines in groundwater levels as a result of increased groundwater pumping (DWR 2008a).

Figure 6-10 also shows the locations of DWR’s extensometers and extent of subsidence at the locations. Data from the GPS subsidence monitoring network and complementary groundwater levels in monitoring wells revealed a correlation between land subsidence and groundwater declines during the growing season (DWR 2008a). DWR found that the land surface partially rebounds as aquifers recharge in winter (DWR 2008a). Out of the 11 extensometers five show potential subsidence over time:

- 09N03E08C004M, in Yolo County within Conaway Ranch: DWR observed higher rates of inelastic land subsidence estimated at approximately 0.2 feet from 2013 to 2014 (DWR 2014b). In comparison, slightly less than 0.1 feet of subsidence occurred over the previous 22 years (1991-2012);

- 11N01E24Q008M, in Yolo County near the Yolo-Zamora area: 0.5 to 0.6 foot decline from 1992 to present;

- 11N04E04N005M, in Sutter County: approximately 0.01 foot decline from 1994 to present;

- 21N02W33M001M, in Glenn County: 0.05 foot decline from 2005 to present; this extensometer is located in areas in which the Tehama Formation is mapped in the subsurface and indicates the potential for inelastic subsidence (West Yost Associates 2012); and

- 16N02W05B001M, in Colusa County: 0.04 foot decline from 2006 to present.

Historically, land subsidence occurred in the eastern portion of Yolo County and the southern portion of Colusa County due to extensive groundwater extraction and geology. The earliest studies on land subsidence in the Sacramento Valley occurred in the early 1970s when the U.S. Geological Survey (USGS), in cooperation with DWR, measured elevation changes along survey lines containing first and second order benchmarks. As much as four feet of land subsidence due to groundwater withdrawal occurred east of Zamora over the last several decades. The area between Zamora, Knights Landing, and Woodland has been most affected (Yolo County 2009). Subsidence in this region is generally related to groundwater pumping and subsequent consolidation of compressible clay sediments.

Groundwater Quality Groundwater quality in the Sacramento Valley Groundwater Basin is generally good and adequate for municipal, agricultural, domestic, and industrial uses. However, there are some localized groundwater quality issues in the basin. In general, groundwater quality is influenced by stream flow and recharge from the surrounding Coast Range and Sierra Nevada. Runoff from the Sierra Nevada is generally of higher quality than runoff from the Coast Range because of the presence of marine sediments in the Coast Range. Specific groundwater quality issues are discussed below.

Within the Sacramento Valley, water quality issues may include occurrences of high TDS or elevated levels of nitrates, naturally occurring boron, and other introduced chemicals. The SWRCB's Groundwater Ambient Monitoring and Assessment (GAMA) Program's Priority Basin Project evaluated statewide groundwater quality and sampled 108 wells within the Central Sacramento Valley region and 96 wells in the Southern Sacramento Valley region in 2005 and 2006. Water quality data was analyzed for inorganic constituents (e.g., nutrients, radioactive constituents, TDS and iron/manganese); special interest constituents (e.g., perchlorate); and organic constituents (e.g., solvents, gasoline additives, and pesticides).

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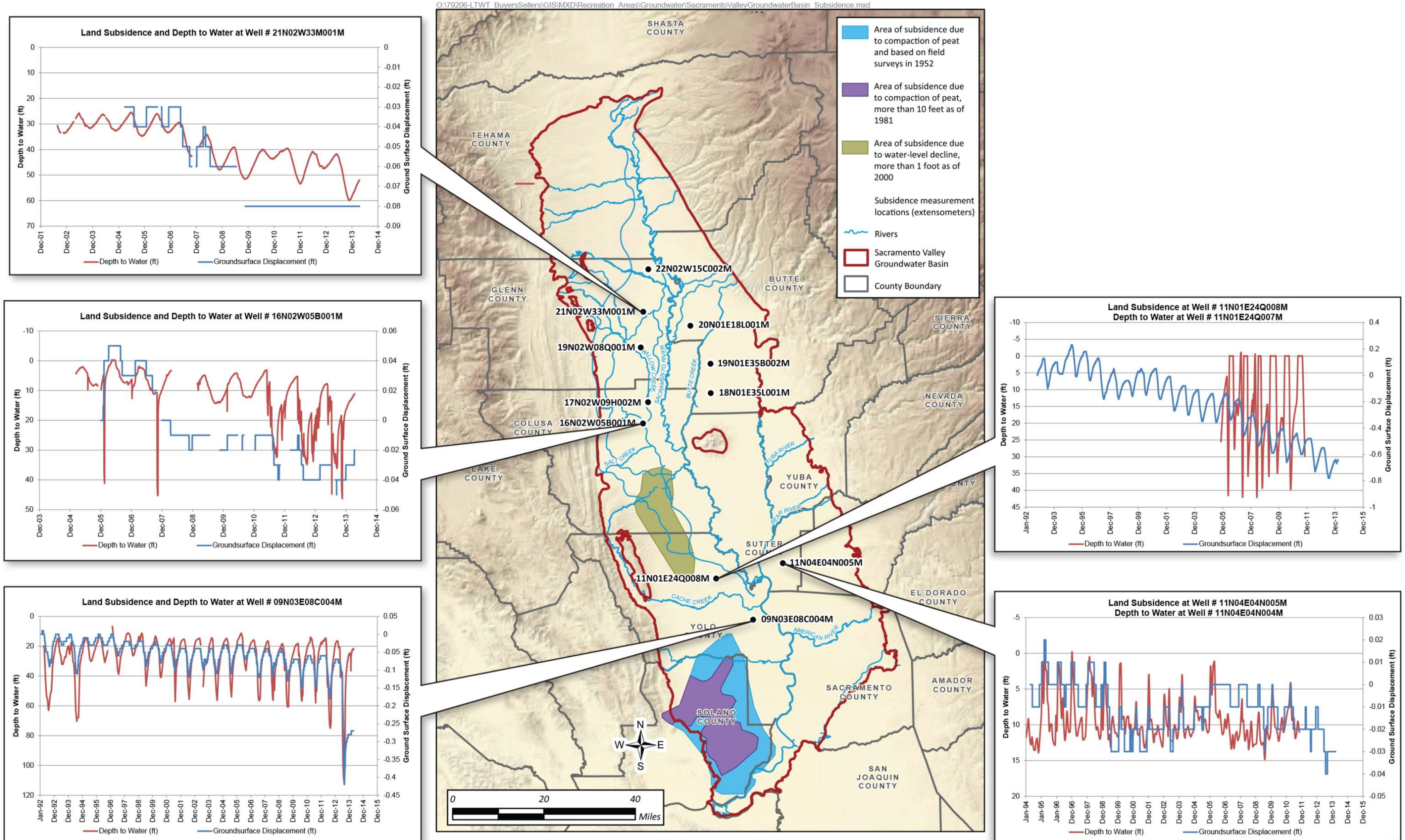

Source: DWR 2014c

Figure 6-10. Sacramento Valley Groundwater Basin Land Subsidence

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Inorganic Constituents Arsenic and boron were the two trace elements that were most frequently detected at concentrations greater than the maximum contaminant level (MCL) within the basin. Arsenic was detected above the MCL of 10 micro grams per liter (µg/L) in approximately 22 percent of the wells sampled. Boron was another trace element that was detected above the MCL of 1 mg/L in seven percent of the wells sampled. Aluminum, chromium, lead, and fluoride were also detected in concentrations above the MCLs (1 mg/L for Aluminum, 50 µg/L for Chromium; 15 µg/L for Lead and 2 mg/L for Fluoride) in less than one percent of the wells sampled. Concentrations of radioactive constituents were above the MCLs in less than one percent of the wells sampled within the Central Sacramento Valley region. Most of the radioactivity in groundwater comes from decay of naturally occurring isotopes of uranium and thorium in minerals in the sediments of the aquifer (Bennett 2011a, 2011b).

Nutrient concentrations within the Central Sacramento Valley region were above the MCLs in about three percent of the wells sampled. In the southern portion of the basin, nutrients were detected above the MCLs in about one percent of the sampled wells (Bennett 2011a, 2011b).

The DDW and United States Environmental Protection Agency's (USEPA) secondary drinking water standard for TDS is 500 mg/L, and the agricultural water quality goal for TDS is 450 mg/L. TDS concentrations were above these standards in about four percent of the sampled wells in the central portion of the valley. TDS levels in the Sacramento Valley Groundwater Basin are generally between 200 and 500 mg/L. TDS levels in the southern part of the basin are higher because of the local geology (DWR 2003). Along the eastern boundary of the basin, TDS concentrations tend to be less than 200 mg/L, indicative of the low concentrations of TDS in Sierra Nevada runoff. Several areas in the basin have naturally occurring high TDS, with concentrations that exceed 500 mg/L. TDS concentrations as high as 1,500 mg/L have been recorded (Bertoldi 1991). One of these high TDS areas is west of the Sacramento River, between Putah Creek and the confluence of the Sacramento and San Joaquin rivers; another is in the south-central part of the Sacramento Basin, south of Sutter Buttes, in the area between the confluence of the Sacramento and Feather rivers.

Organic Constituents Volatile organic compounds (VOCs) are present in many household, commercial, industrial, and agricultural products, and are characterized by their tendency to volatilize into the air. Solvents have been used for a number of purposes, including manufacturing and cleaning. Solvents were detected at concentrations greater than the MCLs in less than one percent of the sampled wells throughout the basin. The solvent present at higher concentrations than the MCL was perchloroethene (PCE). The MCL for PCE is set at 5 µg/L by DDW. Gasoline additives were detected at higher concentrations in less than one percent of the sampled wells throughout the basin. The gasoline additives detected at higher concentrations were benzene and tert-butyl alcohol (Bennett 2011a, 2011b). DDW has set the MCL for benzene at 1µg/L and tert-butyl alcohol at 12µg/L. Additionally, groundwater wells around Chico have exceeded standards for VOCs (trichloroethylene and perchloroethylene) (City of Chico 2006).

6.1.3.2 San Joaquin River Hydrologic Region

San Joaquin Valley Groundwater Basin, Northern Portion The San Joaquin Valley Groundwater Basin extends over the southern two-thirds of the Central Valley regional aquifer system. The Northern Portion of the San Joaquin Valley Groundwater Basin, shown on Figure 6-11, extends from just north of Stockton in San Joaquin County to north of Fresno in Fresno County, covering approximately 5,800 square miles.

Geology, Hydrogeology, and Hydrology The Northern Portion of the San Joaquin Valley Groundwater Basin is similar in shape to the Sacramento Valley Groundwater Basin and was formed by the deposition of several miles of sediment in a north-northwestern trending trough. The Sierra Nevada lies on the eastern side of the basin, and the Coast Range is to the west.

The aquifer system in the Northern Portion of the San Joaquin Valley Groundwater Basin is comprised of continental and marine deposits up to six miles thick, of which the upper 2,000 feet generally contain freshwater (Page 1986). A significant hydrogeologic feature in the basin is the Corcoran Clay. This clay layer divides the aquifer system into two distinct zones, an upper unconfined to semi-confined aquifer and a lower confined aquifer. Both aquifers are composed of formations derived from the deposition of Sierra Nevada sediment in the eastern portions of the basin, and from deposition of Coast Range sediments in the western portions of the basin. Overlying these formations are flood-plain deposits. The formations in the eastern portions of the basin are derived from the granitic Sierra Nevada and are generally more permeable than the sediments derived from the western marine formations.

Sediments derived from marine rocks generally contain more silt and clay and also contain higher concentrations of salts. The lower confined aquifer system contains sediments of mixed origin.

Historically, these aquifers were two separate systems; however, wells in the western side of the basin have penetrated both aquifers and are commonly perforated directly above and below the Corcoran Clay. This has allowed “almost free flow [of groundwater] through the well casings and gravel packs” (Williamson 1989) and has resulted in groundwater interaction between the upper and lower aquifer in some localized areas (Reclamation 1990).

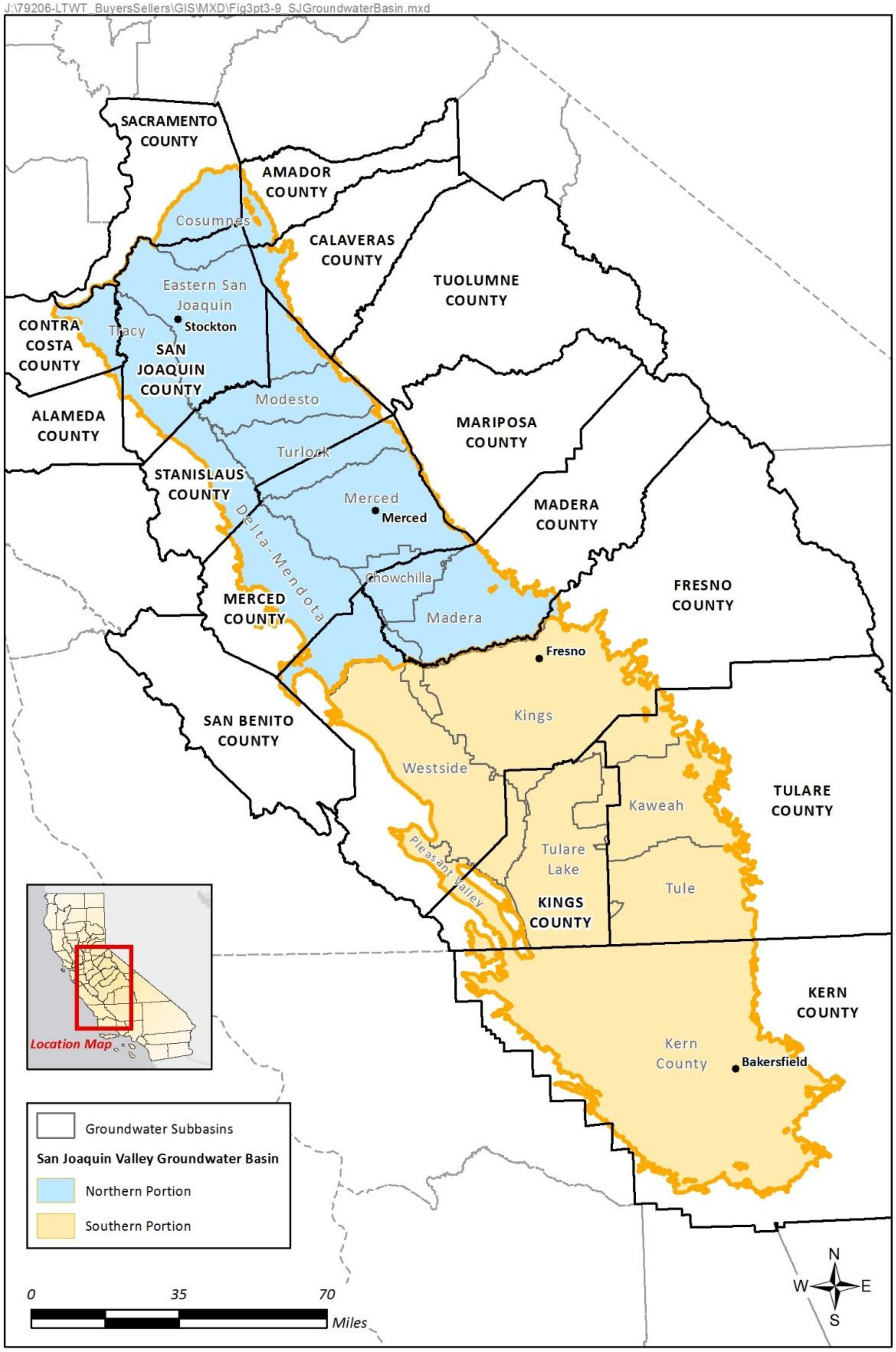
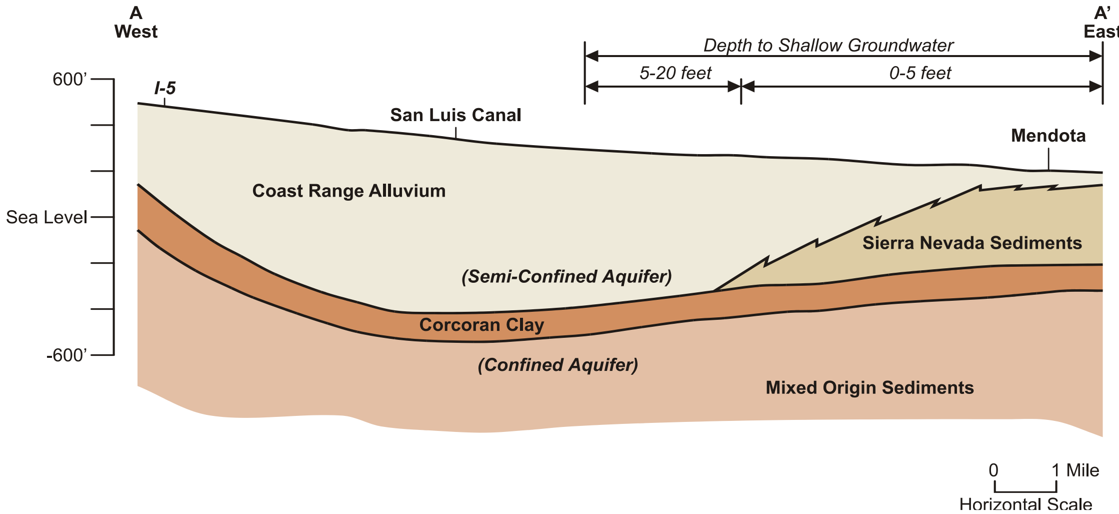


Figure 6-11. San Joaquin Valley Groundwater Basin

Figure 6-12 shows a generalized geologic cross section of the Northern Portion of the San Joaquin Valley Groundwater Basin.



Source: Reclamation 1997

Figure 6-12. Geologic Cross Section of the Northern Portion of the San Joaquin Valley Groundwater Basin

The Corcoran Clay, the most extensive of several clay layers, was formed by the periodic filling and draining of ancient lakes in the San Joaquin Valley. Six laterally extensive clays, designated Clays A through F, have been mapped (Page 1986). The Modified E-Clay includes the Corcoran Clay, which is between 0 and 160 feet thick at depths between 100 and 400 feet bgs. Figure 6-13 shows the lateral extent of the Corcoran Clay layer in the Northern and Southern Portions of the San Joaquin Valley Groundwater Basin along with the locations of the cross section.

Historically, groundwater in the unconfined to semi-confined upper aquifer system was recharged by streambed infiltration, rainfall infiltration, and lateral inflow along the basin boundaries. Average annual precipitation in the area is significantly less than in the Sacramento Valley Groundwater Basin and ranges from 5 to 18 inches (Faunt 2009). The percolation of applied agricultural surface water supplements natural groundwater replenishment. The lower confined aquifer is recharged primarily from lateral inflow from the eastern portions of the basin, beyond the eastern extent of the Corcoran Clay. Precipitation in the Sierra Nevada to the east of the basin can be as high as 65 to 75 inches, although much of it is in the form of snow. Peak runoff in the basin generally lags precipitation by five to six months (Bertoldi 1991).

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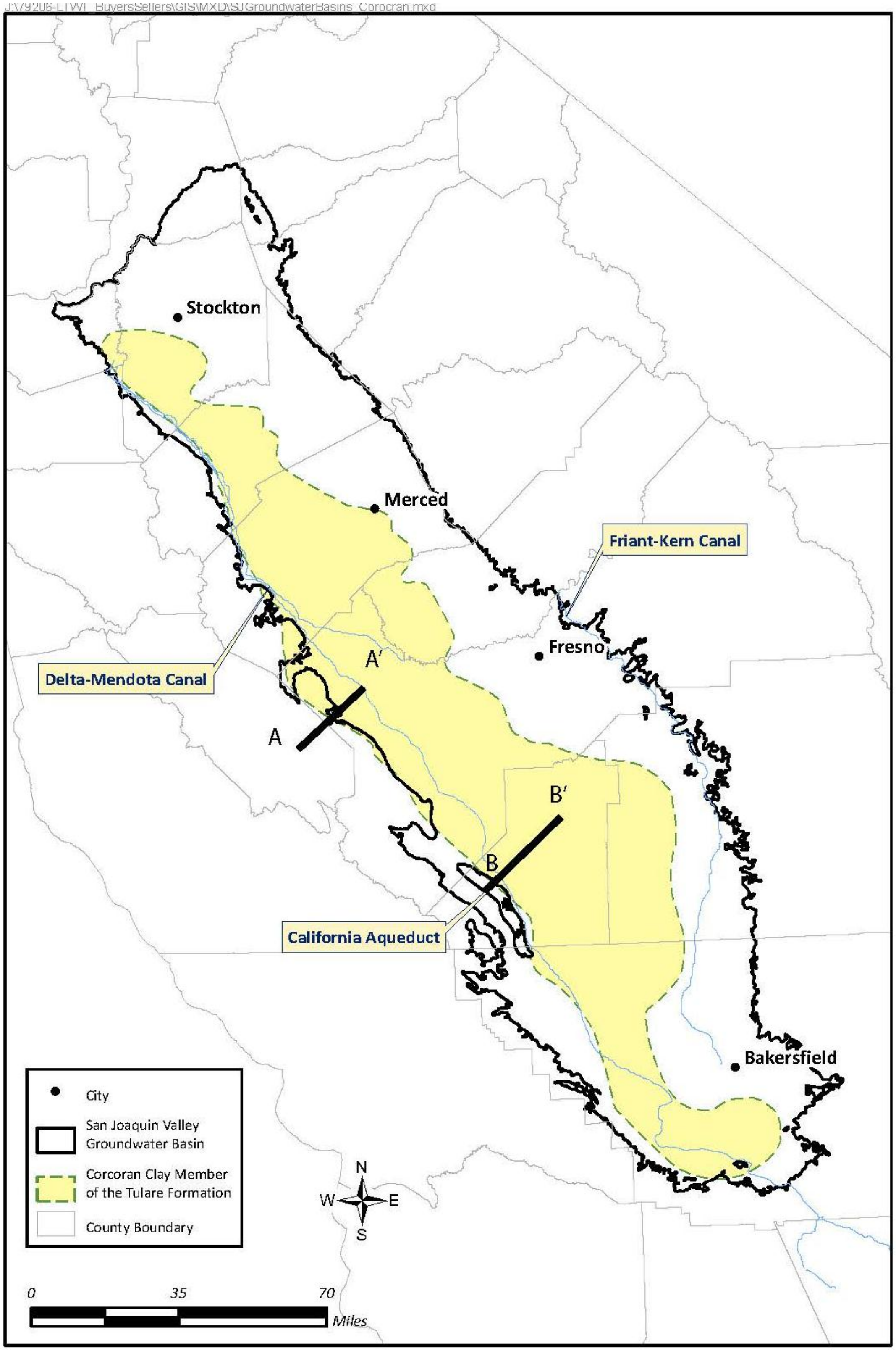

Figure 6-13. Lateral Extent of the Corcoran Clay in the San Joaquin Valley Groundwater Basin

The main surface water feature in the northern portion of the San Joaquin Valley Groundwater Basin is the San Joaquin River, which has several major tributaries draining the Sierra Nevada, including the Fresno, Chowchilla, Merced, Tuolumne, and Stanislaus rivers. Historically, these streams were “gaining” streams (i.e., they had a net gain of water from groundwater discharge into the river). With the decline of groundwater levels in the basin, areas of substantial pumping have reversed the local groundwater flow, and reaches of streams now lose water to the aquifer system (losing streams).

Groundwater Production, Levels, and Storage Prior to the large-scale development of irrigated agriculture, groundwater in the basin generally flowed from areas of higher elevation (i.e., the edges of the basin) toward the San Joaquin River and ultimately to the Delta. Most of the water in the San Joaquin Valley moved laterally, but a small amount leaked upward through the intervening confining unit (Planert and Williams 1995). Upward vertical flow to discharge areas from the deep confined part of the aquifer system was impeded partially by the confining clay beds, particularly the Corcoran Clay. Extensive groundwater pumping and irrigation (with imported surface water) have modified local groundwater flow patterns and in some areas, groundwater depressions are evident. Annual average groundwater production in the basin was estimated to be 0.9 million AF in the Central Valley Hydrologic Model (CVHM) model (Faunt 2009). Groundwater flow in the basin has become more rapid and complex. Groundwater pumping and percolation of excess irrigation water has resulted in steeper hydraulic gradients as well as shortened flow paths between sources and sinks (Faunt 2009).

Irrigated agriculture in the Northern Portion of the San Joaquin Valley Groundwater Basin increased from about 1 million acres in the 1920s to more than 2.2 million acres by the early 1980s (Reclamation 1997). The USGS’s CVHM shows the average groundwater pumping to be 799,000 AF per year (AFY) from 1962 through 2003 in the southern portion of the Northern San Joaquin Groundwater Basin (includes the Turlock, Merced, Chowchilla and Madera subbasins) (Faunt 2009).

Figure 6-14 shows spring 2010 groundwater elevation contours and groundwater elevation hydrographs for select monitoring well location for the San Joaquin Valley Groundwater Basin. The two hydrograph locations shown in Figure 6-14 best portray the local groundwater elevations within the San Joaquin Valley Groundwater Basin. Hydrograph 05S12E11G001M is for an irrigation well from a region that lacks surface water and is solely dependent on groundwater within the San Joaquin Valley Groundwater Basin. Groundwater levels have generally declined over time at this location. Groundwater levels briefly stabilized between 1990 and 2002 which could potentially be attributed to the utilization of efficient irrigation techniques. A decline in the water level is observed beginning in 2011 through the end of the period of data shown in Figure 6-14. Monitoring well 11S10E24N001M is an industrial well in the Delta-Mendota subbasin (San Joaquin Valley Groundwater Basin). At this location groundwater levels increased from 1960 to 1987; however, there has been a decline of approximately 30 feet since 1987.

The cumulative change in groundwater storage for the entire San Joaquin Valley Groundwater Basin was relatively constant from 1962 through 2003 according to the CVHM (Figure 6-9). Similar to the Sacramento Valley Groundwater Basin, storage tends to drop during dry periods and increase during wetter years.

Groundwater-Related Land Subsidence From the 1920s through the mid-1960s, the use of groundwater for irrigation of crops in the San Joaquin Valley increased rapidly, causing land subsidence throughout the west and southern portions of the Valley. From 1920 to 1970, approximately 5,200 square miles of irrigated land in the San Joaquin River Watershed showed at least one foot to as much as 28 feet of land subsidence. Land subsidence is concentrated in areas underlain by the Corcoran Clay.

Interferometric Synthetic Aperture Radar (InSAR) analyses conducted over the San Joaquin Valley in 2013 indicate substantial subsidence at: 1) approximately 7,000 square kilometers west of Tulare and east of Kettleman City; and 2) 3,100 square kilometers near El Nido (south of Merced and west of Madera). Land Elevation benchmark surveys conducted by Caltrans along Highway 198 corroborate the InSAR analyses and indicate 9.37 feet of subsidence occurring in this area between 1960 and 2004. Figure 6-15 shows the contours of subsidence in both the subsiding areas from preliminary InSAR analysis (California Water Foundation 2014).

Land subsidence measurements have shown that an increase in groundwater pumping during 1984 to 1996 resulted in land subsidence of up to two feet along the Delta-Mendota Canal (CALFED 2000). Similarly, increased pumping caused Westlands Water District to experience up to two feet of subsidence between 1983 and 2001, with most of the subsidence occurring after 1989 (Westlands Water District 2000).

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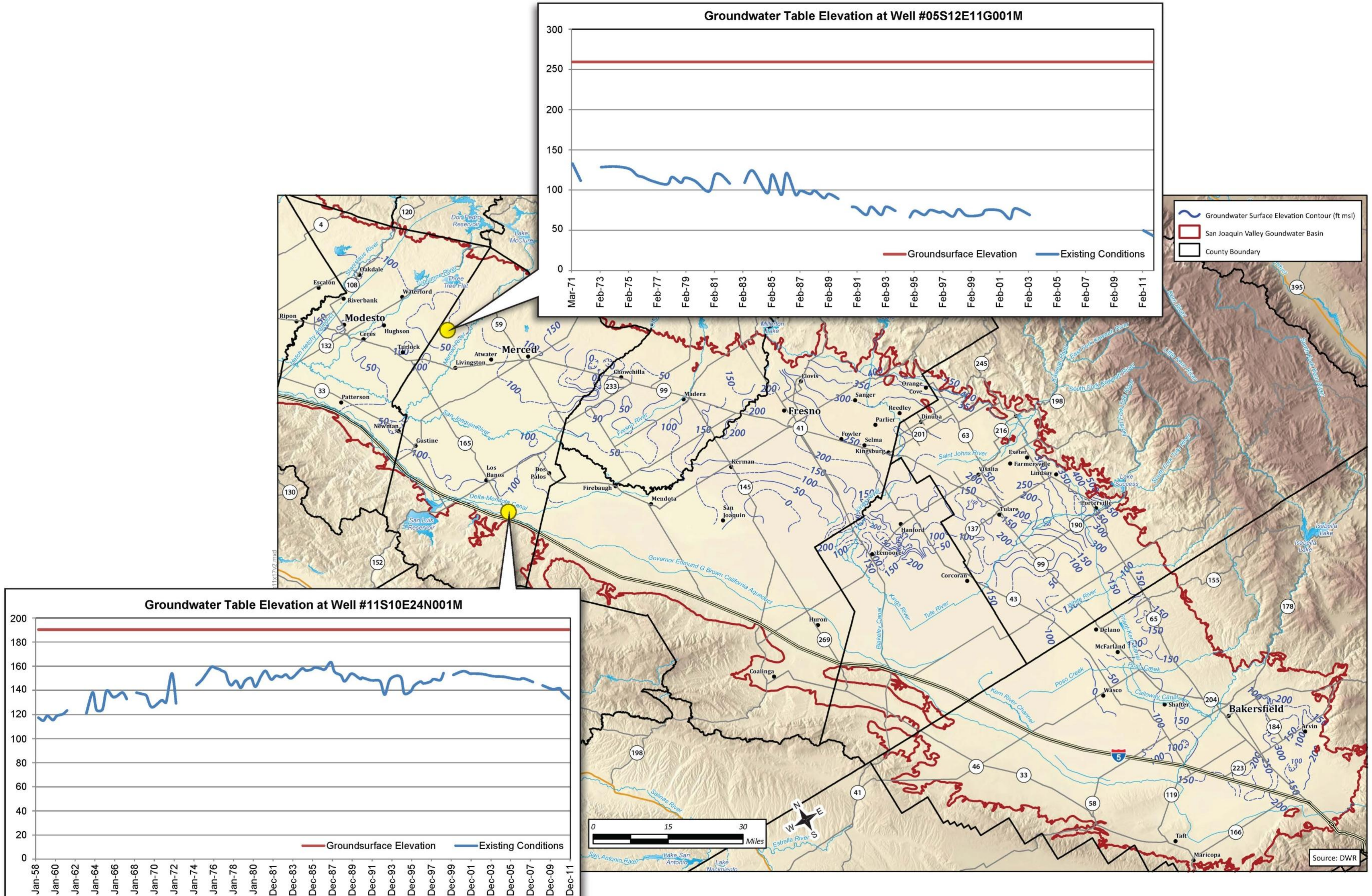

Source: DWR 2011

Figure 6-14. San Joaquin Valley Spring 2010 Groundwater Elevation Contours

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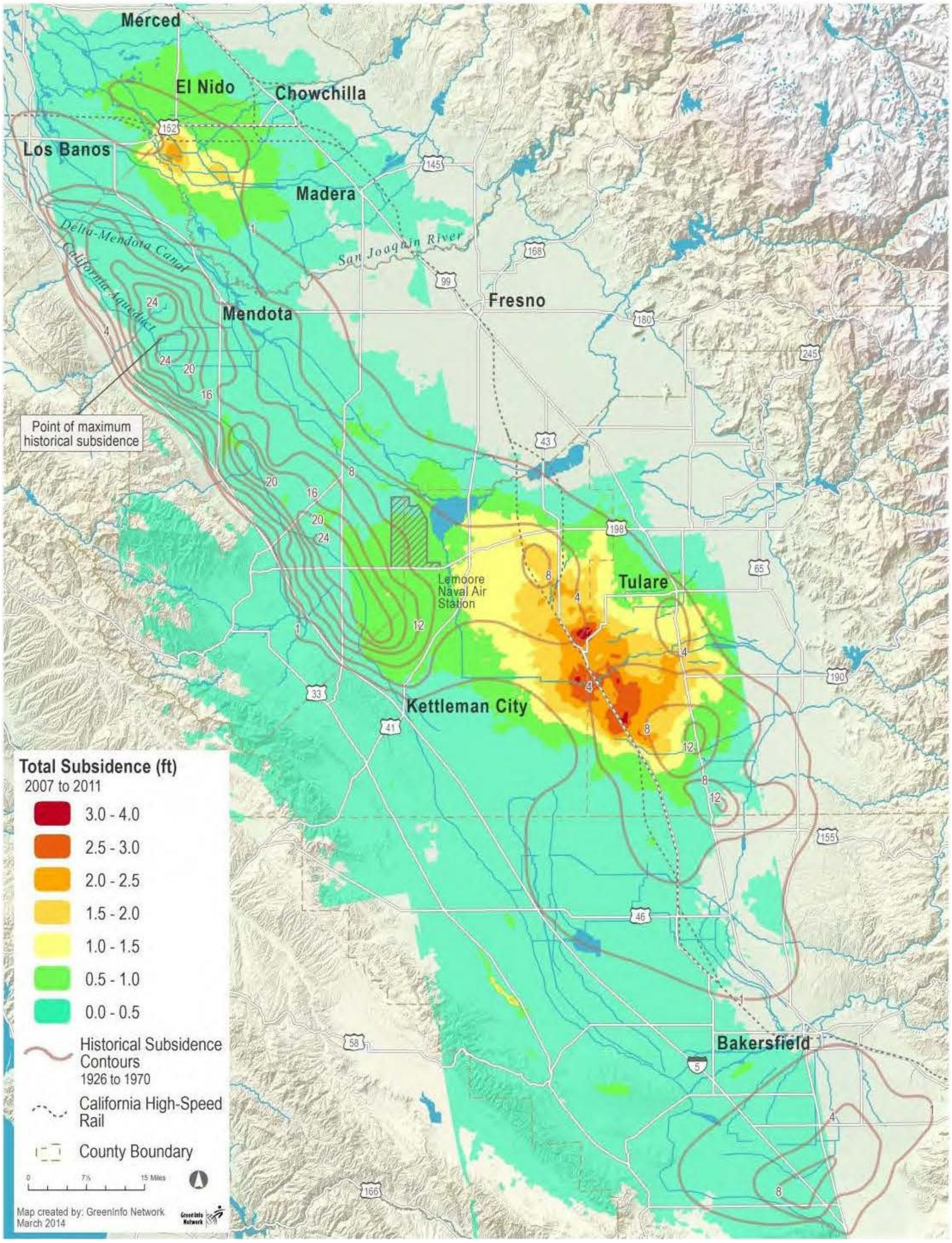


Source: California Water Foundation 2014

Figure 6-15. Land Subsidence in San Joaquin Valley between January 2007 to March 2011 (compiled from InSAR analysis data)

A 2013 USGS study found that the northern portion of the Delta-Mendota Canal was stable or experienced little subsidence from 2003 to 2010. The southern portion of the Delta-Mendota Canal subsided as part of a large area of subsidence centered near the town of El Nido. Subsidence measurements indicated more than 20 millimeters of subsidence from 2008 to 2010 (Sneed et al 2013). Land subsidence appears to be continuing in various areas of the San Joaquin Groundwater Basin.

Groundwater Quality Groundwater quality varies throughout the San Joaquin Valley Groundwater Basin. The GAMA Program's Priority Basin Project evaluates statewide groundwater quality and sampled 67 wells in the northern San Joaquin Valley region; 79 wells in the central region (includes Modesto, Turlock, Merced, and Uplands subbasins) and 126 wells in the southern region (Kings, Kaweah, Tule, and Tulare basins) between 2004 and 2006. Water quality data was analyzed for inorganic constituents (e.g., nutrients, radioactive constituents, TDS, and iron/manganese); special interest constituents (e.g., perchlorate) and organic constituents (e.g., solvents, gasoline additives, and pesticides).

Inorganic Constituents Arsenic, vanadium and boron were the trace elements that were most frequently detected at concentrations greater than the MCL within the basin. Aluminum, barium, lead, antimony, mercury, valadium, and fluoride were also detected at concentrations above the MCL in less than two percent of the sampled wells (Belitz 2010, Bennett 2010, Burton 2012).

Nutrients such as nitrate and nitrite are naturally present at low concentrations in groundwater. High and moderate concentrations generally occur as a result of human activities, such as applying fertilizer to crops. Livestock, when in concentrated numbers, and septic systems also produce nitrogenous waste that can leach into groundwater. Nitrate was present at concentrations greater than the MCL in two percent of the sampled wells in the northern and central portion of the basin and six percent of the wells in the southern region of the basin (Belitz 2010, Bennett 2010, Burton 2012).

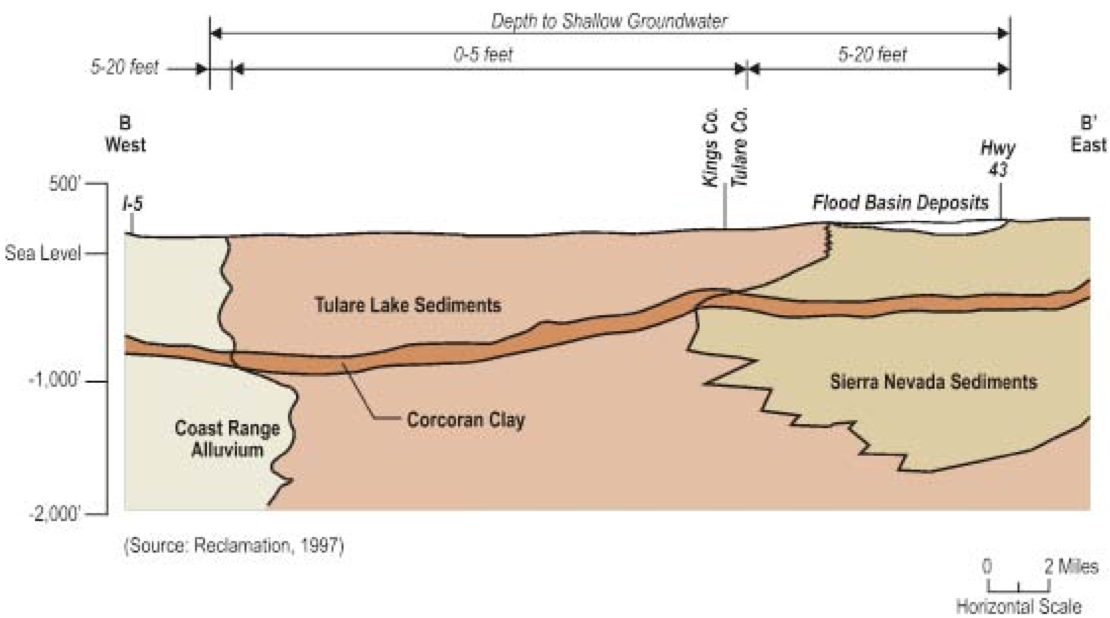
The DDW and USEPA's secondary drinking water standard for TDS is 500 mg/L, and the agricultural water quality goal for TDS is 450 mg/L. TDS concentrations were greater than the upper limit in about two percent of the wells in the central portion of the valley and in about six percent of the primary aquifers in the northern portions of the basin (Belitz 2010, Bennett 2010, Burton 2012). TDS concentrations in the northern portion of the San Joaquin Valley Groundwater Basin are generally higher than in the Sacramento Valley Groundwater Basin. Concentrations of TDS along the east side of the Basin are generally lower than along the west side, as a result of higher quality water recharging the aquifer and soil types.

Organic Constituents Solvents were detected at concentrations greater than the MCL in less than one percent of the sampled wells within the basin. Other VOCs (e.g., trihalomethanes and organic synthesis reagents) were not detected at concentrations above MCLs in the sampled wells (Belitz 2010, Bennett 2010, Burton 2012).

6.1.3.3 Tulare Lake Hydrologic Region

San Joaquin Valley Groundwater Basin, Southern Portion The Southern Portion of the San Joaquin Valley Groundwater Basin extends from the Fresno-Madera County line through Kings and Tulare counties into Kern County. The South San Joaquin Groundwater Basin covers approximately 8,000 square miles.

Geology, Hydrogeology, and Hydrology Similar to the Northern Portion of the San Joaquin Valley Groundwater basin, a significant hydrogeologic feature in the southern basin is the Corcoran Clay. This clay layer divides the aquifer system into two distinct aquifers, an unconfined to semi-confined upper aquifer and a confined aquifer below as shown in Figure 6-16. Both aquifer systems are composed of formations derived from the deposition of Sierra Nevada sediment in the eastern portions of the basin, and from deposition of Coast Range sediments in western portions of the basin. Overlying these formations are flood plain deposits. The axis of the basin contains Tulare Lake sediments. These Tulare Lake sediments are estimated to be more than 3,600 feet thick, with a lateral extent of more than 1,000 square miles (Page 1986). Figure 6-16 shows the cross section for the Southern Portion of the San Joaquin Groundwater Basin and the location of this cross section is show in Figure 6-13.



Source: Reclamation 1997

Figure 6-16. Geologic Cross Section of the Southern Portion of the San Joaquin Valley Groundwater Basin

Groundwater in the unconfined upper aquifer system is recharged by streambed infiltration, rainfall infiltration, and lateral inflow along the basin boundaries. Average annual precipitation in the San Joaquin Valley ranges from 5 to 18 inches (Faunt 2009). The lower confined aquifer is recharged primarily from lateral inflow from the eastern portions of the basin, beyond the eastern extent of the Corcoran Clay. Precipitation in the Sierra Nevada to the east of the basin can be as high as 65 to 75 inches, although much of it is in the form of snow. Peak runoff in the basin generally lags precipitation by five to six months (Bertoldi 1991).

The main surface water features in the southern portion of the San Joaquin Valley Groundwater Basin are the Kern, Kaweah, and Kings Rivers. Agricultural development in the area, with the resultant decline in groundwater levels, has caused the majority of the rivers and streams to lose water to the aquifer system.

Groundwater Production, Levels, and Storage See Groundwater Production, Levels, and Storage discussion under Chapter 6.1.3.2 for details.

Groundwater-Related Land Subsidence See Groundwater-related land subsidence discussion under Chapter 6.1.3.2 for details.

Groundwater Quality See Groundwater Quality discussion under Chapter 6.1.3.2 for details.

Panoche Valley Groundwater Basin Panoche Valley is an elongated northwest-southeast trending basin in the Coast Range Mountains of eastern San Benito County. Panoche Valley Groundwater Basin is part of the Tulare Lake Hydrologic Region. San Benito County Water District (SBCWD) is the only CVP water service contractor overlying the Panoche Valley Groundwater Basin.

Geology, Hydrogeology, and Hydrology The basin is bounded in the northwest by the Franciscan Formation, to the northeast and southeast by Upper Cretaceous marine sedimentary rocks and to the southwest by Lower Miocene marine rocks (DWR 2003). The water bearing unit is most likely formed of alluvium, Quaternary nonmarine terrace deposits and Plio-Pleistocene nonmarine sediments (DWR 2003).

Panoche Creek, Griswold Creek, and their tributaries drain the valley eastward to the San Joaquin Valley. Average precipitation values range from nine inches for the majority of the valley to 13 inches at the western margin.

Groundwater Production, Levels and Storage Bulletin 118 (DWR 2003) reports groundwater depth varying from 30 to over 300 feet based on data collected from 1967 to 2000. Groundwater levels trends have been showing a steady increase since the 1970s, levels have risen as much as 130 feet and on an average up to 40 feet throughout the basin (DWR 2003). No specific information on groundwater production and storage within this basin was found.

Groundwater-Related Land Subsidence No specific published information on groundwater related land subsidence within the basin was found.

Groundwater Quality Salinity is a concern in groundwater in the Panoche Valley Groundwater Basin. Salinity is of the sodium sulfate type and the average TDS is 1,300 mg/L with a range of 394 to 3,530 mg/L. Electrical Conductivity (EC) varies between 630 to 4,090 micromhos per centimeter (µmhos/cm) and averages 1,540 µmhos/cm (DWR 2003).

6.1.3.4 San Francisco Bay/Central Coast Hydrologic Regions

In addition to the groundwater basins discussed in this section there are several smaller basins underlying the East Bay Municipal Utility District and SBCWD. However since these contractors do not heavily rely on groundwater from these smaller basin, they are not discussed in this section. Figure 6-17 shows the groundwater basins and subbasins within the Central Coast and San Francisco Bay Hydrologic Regions.

Santa Clara Valley Groundwater Basin The Santa Clara Valley Groundwater Basin extends over Santa Clara, San Mateo, and Alameda counties and includes the Santa Clara, San Mateo Plain, Niles Cone and East Plain subbasins. The East Bay Plain subbasin is a northwest trending alluvial plain bounded on the north by San Pablo Bay and on the east by the contact with Franciscan Basement rock. To its south lies the Niles Cone groundwater basin bounded on the east by the Diablo Range and on the west by the San Francisco Bay. The Santa Clara subbasin lies to the south of the Niles Cone subbasin occupying a structural trough parallel to the northwest trending Coast Range. The Diablo Range bounds it on the west and the Santa Cruz Mountains form the basin boundary on the east. The San Mateo groundwater subbasin lies to the northwest of the Santa Clara subbasin. The San Mateo subbasin occupies a structural trough, sub-parallel to the northwest trending Coast Range, at the southwest end of San Francisco Bay. San Francisco Bay constitutes its eastern boundary. The Santa Cruz Mountains form the western margin of the San Mateo basin.

Geology, Hydrogeology, and Hydrology The Santa Clara Valley Groundwater Basin includes continental deposits of unconsolidated to semi-consolidated gravel, sand, silt and clay. Two members form this group, the Santa Clara Formation of Plio-Pleistocene age and the younger alluvium of Pleistocene to Holocene age (DWR 1975). The combined thickness of these two units probably exceeds 1,500 feet (DWR 1967).

The Santa Clara Formation is of Plio-Pleistocene age and rests unconformably on impermeable rocks that mark the bottom of the groundwater subbasin (DWR 1975). The Santa Clara Formation is exposed only on the west and east sides of the Santa Clara Valley. The exposed portions are composed of poorly sorted deposits ranging in grain size from boulders to silt (DWR 1975). Well logs indicate that permeability increases from west to east and that in the central part of the valley permeability and grain size decrease with depth (DWR 1975).

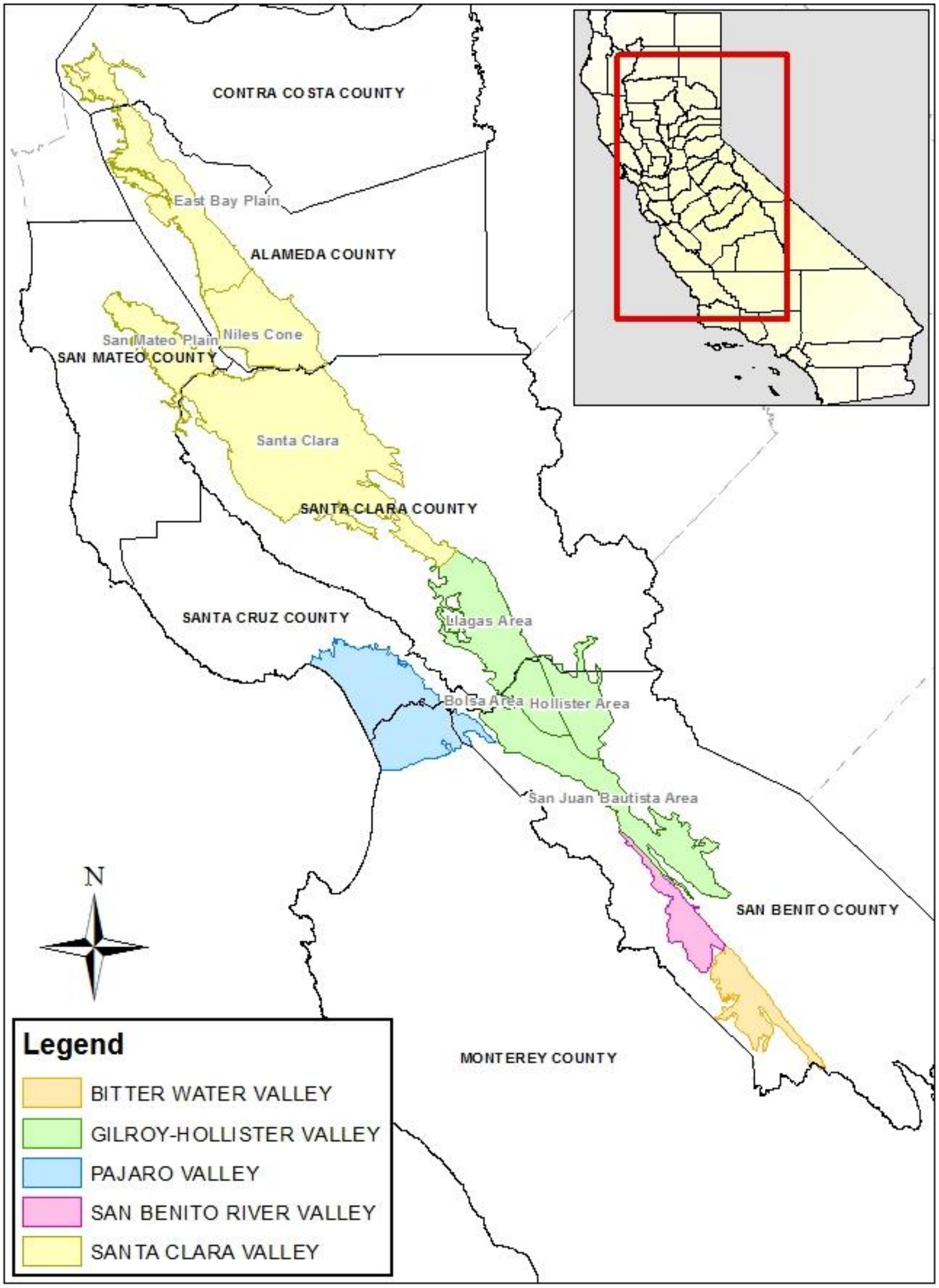


Figure 6-17. Central Coast and San Francisco Hydrologic Region Groundwater Basins

In the Santa Clara Valley, water is primarily present in the Pleistocene to Holocene alluvium deposits. The permeability of the valley alluvium is generally high and principally all large production wells derive their water from it (DWR 1975). Valley alluvium is deposited as a series of convergent alluvial fans comprised generally of unconsolidated gravel, sand, silt, and clay. It becomes progressively finer-grained at the central portions of the valley. A confined zone is created in the northern portion of the subbasin overlain by a clay layer of low permeability (SCVWD 2001). The southern portion of the subbasin is generally unconfined and contains no thick clay layers (SCVWD 2001).

Natural recharge occurs principally as infiltration from streambeds that exit the upland areas within the drainage basin and from direct percolation of precipitation that falls on the basin floor. Annual precipitation for the Santa Clara basin ranges from less than 16 inches in the valley to more than 28 inches in the upland areas (DWR 2003).

The main surface water features in the Santa Clara groundwater subbasin are the tributaries to San Francisco Bay including Coyote Creek, Guadalupe River, and Los Gatos Creek. SCVWD conducts an artificial recharge program. District-wide controlled in-stream recharge accounts for about 45 percent groundwater recharge in district facilities (SCVWD 2001). In-stream recharge occurs along stream channels in the alluvial apron upstream from the confined zone. Spreader dams (creating temporary or permanent impoundments in the stream channel) are a key component of the in-stream recharge program, increasing recharge capacity by approximately 10 percent (SCVWD 2001).

Groundwater Production, Levels, and Storage   SCVWD manages the Santa Clara Valley subbasin. Groundwater is pumped within the district by major water retailers, well owners, and agricultural users. Annual average groundwater pumping within the Santa Clara Valley subbasin has remained fairly constant over the years. Figure 6-18 shows historic groundwater pumping from 2000 to 2009 within the basin.

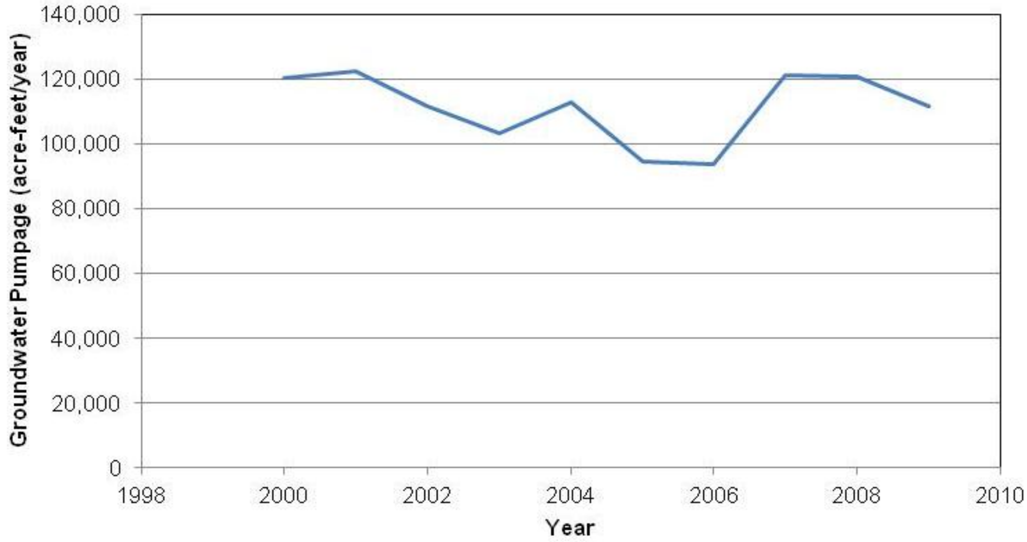


Figure 6-18. Historic Groundwater Pumping Within Santa Clara Valley Subbasin

Historically, since the early 1900s through the mid-1960s groundwater level declines from groundwater pumping have induced subsidence in the Santa Clara Valley subbasin and caused degradation of the aquifer adjacent to the bay from saltwater intrusion. Prior to surface water import via the Hetch Hetchy and South Bay Aqueducts and the introduction of an artificial recharge program, water levels declined more than 200 feet in the Santa Clara Valley (SCVWD 2000). SCVWD has also implemented various recharge programs that use local runoff and imported water deliveries to recharge groundwater through approximately 390 acres of recharge ponds and 90 miles of local creeks to stop groundwater overdraft and land subsidence (SCVWD 2001). Groundwater levels have generally increased since 1965 as a result of increased in-stream and off-stream recharge programs and decreased pumping due to increase in availability of imported surface water (SCVWD 2001). Figure 6-19 shows the location of the monitoring wells within Santa Clara Valley and the groundwater elevation at the wells.

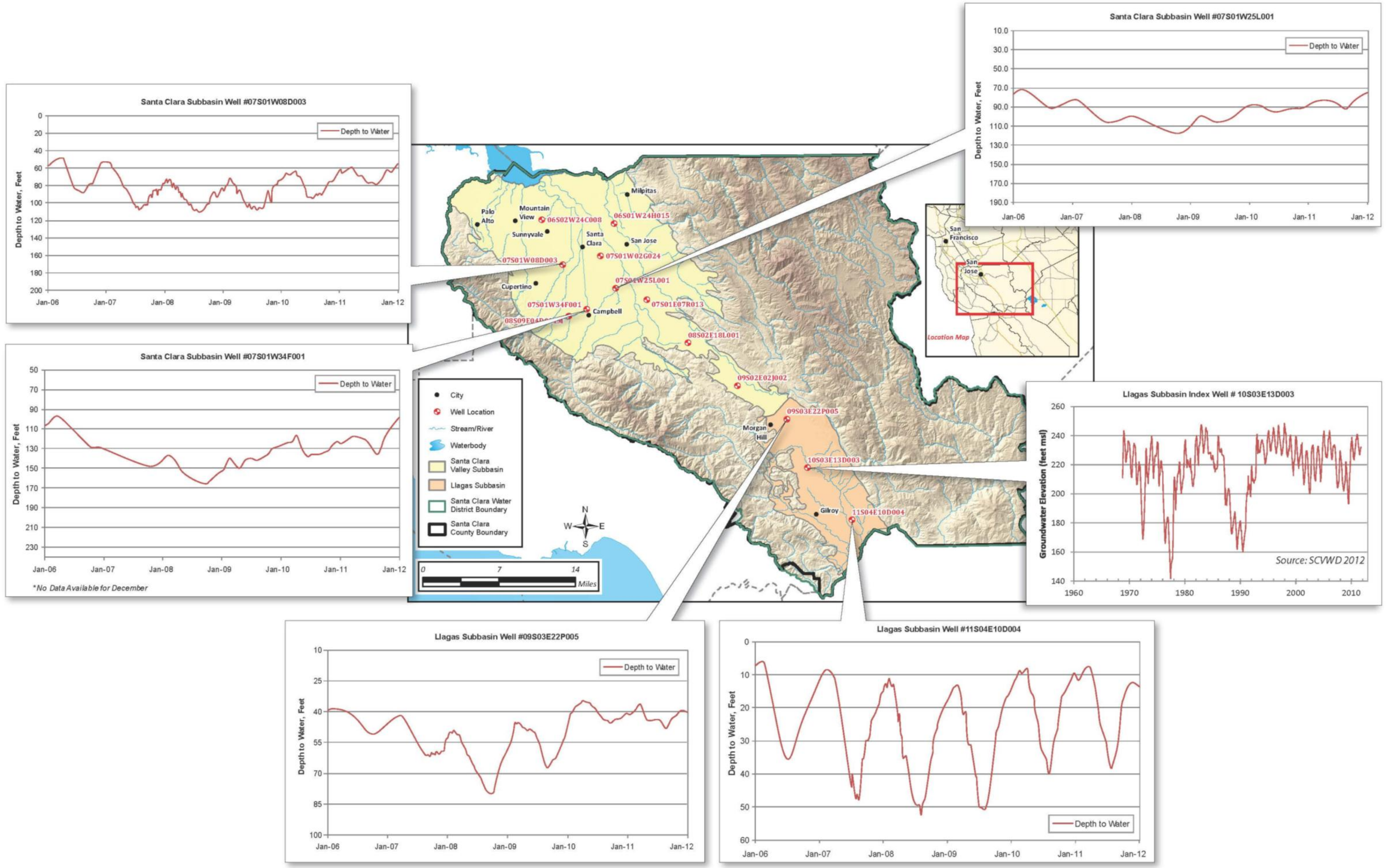


Figure 6-19. Historic Groundwater Elevations at Selected Wells in the Santa Clara Valley and Llagas Subbasin.

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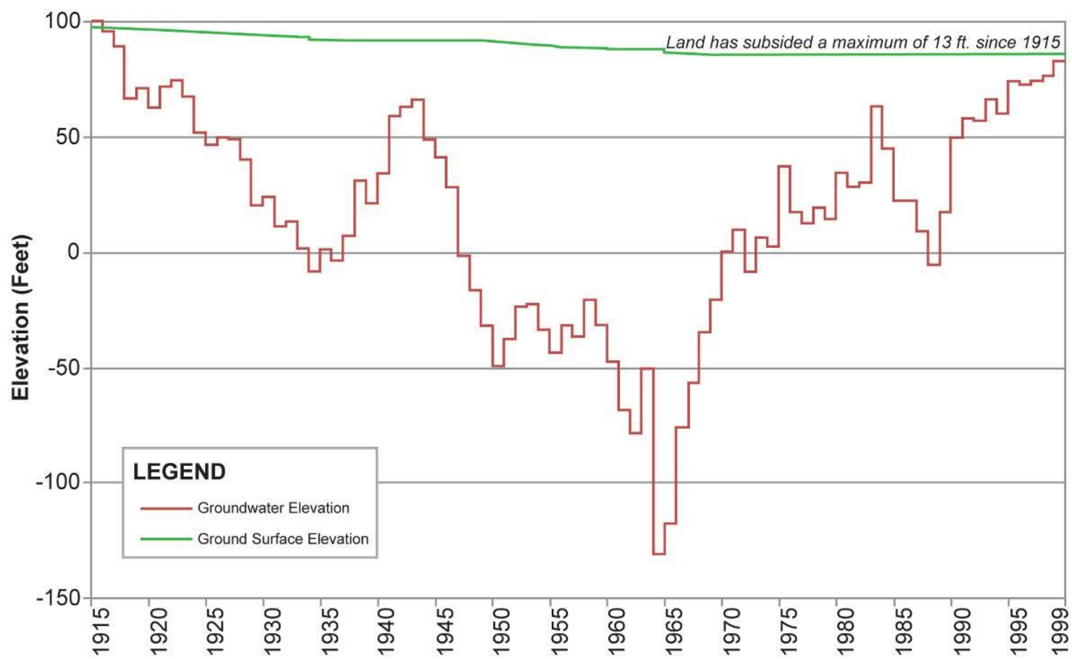
The operational storage capacity of the Santa Clara Valley subbasin is estimated to be 350,000 AF (SCVWD 2001). The operation storage capacity is less than the total storage capacity of the basin and accounts for available pumping capacity, avoidance of land subsidence, and problems associated with high groundwater levels. This estimate of operation storage capacity is based on an area defined by SCVWD that is approximately 15 square miles smaller than the Santa Clara Valley subbasin boundaries as defined in DWR's Bulletin 118 (DWR 2003).

Groundwater-Related Land Subsidence Historically, Santa Clara County has experienced as much as 13 feet of subsidence caused by excessive pumping of groundwater. One serious consequence of subsidence in Santa Clara County was that lands near the Bay sank below sea level between 1940 and 1970, enabling salt water to intrude upstream through the mouths of rivers dramatically affecting the riparian habitat of the rivers. Land subsidence also increased potential for tidal flooding (SCVWD 2000). Figure 6-20 shows the elevation of groundwater at the downtown San Jose index well (7S01E07R013) and the land subsidence measured at First and St. James Streets, San Jose.



Source: SCVWD 2000

Figure 6-20. Land Subsidence at San Jose Index Well

Groundwater Quality Though groundwater quality in the Santa Clara Valley is hard, it is suitable for most uses and drinking water standards are met at public supply wells without the use of treatment methods (SCVWD 2001). Groundwater alkalinity in the Santa Clara Valley is generally bicarbonate type with sodium and calcium being the principal cations (DWR 1975).

Groundwater in the region has elevated mineral levels which could be associated with historical saltwater intrusion observed in the northern basin due to land subsidence (SCVWD 2001). Some wells with elevated nitrate concentration have been identified in the southern portion of the basin (SCVWD 2001).

San Benito River Valley Groundwater Basin The San Benito River Valley Groundwater Basin occupies the middle reaches of the San Benito River Valley within the San Andres Fault Rift Zone and a dissected upland area of Middle-Miocene, nonmarine rocks west of the San Andres Fault. The basin is bounded on the west and southwest by granitic and volcanic rocks along the Pinnacles and Chalone Creek Faults. SBCWD is the only CVP water service contractor overlying the San Benito River Valley Groundwater Basin. No published information on groundwater resources within the basin was found.

Pajaro Valley Groundwater Basin The Pajaro Valley Groundwater Basin is bounded to the west by Monterey Bay and to the east by the San Andreas Fault, adjacent pre-Quaternary formations, and the Santa Cruz Mountains beyond. Pajaro Valley Water Management Agency (PVWMA) is the only CVP water service contractor overlying this groundwater basin. PVWMA is dependent on groundwater for their water supply. Although the agency has a CVP water service contract for 19,900 AFY, the pipeline connecting PVWMA and the CVP was never built due to the high cost of construction, local opposition to construction of pipeline, and concerns over CVP supply reliability (Levy et al. n.d.).

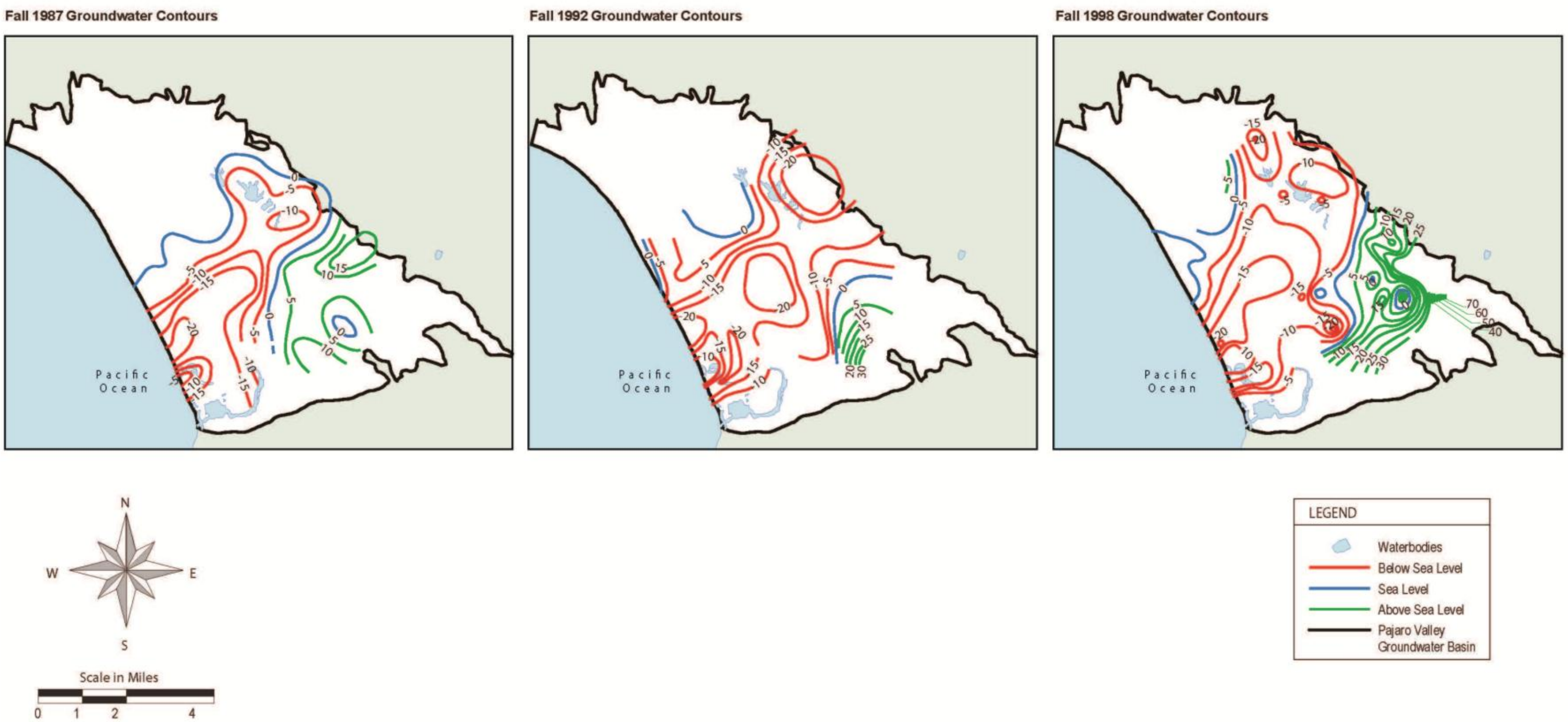
Geology, Hydrogeology, and Hydrology The water-bearing formations of the basin include the Purisima Formation, the Aromas Red Sands, Terrace and Pleistocene Eolian Deposits, Quaternary alluvium and Dune Deposits (DWR 2003). The alluvium deposits vary in thickness between 50-300 feet and are composed of Pleistocene terrace deposits, which is overlain by Holocene alluvium and then by Holocene dune sands; the dune sands are largely unsaturated (DWR 2003). Terrace deposits consist of unconsolidated basal gravel, sand, silt, and clay; alluvium consists of sand, gravel and clay deposited in the Pajaro River flood plain (DWR 2003). The basal gravel has good hydraulic continuity with the underlying Aromas Red Sands Formation and is a major source of water for shallow wells in the Pajaro River floodplain (DWR 2003).

The Aromas Red Sands formation are considered the primary water-bearing unit of the basin and vary in thickness ranging from 100 feet near the foothills to approximately 900 feet below sea level close to the Pajaro River (DWR 2003). The water producing zones within the Aromas Red Sands formation can vary greatly in their ability to transmit water (DWR 2003).

The Purisima Formation is a thick sequence of highly variable sediments ranging from extensive shale beds near its base to continental deposits in its upper portion (DWR 2003). The thickness of this formation varies from 1,000 to 2,000 feet in the central portion of the valley to approximately 4,000 feet in the down-dropped graben between the San Andreas and Zayante-Vergales faults (DWR 2003). The sediments are chiefly poorly indurated, moderately permeable gravel, sands, silts, and silty clays. In the valley portion of the basin, the Purisima has been developed to a minor degree. Hydrologically, the most important outcrops are north and east of Pajaro Valley where this unit acts as a source of recharge to the basin (DWR 2003)

Groundwater Levels and Storage Figure 6-21 shows contour maps of groundwater levels within the Pajaro Valley for the fall of 1987, 1992 and 1998. As seen in Figure 6-21 groundwater levels in inland wells are steadily declining over time (PVWMA 2002). PVWMA’s Basin Management Plan Update indicates that if drought conditions were to occur again (similar to 1987-1992), overdraft conditions would worsen and seawater intrusion rates would accelerate beyond what has been measured in the past (PVWMA 2013).

The total storage capacity of the basin is estimated to be 2 million AF above the Purisima Formation (DWR 2003). If the storage from the upper Purisima Formation is included, then the estimate of total storage capacity of the basin is 7.77 million AF (DWR 2003). Between 1964 and 1997, there has been an estimated loss of 300 TAF of freshwater storage from the basin. Approximately 200 TAF of this freshwater storage loss is due to seawater intrusion, while 100 TAF is due to conditions of chronic overdraft and resultant falling groundwater levels (DWR 2003).



Source: PVWMA 2002

Figure 6-21. Pajaro Valley Fall 1987, 1992, and 1998 Groundwater Elevation Contours

Groundwater-Related Land Subsidence No published information on land subsidence within the Pajaro Valley was available.

Groundwater Quality The greatest and most immediate threat to groundwater supplies in the Pajaro Valley is from seawater intrusion in the coastal areas. Other groundwater quality issues to be addressed include nitrate contamination and elevated boron concentrations (PVWMA 2013).

Bitterwater Valley Groundwater Basin Bitterwater Valley Groundwater Basin is comprised of several valley areas along the San Andres Rift Zone and a somewhat upland area west of the Rift Zone within the Coast Range Mountains of San Benito County. The basin is approximately 18 miles long and has a maximum width of six miles. No specific published information on groundwater resources within the basin was found.

Gilroy-Hollister Valley Groundwater Basin The Gilroy-Hollister Valley Groundwater Basin lies between the Diablo Range on the east and the Gabilan Range and the Santa Cruz Mountains to the west. The northern portion is drained toward Monterey Bay by the Pajaro River and its tributaries. The southern portion is drained by the San Benito River and its tributaries. Bulletin 118 (DWR, 2003) divides the Gilroy-Hollister Valley Groundwater Basin into four subbasins: Llagas Area, Bolsa Area, Hollister Valley and the San Juan Bautista Area. This section focuses on the southern portion of the Gilroy-Hollister Valley Groundwater Basin (Hollister subbasin) underlying SBCWD and the Llagas subbasin underlying SCVWD.

Geology, Hydrogeology, and Hydrology The Gilroy-Hollister Valley Groundwater Basin is comprised of a sedimentary sequence consisting mainly of clays, silts, sands, and gravels (DWR 2003). The basin is bound by three fault lines (Calaveras, San Andreas, and Sargent) that also form impermeable barriers to groundwater flow. The basin consists of three geologic units: Alluvium, which consists of sediment that is generally coarser near the fringes of the subbasins and finer toward the flatter central portion of the valley; Older Alluvium, which consists of deposits that are weakly consolidated interbedded gravel, sand, and mudstones; and the Panoche Formation, which consists of deposits that are consolidated, thick interbedded sand and gravels and mudstones (Bookman-Edmonston Engineering 2006 as cited in SBCWD 2010). San Benito Gravels are included in the Older Alluvium unit and constitute the main source of groundwater within the Hollister Valley subbasin.

The Llagas subbasin is geometrically similar to the Santa Clara Valley subbasin and was formed by continental deposits of unconsolidated to semi-consolidated gravel, sand, silt and clay (DWR 1981). The water bearing formation of the subbasin includes the Santa Clara Formation and the valley fill material (alluvial and alluvial fan deposits) (DWR 1981).

The Santa Clara Formation is of Plio-Pleistocene age. This formation underlies much of the valley and unconformably overlies older non-water bearing sediments (DWR 1981). It consists of fairly well consolidated clay, silt, and sand with lenses of gravel. These sediments are generally of fluvial origin with an estimated maximum thickness of 1,800 feet (DWR 1981). The lower portions of deeper wells within the subbasin likely intersect the Santa Clara Formation. Alluvial fan deposits of Holocene age occur at the margin of the valley basin. They are composed of a heterogeneous mixture of unconsolidated to semi-consolidated clay, silt, sand, and gravel usually locally partially confined (DWR 1981). The alluvial fan deposits range in thickness from 3 feet to 125 feet and overlie the Santa Clara Formation and other older non water bearing deposits (DWR 1981). A number of these wells supply water of excellent quality for irrigation and municipal purposes (DWR 1981).

Older alluvium of the Plio-Pleistocene age is distributed in the central portion of the valley from the northern boundary of the subbasin to Gilroy. It consists of unconsolidated clay, silt, and sand formed as floodplain deposits. It characteristically is identified by a dense clayey subsoil that acts as an aquitard to vertical movement of water and limits recharge potential (DWR 1981). It provides adequate yields to wells up to 100 feet in depth and water obtained from this formation is generally suitable for most uses (DWR 1981). Younger alluvium of the Holocene age occurs in the flat lying areas from Gilroy south to the basin's southern boundary. Similarly to the older alluvium, the younger alluvium has been formed principally as a flood plain deposit but it does not have a well-defined clay subsoil. The younger alluvium has a maximum thickness of about 100 feet and generally overlies the older alluvium and alluvial fan deposits (DWR 1981). Groundwater in the younger alluvium is generally unconfined and the quality of water is acceptable for domestic purposes (DWR 1981).

Annual precipitation for the Llagas subbasin ranges from less than 16 inches in the south to more than 24 inches in the north (DWR 2003).

Groundwater Production, Levels, and Storage SCVWD manages the Llagas subbasin where groundwater is pumped within the district by major water retailers, well owners and agricultural users. Annual average groundwater pumping within the Llagas subbasin has remained fairly constant over the years. Figure 6-22 shows historic groundwater pumping from 2000 to 2009 within the subbasin.

Figure 6-19 shows the groundwater elevation in the Llagas subbasin index well (10S03E13D003). Groundwater levels remained relatively stable over the period of record with the exception of water level declines and subsequent recovery associated with the 1976-1977 and 1987-1992 drought periods. While groundwater elevations in the index well are not indicative of elevations in all wells within the subbasin it is indicative of relative changes in groundwater levels within the subbasin (SCVWD 2001).

Figure 6-23 shows the historic groundwater elevations at key wells within the Gilroy-Hollister Valley Groundwater Basin (Hollister, San Juan, Tres Pinos, Bolsa, and Pacheco Valley subbasins). The hydrographs in Figure 6-23 are generated by averaging elevations from key wells from each subbasin for each monitoring event. In general groundwater levels have remained relatively stable in most subbasins over the past five years. However, water levels in the Bolsa and Bolsa Southeast (the bottom two lines on the lower hydrograph) appear to show a more muted seasonal fluctuation in the past two years.

Natural groundwater recharge based on the long-term average for the Llagas subbasin is estimated to be 44,300 AFY (SCVWD 2001). Total facility recharge (Artificial Recharge) countywide is estimated to be 157,200 AF (SCVWD 2001). The operational storage capacity of the Llagas subbasin is estimated to be between 150,000 and 165,000 AF (SCVWD 2010). The operation storage capacity is less than the total storage capacity of the basin and accounts for available pumping capacity, avoidance of land subsidence, and problems associated with high groundwater levels.

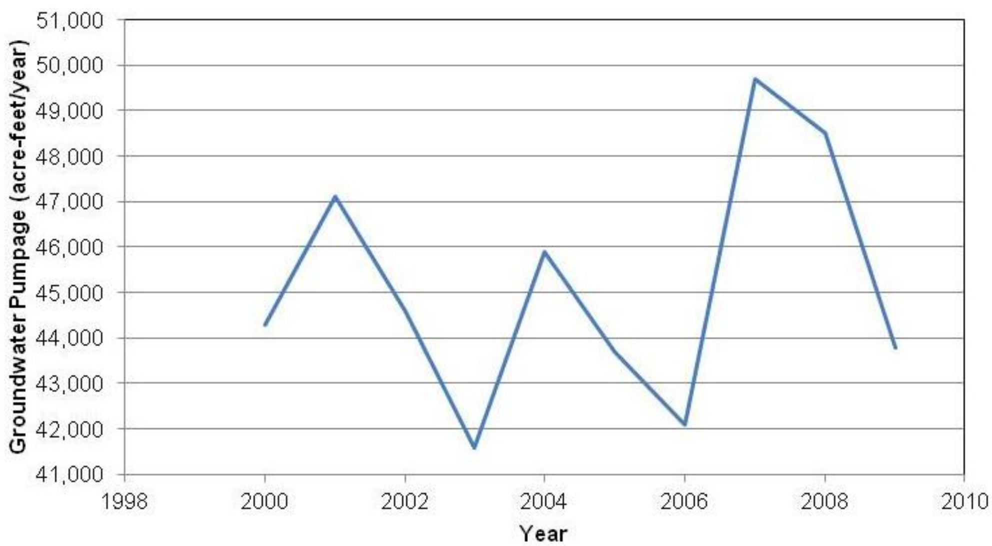
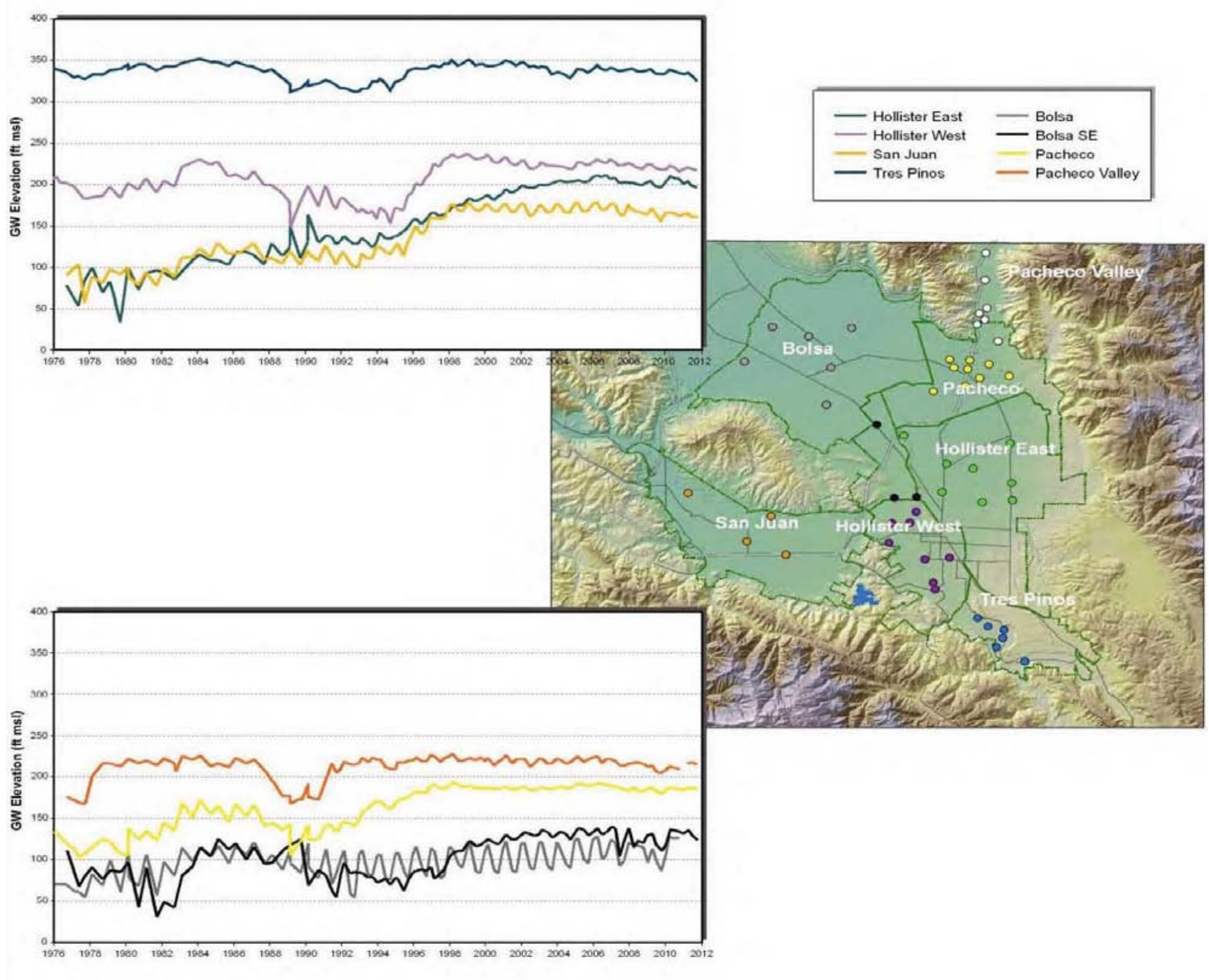


Figure 6-22. Historic Groundwater Pumping within the Llagas Subbasin



Source: SBCWD 2012

Figure 6-23. Hydrographs of Key Wells within the Gilroy-Hollister Valley Groundwater Basin

Land Subsidence Historically, Santa Clara County has experienced as much as 13 feet of subsidence caused by excessive pumping of groundwater. Most of the subsidence occurred in the Santa Clara Valley subbasin (SCVWD 2000) and it is being monitored by SCVWD.

Groundwater Quality Groundwater quality in the Gilroy-Hollister Valley Groundwater Basin is marginally acceptable for potable and irrigation use, but its levels of salinity, sodium, chloride, sulfate, nitrate, boron, arsenic, hardness, and trace elements can occasionally exceed drinking water standards (SBCWD 2010). A total of 18 monitoring wells are located throughout northern San Benito County. Water quality from the majority of these wells includes TDS concentrations exceeding 500 mg/L, the recommended limit for drinking water by DDW. Additionally, 10 of the 18 wells have TDS concentrations exceeding 1,000 mg/L, the DDW limit for drinking water, including all five wells located in the San Juan subbasin (SBCWD and SCVWD 2007 as cited in SBCWD 2010). Groundwater in the Hollister East and West subbasins also has high TDS concentrations and historically has been used as the M&I supply for SCVWD. An area of good quality water, with a TDS of less than 500 mg/L, extends from the mouth of Pacheco Creek and Arroyo de las Viboras to the west (GEI Consultants 2009 as cited in SBCWD 2010).

Almost all groundwater in the basin is hard and has a very high calcium and magnesium content. Total hardness concentrations in the groundwater have ranges from 295 to 594 mg/L as calcium carbonate (SBCWD 2010). Groundwater alkalinity in the Llagas subbasin is generally high similar to the Santa Clara Valley subbasin. Though the water is hard, it is suitable for most uses and drinking water standards are met at public supply wells without the use of treatment methods (SCVWD 2001).

SCVWD created a Nitrate Management Program in October 1991 to investigate and remediate increasing nitrate concentrations in the Llagas subbasin (SCVWD 2001). Nitrate concentrations appear to be increasing over time and elevated concentrations of nitrate still exist in the Llagas subbasin (SCVWD 2001). Since 1997, more than 600 wells in south Santa Clara County including the Llagas and Coyote subbasins have been tested for nitrate. The 2009 median nitrate concentration for the principal aquifer zone of the Llagas subbasin was 30 mg/L, with a maximum value of 155 mg/L (SCVWD 2010).

6.2 Environmental Consequences

6.2.1 Assessment Methods

This section presents the assessment methods and environmental consequences of each alternative.

Two models, CalSim II and the Statewide Agricultural Production (SWAP) model, were used in the analysis of the alternatives. Each model is briefly described below and in more detail in Appendix B, Water Operations Model Documentation, and Appendix D, Statewide Agricultural Production Model Documentation, respectively.

CalSim II is a hydrologic and operations model used by Reclamation and the DWR to conduct planning and impact analyses for the Sacramento River, San Joaquin River, and Delta. It is considered the best available tool for modeling operations of the CVP and the State Water Project (SWP). The model incorporates operating rules for the CVP and SWP that reflect a complex and extensive set of regulatory standards and operating criteria. CalSim II uses an 82-year historical period of simulation on a monthly time step. This period provides a variety of hydrologic conditions sufficient to evaluate potential impacts. It includes many different types and sequences of actual hydrologic conditions, ranging from floods to droughts of different magnitudes and durations. The CalSim II modeling provided results for changes in CVP deliveries to M&I water service contractors.

The evaluation of CVP deliveries to help meet public health and safety (PHS) needs utilizes 2030 population projections and projected 2030 demands by customer type for each contractor (where available). The future PHS demand is then calculated using Reclamation's PHS formula[2]. This calculated PHS demand is then compared against modeled CalSim II deliveries and, when available, data on each district's non-CVP supplies to identify any unmet PHS need. Unmet PHS needs are detailed in Chapter 4. The section analyzes the potential effects to groundwater resources if M&I water service contractors choose to meet all the unmet PHS need by temporarily increasing the use of groundwater. This estimate is a conservative assumption of potential groundwater use, as M&I contractors may have a number of methods available to deal with water shortages.

The SWAP model is a regional agricultural production and economic optimization model that simulates the decisions of farmers. The model assumes that farmers maximize profit subject to resource, technical, and market constraints. The SWAP model incorporates project water supplies (SWP and CVP), other local water supplies, and groundwater. As conditions change within a SWAP region (e.g., the quantity of available project water supply increases or the cost of groundwater pumping increases), the model optimizes production by adjusting the crop mix, water sources and quantities used, and other inputs. The SWAP model is used to compare the long-run response of agriculture to potential changes in SWP and CVP irrigation water delivery, other surface or groundwater conditions, or other economic values or restrictions. Results from Reclamation's and DWR's operations planning model CalSim II model are used as inputs into SWAP through a standardized data linkage tool. The SWAP modeling provided results for changes in groundwater pumping based on changes in CVP deliveries

[2] As discussed in Chapter 4, PHS demand = (Population * 55 gpd) + (80% of Historic/Forecasted Commercial & Institutional Demand) + (90% of Historic/Forecasted Industrial) + (10% for system losses)

to agricultural water service contractors in three modeled regions which overlay the groundwater basins: Sacramento Valley, San Joaquin River, and Tulare Lake. The Sacramento Valley Region falls within the North of Delta geographic area, and the San Joaquin River and Tulare Lake regions fall within the South of Delta geographic area.

CalSim II and SWAP provide the projected increase in groundwater pumping under each alternative. Potential changes to groundwater levels, land subsidence, and changes in groundwater quality were assessed qualitatively. Potential effects to groundwater levels were analyzed by comparing the projected pumping between alternatives. Groundwater quality and land subsidence impacts were assessed by considering areas of known water quality/subsidence concerns and determining whether decreasing groundwater levels could detrimentally impact those areas.

6.2.2 Alternative 1: No Action

6.2.3.1 Sacramento River Region

Changes in CVP deliveries compared to existing conditions could cause water service contractors to supplement their water supplies through additional groundwater pumping. Under the No Action Alternative, CVP deliveries to agricultural water service contractors would be lower than under existing conditions in all year types and deliveries to M&I water service contractors would be greater than existing conditions under all year types, due to changes in population growth and land use not attributable to the M&I WSP.

Table 6-2 presents the estimated net change in groundwater pumping under the No Action Alternative due to changes in agricultural deliveries and potential groundwater use to meet unmet M&I PHS needs. Under the No Action Alternative, agricultural pumping in the Sacramento River Region is expected to decrease in the future. This decrease in pumping can be attributed to an increase in groundwater pumping costs in the future of approximately 17 percent, as discussed in the SWAP modeling documentation in Appendix D. In response to this substantial increase in electricity costs, farmers are expected to substitute away from groundwater pumping to other available surface water sources, or take other actions, to maximize profits. Therefore, the expected agricultural groundwater pumping in the Sacramento River Region will be lower under the No Action Alternative than existing conditions by up to 70.5 TAF as seen in Table 6-2. As described in Chapter 4, the M&I water service contractors would experience a very small unmet PHS demand in critical years under the No Action Alternative based on their anticipated combination of CVP supplies and available non-CVP supplies.

Table 6-2. Change in Groundwater Pumping in the Sacramento River Region between the No Action Alternative and Existing Conditions

Hydrologic Year Type	Change in Agricultural Groundwater Pumping[1]		Maximum Change in M&I Groundwater Pumping (Unmet PHS Need)[2]	Net Change in Groundwater Pumping
	TAF	Percent change	TAF	TAF
Wet	-67.8	-5.4%	0.0	-67.8
Above Normal	-70.5	-5.7%	0.0	-70.5
Below Normal	-69.4	-5.5%	NA	NA
Dry	-62.1	-4.9%	0.0	-62.1
Critical	-50.1	-3.8%	+0.04	-50.1

[1] *SWAP Modeling Results*

[2] *See Chapters 1 and 4 for derivation of unmet PHS need. "Below normal" years not calculated.*

Note:

NA: Data not available/simulated

"+" sign indicates increase in pumping

"-" sign indicates decrease in pumping

Changes in groundwater pumping to supplement CVP supply shortages may cause groundwater level declines that could lead to permanent land subsidence. Groundwater pumping is expected to decrease in the future in comparison to existing conditions. Therefore, groundwater levels are not expected to decline further under the No Action Alternative. Changes in groundwater pumping under the No Action Alternative are not expected to contribute to land subsidence in this region.

Changes in groundwater levels or in the prevailing groundwater flow regime due to increased pumping to supplement CVP supply shortages could cause a change in groundwater quality. Under the No Action Alternative there will be a net reduction in groundwater pumping and, therefore, groundwater levels are not expected to decline further. As groundwater levels will not decrease, general groundwater flow patterns in this region are not expected to change. Groundwater quality, therefore, is not expected to change due to changes in flow patterns.

6.2.3.2 San Joaquin River Region

Changes in CVP deliveries compared to existing conditions could cause water service contractors to supplement their water supplies through additional groundwater pumping. Under the No Action Alternative, CVP deliveries to agricultural water service contractors would be lower than under existing conditions in all year types and deliveries to M&I water service contractors would be greater than existing conditions under all year types, due to changes in population growth and land use not attributable to the M&I WSP.

Table 6-3 presents the estimated net change in groundwater pumping under the No Action Alternative due to changes in agricultural deliveries and potential unmet M&I PHS needs. Similar to agricultural pumping in the Sacramento River Region, pumping in the San Joaquin Valley is expected to decrease in the future under all hydrologic year types. This decrease in pumping can be attributed to an increase in groundwater pumping costs in the future of approximately 17 percent, as discussed in the SWAP modeling documentation in Appendix D. In response to this substantial increase in electricity costs, farmers are expected to substitute away from groundwater pumping to other available surface water sources, or take other actions, to maximize profits. Therefore, the expected agricultural groundwater pumping in the San Joaquin River Region will be lower under the No Action Alternative than existing conditions by up to 50 TAF as seen in Table 6-3. As described in Chapter 4, the M&I water service contractors would experience a small unmet PHS demand under the No Action Alternative based on their anticipated combination of CVP supplies and available non-CVP supplies. The small increase in groundwater pumping to meet any unmet PHS needs reported in Table 6-3 is not expected to increase the net change in groundwater pumping in the San Joaquin River Region.

Table 6-3. Change in Groundwater Pumping in the San Joaquin River Region between the No Action Alternative and Existing Conditions

Hydrologic Year Type	Change in Agricultural Groundwater Pumping[1]		Maximum Change in M&I Groundwater Pumping (Unmet PHS Need)[2]	Net Change in Groundwater Pumping
	TAF	Percent change	TAF	TAF
Wet	-48.5	-4.9%	+0.08	-48.4
Above Normal	-49.9	-4.4%	+0.08	-49.8
Below Normal	-46.2	-3.8%	NA	NA
Dry	-33.0	-2.5%	+0.14	-32.9
Critical	-6.4	-0.4%	+0.36	-6.0

[1] *SWAP Modeling Results*
[2] *See Chapters 1 and 4 for derivation of unmet PHS need. "Below normal" years not calculated.*
Note:
NA: Data not available/simulated
"+" sign indicates increase in pumping
"-" sign indicates decrease in pumping

Changes in groundwater pumping to supplement CVP supply shortages may cause groundwater level declines that could lead to permanent land subsidence. Groundwater Pumping is expected to decrease in the future in comparison to existing conditions. Therefore, groundwater levels are not expected to decline further under the No Action Alternative. Changes in groundwater pumping under the No Action Alternative are not expected to contribute to land subsidence in this region.

Changes in groundwater levels or in the prevailing groundwater flow regime due to increased pumping to supplement CVP supply shortages could cause a change in groundwater quality. Under the No Action Alternative there will be a net reduction in groundwater pumping and, therefore, groundwater levels are not expected to decline further. As groundwater levels will not decrease, general groundwater flow patterns in this region are not expected to change. Groundwater quality, therefore, is not expected to change due to changes in flow patterns.

6.2.3.3 Tulare Lake Region

Changes in CVP deliveries compared to existing conditions could cause water service contractors to supplement their water supplies through additional groundwater pumping. Under the No Action Alternative, CVP deliveries to agricultural water service contractors would be lower than under existing conditions in all year types and deliveries to M&I water service contractors would be greater than existing conditions under all year types, due to changes in population growth and land use not attributable to the M&I WSP.

Table 6-4 presents the estimated net change in groundwater pumping under the No Action Alternative due to changes in agricultural deliveries and potential unmet M&I PHS needs. Agricultural pumping in the Tulare Lake region is expected to decrease in some year types and increase in some year types (see Table 6-4 for details). Decrease in pumping can be attributed to substantial increase in electricity costs, farmers are expected to substitute away from groundwater pumping to other available surface water sources, or take other actions, to maximize profits. Therefore, the expected agricultural groundwater pumping in the Tulare Lake Region could be lower than existing conditions by up to 30 TAF or higher than existing conditions up to 21.5 TAF as seen in Table 6-4. As described in Chapter 4, the M&I water service contractors would experience some unmet PHS demand under the No Action Alternative, based on their anticipated combination of CVP supplies and available non-CVP supplies. As shown in Table 6-4, the net change in groundwater pumping in the Tulare Lake Region is expected to increase under the No Action Alternative due to the increase in agricultural pumping. As described in the Existing Conditions section, groundwater levels in the Tulare Lake Region have been declining during drought periods and recovering to pre-drought levels after subsequent wet periods. Increases in groundwater pumping in this region particularly during the Critical hydrologic year types, up to 12.5 TAF, could have adverse groundwater level impacts.

Table 6-4. Change in Groundwater Pumping in the Tulare Lake Region between the No Action Alternative and Existing Conditions

Hydrologic Year Type	Change in Agricultural Groundwater Pumping[1]		Maximum Change in M&I Groundwater Pumping (Unmet PHS Need)[2]	Net Change in Groundwater Pumping
	TAF	Percent change	TAF	TAF
Wet	-21.5	-0.9%	+0.68	-20.8
Above Normal	-30.1	-1.1%	+0.68	-29.4
Below Normal	+21.5	+0.7%	NA	NA
Dry	-3.7	-0.1%	+1.18	-2.6
Critical	+10.5	+0.3%	+1.97	+12.5

As described in Chapter 6.1.3.2, subsidence is a serious concern in various areas of the San Joaquin Groundwater Basin. The net increase in groundwater pumping under this alternative could potentially cause an increase in permanent land subsidence within the San Joaquin Valley Groundwater Basin.

Changes in groundwater levels or in the prevailing groundwater flow regime due to increased pumping to supplement supply shortages, could cause a change in groundwater quality. Under this alternative there will be a net increase in groundwater pumping. Inducing the movement or migration of reduced quality water into previously unaffected areas through groundwater pumping is not likely to be a concern unless groundwater levels and/or flow patterns are substantially altered for a long period of time. Agricultural groundwater extraction under the No Action Alternative would be limited to short-term withdrawals during the irrigation season.

6.2.3.4 San Francisco Bay/Central Coast Region

Changes in CVP deliveries compared to existing conditions could cause water service contractors to supplement their water supplies through additional groundwater pumping.

Agricultural contractors in the San Francisco Bay/Central Coast Region could increase pumping under this Alternative. However, there will be no unmet PHS demand for the M&I contractors in the San Francisco Bay/Central Coast Region. There could be a net increase in groundwater pumping under this alternative; the amount of increase has not been quantified.

6.2.3 Alternative 2: Equal Agricultural and M&I Allocation

6.2.3.1 Sacramento River Region

Changes in CVP deliveries compared to the No Action Alternative could cause water service contractors to supplement their water supplies through additional groundwater pumping. Under Alternative 2, CVP deliveries to agricultural water service contractors would be higher than under the No Action Alternative in all year types and deliveries to M&I water service contractors would be lower than the No Action Alternative under all year types.

Table 6-5 presents the estimated net change in groundwater pumping under Alternative 2 due to changes in agricultural deliveries and potential unmet M&I PHS needs. Under Alternative 2, allocations to agricultural water service contractors are higher than the allocation under the No Action Alternative. Therefore, the expected agricultural groundwater pumping in the Sacramento River Region would be lower than under the No Action Alternative, up to 5 TAF. CVP deliveries to M&I water service contractors under Alternative 2 would be lower than deliveries under the No Action Alternative. As shown in Table 6-5, M&I water service contractors would experience unmet PHS demands in Alternative 2, ranging from 0.3 TAF to 1.6 TAF. M&I contractors may choose to pump additional groundwater to meet these needs. The net change in pumping under this Alternative is expected to be lower than the pumping under the No Action Alternative, up to 4.3 TAF. Therefore, the net reduction in pumping under this Alternative would not cause a decline in groundwater levels within the Sacramento River Region.

Table 6-5. Change in Groundwater Pumping in the Sacramento River Region between Alternative 2 and the No Action Alternative

Hydrologic Year Type	Change in Agricultural Groundwater Pumping[1]		Maximum Change in M&I Groundwater Pumping (Unmet PHS Need)[2]	Net Change in Groundwater Pumping
	TAF	Percent change	TAF	TAF
Wet	-3.01	-0.2%	+0.27	-2.74
Above Normal	-4.58	-0.4%	+0.27	-4.31
Below Normal	-1.28	-0.1%	NA	NA
Dry	-1.36	-0.1%	+0.42	-0.94
Critical	-3.13	-0.2%	+1.59	-1.54

Increased groundwater pumping to supplement supply shortages may cause groundwater level declines that could lead to permanent land subsidence. Under Alternative 2 there will be a net reduction in groundwater pumping and, therefore, groundwater levels are not expected to decline further. Therefore, the changes in groundwater pumping under Alternative 2 are not expected to increase land subsidence in this region.

Changes in groundwater levels or in the prevailing groundwater flow regime due to increased pumping to supplement supply shortages could cause a change in groundwater quality. Under Alternative 2 there will be a net reduction in groundwater pumping and, therefore, groundwater levels are not expected to decline further. As groundwater levels will not decrease, general groundwater flow patterns in this region are not expected to change. Groundwater quality, therefore, is not expected to change due to changes in flow patterns.

Idling cropland could decrease applied water recharge to the local groundwater system underlying the barren (idled) fields that could result in a decline in groundwater levels. There will be an increase in agricultural deliveries under Alternative 2 and this is not expected to increase the acreage of idled farmlands; therefore, there will be no change in applied water recharge in comparison to Alternative.

6.2.3.2 San Joaquin River Region

Changes in CVP deliveries compared to the No Action Alternative could cause water service contractors to supplement their water supplies through additional groundwater pumping. Under Alternative 2, CVP deliveries to agricultural water service contractors would be higher than under the No Action Alternative in all year types and deliveries to M&I water service contractors would be lower than the No Action Alternative under all year types.

Table 6-6 presents the estimated net change in groundwater pumping under Alternative 2 due to changes in agricultural deliveries and potential unmet M&I PHS needs. Similar to allocations in the Sacramento River region, allocations to agricultural water service contractors under Alternative 2 are higher than the allocation under the No Action Alternative. Therefore, the expected agricultural groundwater pumping in the San Joaquin River Region would be lower than under the No Action Alternative, up to 35 TAF.

CVP deliveries to M&I water service contractors would be lower than deliveries under the No Action Alternative. As shown in Table 6-6, there would be an increase in unmet PHS demand in Alternative 2. M&I contractors may choose to pump additional groundwater to meet this unmet demand. The increase in groundwater pumping for M&I contractors in Alternative 2 could be as high as 3.2 TAF. The net change in pumping under Alternative 2 is expected to be lower than the pumping under the No Action Alternative, up to 31.5 TAF. Therefore, the net reduction in pumping under this Alternative would not cause a decline in groundwater levels within the San Joaquin River Region.

Table 6-6. Change in Groundwater Pumping in the San Joaquin River Region between Alternative 2 and the No Action Alternative

Hydrologic Year Type	Change in Agricultural Groundwater Pumping[1]		Maximum Change in M&I Groundwater Pumping (Unmet PHS Need)[2]	Net Change in Groundwater Pumping
	TAF	Percent change	TAF	TAF
Wet	-9.52	-1.0%	+0.19	-9.33
Above Normal	-11.94	-1.1%	+0.19	-11.75
Below Normal	-17.42	-1.5%	NA	NA
Dry	-30.20	-2.3%	+0.74	-29.46
Critical	-34.78	-2.3%	+3.2	-31.58

Increased groundwater pumping to supplement supply shortages may cause groundwater level declines that could lead to permanent land subsidence. Under Alternative 2 there will be a net reduction in groundwater pumping and, therefore, groundwater levels are not expected to decline further. Therefore, the changes in groundwater pumping under Alternative 2 are not expected to increase land subsidence in this region.

Changes in groundwater levels or in the prevailing groundwater flow regime due to increased pumping to supplement supply shortages, could cause a change in groundwater quality. Under Alternative 2 there will be a net reduction in groundwater pumping and, therefore, groundwater levels are not expected to decline further. As groundwater levels will not decrease, general groundwater flow patterns in this region are not expected to change. Groundwater quality, therefore, is not expected to change due to changes in flow patterns.

Idling cropland could decrease applied water recharge to the local groundwater system underlying the barren (idled) fields that could result in a decline in groundwater levels. There will be an increase in agricultural deliveries under this Alternative and this is not expected to increase the acreage of idled farmlands, therefore, there will be no change in applied water recharge in comparison to Alternative.

6.2.3.3 Tulare Lake Region

Changes in CVP deliveries compared to the No Action Alternative could cause water service contractors to supplement their water supplies through additional groundwater pumping. Under Alternative 2, CVP deliveries to agricultural water service contractors would be higher than under the No Action Alternative in all year types and deliveries to M&I water service contractors would be lower than the No Action Alternative under all year types.

Table 6-7 presents the estimated net change in groundwater pumping under Alternative 2 due to changes in agricultural deliveries and potential unmet M&I PHS needs. Similar to allocations in the Sacramento and San Joaquin River

Region, allocations to agricultural water service contractors under Alternative 2 are higher than the allocation under the No Action Alternative. Therefore, the expected agricultural groundwater pumping in the Tulare Lake Region would be lower than under the No Action Alternative, up to 38 TAF.

CVP deliveries to M&I water service contractors would be lower than deliveries under the No Action Alternative. As shown in Table 6-7, contractors would experience unmet PHS demands under Alternative 2. M&I contractors may choose to pump additional groundwater to meet this unmet demand. The increase in groundwater pumping for M&I contractors in Alternative 2 could be as high as 1.8 TAF. The net change in pumping under this Alternative is expected to be lower than the pumping under the No Action Alternative, up to 38 TAF. Therefore, the net reduction in pumping under this Alternative would not cause a decline in groundwater levels within the Tulare Lake Region.

Table 6-7. Change in Groundwater Pumping in the Tulare Lake Region between Alternative 2 and the No Action Alternative

Hydrologic Year Type	Change in Agricultural Groundwater Pumping[1]		Maximum Change in M&I Groundwater Pumping (Unmet PHS Need)[2]	Net Change in Groundwater Pumping
	TAF	Percent change	TAF	TAF
Wet	-25.05	-1.0%	+0.18	-24.87
Above Normal	-38.02	-1.4%	+0.18	-37.84
Below Normal	-25.69	-0.9%	NA	NA
Dry	-11.97	-0.4%	+0.29	-11.68
Critical	-13.55	-0.4%	+1.76	-11.79

[1] *SWAP Modeling Results*
[2] *See Chapters 1 and 4 for derivation of unmet PHS need. "Below normal" years not calculated.*
Note:
NA: Data not available/simulated
"+" sign indicates increase in pumping
"-" sign indicates decrease in pumping

Increased groundwater pumping to supplement supply shortages may cause groundwater level declines that could lead to permanent land subsidence. Under Alternative 2 there will be a net reduction in groundwater pumping and, therefore, groundwater levels are not expected to decline further. Therefore, the changes in groundwater pumping under Alternative 2 are not expected to increase land subsidence in this region.

Changes in groundwater levels or in the prevailing groundwater flow regime due to increased pumping to supplement supply shortages, could cause a change in groundwater quality. Under Alternative 2 there will be a net reduction in groundwater pumping and, therefore, groundwater levels are not expected to decline further. As groundwater levels will not decrease, general groundwater flow patterns in this region are not expected to change. Groundwater quality, therefore, is not expected to change due to changes in flow patterns.

Idling cropland could decrease applied water recharge to the local groundwater system underlying the barren (idled) fields that could result in a decline in groundwater levels. There will be an increase in agricultural deliveries under this Alternative and this is not expected to increase the acreage of idled farmlands, therefore, there will be no change in applied water recharge in comparison to the No Action Alternative.

6.2.3.4 San Francisco Bay/Central Coast Region

Changes in CVP deliveries compared to the No Action Alternative could cause water service contractors to supplement their water supplies through additional groundwater pumping. Under Alternative 2, CVP deliveries to agricultural water service contractors would be higher than under the No Action Alternative in all year types and deliveries to M&I water service contractors would be lower than the No Action Alternative under all year types.

Agricultural water service contractors within the San Francisco Bay/Central Coast Region could have an increase in allocations under this alternative. This increase in CVP deliveries would result in a decrease in the amount of agricultural pumping; however the amount of reduction has not been quantified under this alternative.

CVP deliveries to M&I water service contractors under Alternative 2 would be lower than deliveries under the No Action Alternative. As a result, there would be an increase in unmet PHS demand, as shown in Table 6-8. M&I contractors may choose to pump additional groundwater to meet this remaining demand. As a result, there will be a net increase in pumping up to 21 TAF in this region.

Table 6-8. Change in Groundwater Pumping between Alternative 2 and the No Action Alternative within the San Francisco Bay/Central Coast Region

Hydrologic Year Type	Change in Unmet in PHS Demand (Alternative 2 vs. the No Action Alternative) (TAF)
Normal	+1.33
Dry	+20.95
Critical	+3.26

Note:
"+" sign indicates increase in pumping

Increased groundwater pumping to supplement supply shortages may cause groundwater level declines that could lead to permanent land subsidence. Groundwater pumping in this region is expected to increase due to the reduction in M&I allocations. There will be a net increase in groundwater pumping and, therefore, groundwater levels are expected to decline in this region. Land Subsidence has been a serious concern in some of the groundwater basins within this region. Increase in groundwater pumping under this alternative could increase subsidence in this region.

Changes in groundwater levels or in the prevailing groundwater flow regime due to increased pumping to supplement supply shortages, could cause a change in groundwater quality. Groundwater pumping in this region is expected to increase due to the reduction in M&I allocations. There will be a net increase in groundwater pumping and, therefore, groundwater levels are expected to decline in this region. Inducing the movement or migration of reduced quality water into previously unaffected areas through groundwater pumping is not likely to be a concern unless groundwater levels and/or flow patterns are substantially altered for a long period of time. As pumping is expected to increase substantially only under dry conditions, flow patterns are not expected to change substantially under Alternative 2. Groundwater quality, therefore, is not expected to change due to changes in flow patterns.

Idling cropland could decrease applied water recharge to the local groundwater system underlying the barren (idled) fields that could result in a decline in groundwater levels. There will be an increase in agricultural deliveries under Alternative 2 and this is not expected to increase the acreage of idled farmlands, therefore, there will be no change in applied water recharge in comparison to the No Action Alternative.

6.2.4 Alternative 3: Full M&I Allocation Preference

6.2.4.1 Sacramento River Region

Changes in CVP deliveries compared to the No Action Alternative could cause water service contractors to supplement their water supplies through additional groundwater pumping. Under Alternative 3, M&I water service contractors would receive a 100 percent allocation as compared to the No Action Alternative and other action alternatives. This would be achieved by reducing the allocations to agricultural water service contractors as needed to maximize the frequency of full allocations to the M&I water service contractors.

Table 6-9 presents the estimated net change in groundwater pumping under Alternative 3 due to changes in agricultural deliveries and potential unmet M&I PHS needs. Under Alternative 3, reduced allocations to agricultural water services contractors would result in agricultural water services contractors supplementing their surface water supplies through additional groundwater pumping. Therefore, the expected agricultural groundwater pumping in the Sacramento River Region would be higher than under the No Action Alternative, up to 2 TAF.

M&I water service contractors would receive a 100 percent allocation under Alternative 3. Therefore, as shown in Table 6-9, there would be zero or minimal unmet PHS demand. There will be a net increase in pumping under this

Alternative due to the increased agricultural pumping within the Sacramento River Region.

As described in the Existing Conditions section, groundwater levels in the Sacramento River Region have been declining during drought periods and recovering to pre-drought levels after subsequent wet periods. Increase in groundwater pumping in this region particularly during the Critical hydrologic year types could have adverse groundwater level impacts.

Table 6-9. Change in Groundwater Pumping in the Sacramento River Region between Alternative 3 and the No Action Alternative

Hydrologic Year Type	Change in Agricultural Groundwater Pumping[1]		Maximum Change in M&I Groundwater Pumping (Unmet PHS Need)[2]	Net Change in Groundwater Pumping
	TAF	Percent change	TAF	TAF
Wet	+0.43	+0.1%	+0.00	+0.43
Above Normal	+1.97	+0.2%	+0.00	+1.97
Below Normal	+0.60	+0.1%	NA	NA
Dry	-0.33	-0.1%	+0.00	-0.33
Critical	+1.21	+0.1%	+0.03	+1.24

[1] *SWAP Modeling Results*
[2] *See Chapters 1 and 4 for derivation of unmet PHS need. "Below normal" years not calculated.*
Note:
NA: Data not available/simulated
"+" sign indicates increase in pumping
"-" sign indicates decrease in pumping

Increased groundwater pumping to supplement supply shortages may cause groundwater level declines that could lead to permanent land subsidence. As shown in Figure 6-10, portions of Colusa and Yolo counties have experienced historic subsidence and increased subsidence has also been noticed at Conaway Ranch (Yolo County). Under this alternative there will be a net increase in groundwater pumping that could potentially cause an increase in permanent land subsidence within the Sacramento Valley.

Changes in groundwater levels or in the prevailing groundwater flow regime due to increased pumping to supplement supply shortages, could cause a change in groundwater quality. Under this alternative there will be a net increase in groundwater pumping. Inducing the movement or migration of reduced quality water into previously unaffected areas through groundwater pumping is not likely to be a concern unless groundwater levels and/or flow patterns are substantially altered for a long period of time. Agricultural groundwater extraction under Alternative 3 would be limited to short-term withdrawals during the irrigation season.

Idling cropland could decrease applied water recharge to the local groundwater system underlying the barren (idled) fields that could result in a decline in groundwater levels. There will be a decrease in agricultural deliveries under Alternative 3. Reduced surface water supplies and increasing groundwater pumping costs could force some farmers to idle their lands. This could decrease applied water recharge and cause declines in groundwater levels within the region.

6.2.4.2 San Joaquin River Region

Changes in CVP deliveries compared to the No Action Alternative could cause water service contractors to supplement their water supplies through additional groundwater pumping. Under Alternative 3, M&I water service contractors would receive the highest deliveries compared to the No Action Alternative and other action alternatives. This would be achieved by reducing the allocations to agricultural water service contractors as needed to maximize the frequency of full allocations to the M&I water service contractors.

Table 6-10 presents the estimated net change in groundwater pumping under Alternative 3 due to changes in agricultural deliveries and potential unmet M&I PHS needs. Under Alternative 3, reduced allocations to agricultural water service contractors would result in agricultural water service contractors supplementing their surface water supplies through additional groundwater pumping. Therefore, the expected agricultural groundwater pumping in the San Joaquin River Region would be higher than under the No Action Alternative, up to 21 TAF.

M&I water service contractors would receive a 100 percent allocation under Alternative 3. Therefore, as shown in Table 6-10, the unmet PHS demand under Alternative 3 will be very small in comparison to the No Action Alternative. There will be a net increase in pumping under this Alternative due to the increased agricultural pumping within the San Joaquin River Region.

As described in the Existing Conditions section, groundwater levels in the San Joaquin River Region have been declining during drought periods and recovering to pre-drought levels after subsequent wet periods. Increase in groundwater pumping in this region particularly during the Critical and Dry hydrologic year types could have adverse groundwater level impacts.

Table 6-10. Change in Groundwater Pumping in the San Joaquin River Region between Alternative 3 and the No Action Alternative

Hydrologic Year Type	Change in Agricultural Groundwater Pumping[1]		Maximum Change in M&I Groundwater Pumping (Unmet PHS Need)[2]	Net Change in Groundwater Pumping
	TAF	Percent change	TAF	TAF
Wet	+3.40	+0.3%	+0.09	+3.49
Above Normal	+4.29	+0.4%	+0.09	+4.38
Below Normal	+9.89	+0.8%	NA	NA
Dry	+20.64	+1.5%	+0.19	+20.83
Critical	+18.74	+1.2%	+0.42	+19.16

[1] *SWAP Modeling Results*
[2] *See Chapters 1 and 4 for derivation of unmet PHS need. "Below normal" years not calculated.*
Note:
NA: Data not available/simulated
"+" sign indicates increase in pumping
"-" sign indicates decrease in pumping

Increased groundwater pumping to supplement supply shortages may cause groundwater level declines that could lead to permanent land subsidence. As described in Chapter 6.1.3.2, subsidence is a serious concern in various areas of the San Joaquin Groundwater Basin. Under Alternative 3 there will be a net increase in groundwater pumping that could potentially cause an increase in permanent land subsidence within the San Joaquin Valley.

Changes in groundwater levels or in the prevailing groundwater flow regime due to increased pumping to supplement supply shortages, could cause a change in groundwater quality. Under this alternative there will be a net increase in groundwater pumping. Inducing the movement or migration of reduced quality water into previously unaffected areas through groundwater pumping is not likely to be a concern unless groundwater levels and/or flow patterns are substantially altered for a long period of time. Agricultural groundwater extraction under Alternative 3 would be limited to short-term withdrawals during the irrigation season.

Idling cropland could decrease applied water recharge to the local groundwater system underlying the barren (idled) fields that could result in a decline in groundwater levels. There will be a decrease in agricultural deliveries under Alternative 3. Reduced surface water supplies and increasing groundwater pumping costs could force some farmers to idle their lands. This could decrease applied water recharge and cause declines in groundwater levels within the region.

6.2.4.3 Tulare Lake Region

Changes in CVP deliveries compared to the No Action Alternative could cause water service contractors to supplement their water supplies through additional *groundwater pumping*. Under Alternative 3, M&I water service contractors would receive the highest deliveries compared to the No Action Alternative and other action alternatives. This would be achieved by reducing the allocations to agricultural water service contractors as needed to maximize the frequency of full allocations to the M&I water service contractors.

Table 6-11 presents the estimated net change in groundwater pumping under Alternative 3 due to changes in agricultural deliveries and potential unmet M&I PHS needs. Under Alternative 3, reduced allocations to agricultural water service contractors would result in agricultural water service contractors supplementing their surface water supplies through additional groundwater pumping. Therefore, the expected agricultural groundwater pumping in the Tulare Lake Region would be higher than under the No Action Alternative, up to 14.5 TAF.

M&I water service contractors would receive a 100 percent allocation under Alternative 3. Therefore, as shown in Table 6-10, the unmet PHS demand under Alternative 3 will be very small in comparison to the No Action Alternative.

There will be a net increase in pumping under this Alternative due to the increased agricultural pumping within the San Joaquin River Region. As described in the Existing Conditions section, groundwater levels in the Tulare Lake Region have been declining during drought periods and recovering to pre-drought levels after subsequent wet periods. Increase in groundwater pumping in this region particularly during the Critical and Dry hydrologic year types could have adverse groundwater level impacts.

Table 6-11. Change in Groundwater Pumping in the Tulare Lake Region between Alternative 3 and the No Action Alternative

Hydrologic Year Type	Change in Agricultural Groundwater Pumping[1]		Maximum Change in M&I Groundwater Pumping (Unmet PHS Need)[2]	Net Change in Groundwater Pumping
	TAF	Percent change	TAF	TAF
Wet	+10.98	+0.4%	+0.09	+11.07
Above Normal	+14.52	+0.5%	+0.09	+14.61
Below Normal	+3.11	+0.1%	NA	NA
Dry	+8.49	+0.3%	+0.18	+8.67
Critical	+7.01	+0.2%	+0.42	+7.43

Increased groundwater pumping to supplement supply shortages may cause groundwater level declines that could lead to permanent land subsidence. As described in Chapter 6.1.3.2, subsidence appears to be a serious concern in various areas of the San Joaquin Groundwater Basin. Under this alternative there will be a net increase in groundwater pumping that could potentially cause an increase in permanent land subsidence within the Tulare Lake Region.

Changes in groundwater levels or in the prevailing groundwater flow regime due to increased pumping to supplement supply shortages, could cause a change in groundwater quality. Under this alternative there will be a net increase in groundwater pumping. Inducing the movement or migration of reduced quality water into previously unaffected areas through groundwater pumping is not likely to be a concern unless groundwater levels and/or flow patterns are substantially altered for a long period of time. Agricultural groundwater extraction under Alternative 3 would be limited to short-term withdrawals during the irrigation season.

Idling cropland could decrease applied water recharge to the local groundwater system underlying the barren (idled) fields that could result in a decline in groundwater levels. There will be a decrease in agricultural deliveries under Alternative 3. Reduced surface water supplies and increasing groundwater pumping costs could force some farmers to idle their lands. This could decrease applied water recharge and cause declines in groundwater levels within the region.

6.2.4.4 San Francisco Bay/Central Coast Region

Changes in CVP deliveries compared to the No Action Alternative could cause water service contractors to supplement their water supplies through additional groundwater pumping. Under Alternative 3, M&I water service contractors would receive the highest deliveries compared to the No Action Alternative and other action alternatives. This would be achieved by reducing the allocations to agricultural water service contractors as needed to maximize the frequency of full allocations to the M&I water service contractors.

Agricultural water service contractors within the San Francisco Bay/Central Coast Region could supplement their supply shortages through groundwater pumping. The amount of increase in agricultural pumping has not been quantified under this alternative. M&I allocations will be higher than the allocation under the No Action Alternative. As a result, there will be a net decrease in pumping up to 1.5 TAF in this region, shown in Table 6-12.

Table 6-12. Change in Groundwater Pumping between Alternative 3 and No Action Alternative within the San Francisco Bay/Central Coast Region

Hydrologic Year Type	Change in Unmet in PHS Demand (Alternative 2 – the No Action Alternative) (TAF)
Normal	-1.0
Dry	-0.6
Critical	-1.5

Note:
"-" sign indicates decrease in pumping

6.2.5 Alternative 4: Updated M&I WSP

Under Alternative 4, there will be no change in water supply deliveries to agricultural and M&I contractors within the Sacramento River, San Joaquin Valley, Tulare Lake, and San Francisco Bay/Central Coast regions compared to the No Action Alternative. Allocations under Alternative 4 will be similar to those under the No Action Alternative. Therefore, groundwater effects generated by Alternative 4 would be identical to the effects under the No Action Alternative.

6.2.6 Alternative 5: M&I Contractor Suggested WSP

6.2.6.1 Sacramento River Region

Changes in CVP deliveries compared to the No Action Alternative could cause water service contractors to supplement their water supplies through additional groundwater pumping. Alternative 5 provides a greater level of assurance that CVP water will be allocated to M&I water service contractors to supply the unmet portion of the PHS demands during shortage years. This will result in reduced allocations to agricultural water service contractors.

Table 6-13 presents the estimated net change in groundwater pumping under Alternative 5 due to changes in agricultural deliveries and potential unmet M&I PHS needs. Under Alternative 5, reduced allocations to agricultural water service contractors would result in agricultural water service contractors supplementing their surface water supplies through additional groundwater pumping. As shown in Table 6-13, the expected increase in groundwater pumping will be very small and will not cause any adverse impacts to groundwater levels in the Sacramento River Region.

Table 6-13. Change in Groundwater Pumping in the Sacramento River Region between Alternative 5 and the No Action Alternative

Hydrologic Year Type	Change in Agricultural Groundwater Pumping[1]		Maximum Change in M&I Groundwater Pumping (Unmet PHS Need)[2]	Net Change in Groundwater Pumping
	TAF	Percent change	TAF	TAF
Wet	0.00	~0.0%	0.00	0.00
Above Normal	+0.02	~0.0%	0.00	+0.02
Below Normal	0.00	~0.0%	NA	NA
Dry	+0.11	~0.0%	0.00	+0.11
Critical	+0.01	~0.0%	0.00	+0.01

[1] *SWAP Modeling Results*
[2] *See Chapters 1 and 4 for derivation of unmet PHS need. "Below normal" years not calculated.*
Note
NA: Data not available/simulated
"+" sign indicates increase in pumping
"-" sign indicates decrease in pumping

Increased groundwater pumping to supplement supply shortages may cause groundwater level declines that could lead to permanent land subsidence. Under Alternative 5, there will be a very small (up to 110 AF) net increase in groundwater pumping; therefore, groundwater levels are not expected to decline substantially. Therefore, the changes in groundwater pumping under Alternative 5 are not expected to increase land subsidence in this region.

Changes in groundwater levels or in the prevailing groundwater flow regime due to increased pumping to supplement supply shortages, could cause a change in groundwater quality. Under Alternative 5, there will be a very small (up to 110 AF) net increase in groundwater pumping; therefore, groundwater levels are not expected to decline substantially. As groundwater levels will not decrease, general groundwater flow patterns in this region are not expected to change. Groundwater quality, therefore, is not expected to change due to changes in flow patterns.

6.2.6.2 San Joaquin River Region

Changes in CVP deliveries compared to the No Action Alternative could cause water service contractors to supplement their water supplies through additional groundwater pumping. Alternative 5 provides a greater level of assurance that CVP water will be allocated to M&I water service contractors to supply the unmet portion of the PHS demands during shortage years. This will result in reduced allocations to agricultural water service contractors.

Table 6-14 presents the estimated net change in groundwater pumping under Alternative 5 due to changes in agricultural deliveries and potential unmet M&I PHS needs. As shown in Table 6-14, the unmet PHS demand under Alternative 5 will be very small and there will be very small increase in agricultural pumping. The net change in groundwater pumping in the San Joaquin River Region would be very small (up to 800 AF) and is not expected to cause adverse effects to groundwater levels in the San Joaquin River Region.

Table 6-14. Change in Groundwater Pumping in the San Joaquin River Region between Alternative 5 and the No Action Alternative

Hydrologic Year Type	Change in Agricultural Groundwater Pumping[1]		Maximum Change in M&I Groundwater Pumping (Unmet PHS Need)[2]	Net Change in Groundwater Pumping
	TAF	Percent change	TAF	TAF
Wet	+0.03	~0.0%	+0.17	+0.20
Above Normal	+0.07	~0.0%	+0.17	+0.24
Below Normal	-0.01	~0.0%	NA	NA
Dry	+0.08	~0.0%	+0.29	+0.37
Critical	+0.06	~0.0%	+0.74	+0.80

Increased groundwater pumping to supplement supply shortages may cause groundwater level declines that could lead to permanent land subsidence. Under this alternative there will be a very small (up to 800 AF) net increase in groundwater pumping therefore, groundwater levels are not expected to decline substantially. Therefore, the changes in groundwater pumping under Alternative 5 are not expected to increase land subsidence in this region.

Changes in groundwater levels or in the prevailing groundwater flow regime due to increased pumping to supplement supply shortages, could cause a change in groundwater quality. Under Alternative 5, there will be a very small (up to 800 AF) net increase in groundwater pumping; therefore, groundwater levels are not expected to decline substantially. As groundwater levels will not decrease, general groundwater flow patterns in this region are not expected to change. Groundwater quality, therefore, is not expected to change due to changes in flow patterns.

6.2.6.3 Tulare Lake Region

Changes in CVP deliveries compared to the No Action Alternative could cause water service contractors to supplement their water supplies through additional groundwater pumping. Alternative 5 provides a greater level of assurance that CVP water will be allocated to M&I water service contractors to supply the unmet portion of the PHS demands during shortage years. This will result in reduced allocations to agricultural water service contractors.

Table 6-15 presents the estimated net change in groundwater pumping under Alternative 5 due to changes in agricultural deliveries and potential unmet M&I PHS needs. As shown in Table 6-15, there would be no unmet PHS demand under this Alternative and a very small increase in agricultural pumping. The net change in groundwater pumping in the Tulare Lake Region would be very small and is not expected to cause adverse effects to groundwater levels in the Tulare Lake Region.

Table 6-15. Change in Groundwater Pumping in the Tulare Lake Region between Alternative 5 and the No Action Alternative

Hydrologic Year Type	Change in Agricultural Groundwater Pumping[1]		Maximum Change in M&I Groundwater Pumping (Unmet PHS Need)[2]	Net Change in Groundwater Pumping
	TAF	Percent change	TAF	TAF
Wet	+0.18	~0.0%	0.00	+0.18
Above Normal	+0.59	~0.0%	0.00	+0.59
Below Normal	+0.08	~0.0%	NA	NA
Dry	+0.03	~0.0%	0.00	+0.03
Critical	+0.01	~0.0%	0.00	+0.01

Increased groundwater pumping to supplement supply shortages may cause groundwater level declines that could lead to permanent land subsidence. Under this alternative there will be a very small (up to 600 AF) net increase in groundwater pumping thus, groundwater levels are not expected to decline substantially. Therefore, the changes in groundwater pumping under Alternative 5 are not expected to increase land subsidence in this region.

Changes in groundwater levels or in the prevailing groundwater flow regime due to increased pumping to supplement supply shortages, could cause a change in groundwater quality. Under Alternative 5, there will be a very small (up to 600 AF) net increase in groundwater pumping; therefore, groundwater levels are not expected to decline substantially. As groundwater levels will not decrease, general groundwater flow patterns in this region are not expected to change. Groundwater quality, therefore, is not expected to change due to changes in flow patterns.

6.2.3.4 San Francisco Bay/Central Coast Region

Alternative 5 provides a greater level of assurance that CVP water will be allocated to M&I water service contractors to supply the unmet portion of the PHS demands during shortage years. This will result in slightly reduced allocations to agricultural water service contractors. Agricultural water service contractors could supplement their surface water supplies through groundwater pumping. This increased groundwater pumping could result in temporary groundwater level declines. Pajaro Valley is the only agricultural contractor within the San Francisco Bay/Central Coast Region and they could increase their pumping to meet agricultural demands under this alternative. PHS demands will be completely met within this region as shown in Table 6-16.

Table 6-16. Change in Groundwater Pumping between Alternative 5 and Alternative within the San Francisco Bay/Central Coast Region

Hydrologic Year Type	Change in Unmet in PHS Demand (Alternative 5 vs. No Action Alternative) (TAF)
Normal Condition	+0.0
Dry Condition	+0.0
Critical Condition	+0.0

6.3 Mitigation Measures

There are no mitigation measures needed to reduce the severity of the groundwater impacts.

6.4 Unavoidable Adverse Impacts

As noted in Chapter 6.2, under Alternative 3 there will be a substantial increase in groundwater pumping in the Sacramento River, San Joaquin River, and Tulare Lake regions. This increase in pumping is expected to decrease groundwater levels and could potentially cause land subsidence within these regions.

6.5 Cumulative Impacts

The timeframe for the groundwater resources cumulative effects analysis extends from 2010 through 2030, a twenty year period. The cumulative effects area of analysis for groundwater resources is the same area described in Chapter 6.1.1.

This section analyzes the cumulative effects using the project method, which is further described in Chapter 20, Cumulative Effects Methodology. Chapter 20 describes the projects included in the cumulative condition. Growth and development trends in the area of analysis are factored into the PHS demand evaluation completed in Chapter 4.2 and this cumulative analysis.

The following sections describe potential groundwater resources cumulative effects for each of the proposed alternatives.

6.5.1 Alternative 2: Equal Agricultural and M&I Allocation

Equal allocation of available CVP water supplies between M&I and agricultural water service contractors under Alternative 2 would result in increased water supply deliveries to agricultural water service contractors, and increased unmet M&I demand in the Sacramento River, San Joaquin River, Tulare Lake, and San Francisco Bay/Central Coast Regions. M&I and agricultural water service contractors could supplement their surface water supplies through groundwater pumping. This increased groundwater pumping could result in temporary groundwater level declines.

In addition to groundwater pumping that would occur by M&I and agricultural water service contractors to supplement their surface water supplies, annual groundwater substitution transfers could occur in the Sacramento Valley Groundwater Basin, as analyzed in the Long-Term Water Transfers (LTWT) Environmental Impact Statement/Environmental Impact Report (EIS/EIR), which is included in the area of analysis for Alternative 2. Reclamation's LTWT program would occur between 2015 through 2024. It is possible that groundwater substitution transfers under the LTWT program would compound the declines in groundwater levels in the Sacramento Valley Groundwater Basin.

The Northern Sacramento Valley Integrated Regional Water Management Plan is a project that aims to provide a regional perspective to planning for water use in the northern Sacramento Valley, including Butte, Colusa, Glenn, Shasta, Sutter, and Tehama counties. The Plan is still under development; however, it is expected that the Plan will help to provide management objectives that would be protective of the groundwater resources in the northern Sacramento Valley.

The Tuscan Aquifer Investigation project, conducted by the Butte County Department of Water and Resource Conservation, included numerous field data collection activities to allow for a more complete understanding of the Tuscan Aquifer. This project included the drilling of groundwater monitoring wells and the gaging of several streams in the Sierra Nevada foothills. Aquifer testing (i.e., pumping tests) was also performed at three existing production wells. The pumping associated with this project has been completed and would not contribute to cumulative effects. Information collection was primarily within Butte County, but the information about the Tuscan Aquifer could provide useful information about aquifer properties to other counties overlying the same aquifer (Glenn, Colusa, and Tehama counties).

The increased pumping under this Alternative in combination with other cumulative projects could cause land subsidence. The groundwater substitution pumping associated with the LTWT program would occur in an area that is historically not subject to significant land subsidence. In the overall area of analysis, land subsidence is occurring in several areas, as described in Chapter 6.1.3. This subsidence would not likely result in substantial risk to life or property; however, the existing subsidence along with future increases in groundwater pumping in the cumulative condition could affect life or property within the area of analysis.

The increased pumping under this Alternative in combination with other cumulative projects could cause the movement or mobilization of poorer quality groundwater into existing wells. Groundwater substitution transfers by SWP contractors and the Tuscan Aquifer Investigation Project would increase pumping within (or near) the Sacramento River Region. However, as discussed in Chapter 6.1.3.1, most of this region has high quality groundwater and changes in groundwater flow patterns should not cause migration of poor quality groundwater.

6.5.2 Alternative 3: Full M&I Allocation Preference

The cumulative impacts of Alternative 3 would be the same as described for groundwater pumping under Alternative 2.

6.5.3 Alternative 4: Updated M&I WSP

The cumulative impacts of Alternative 4 would be the same as described for groundwater pumping under Alternative 2.

6.5.4 Alternative 5: M&I Contractor Suggested WSP

The cumulative impacts of Alternative 5 would be the same as described for groundwater pumping under Alternative 2.

6.6 References

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