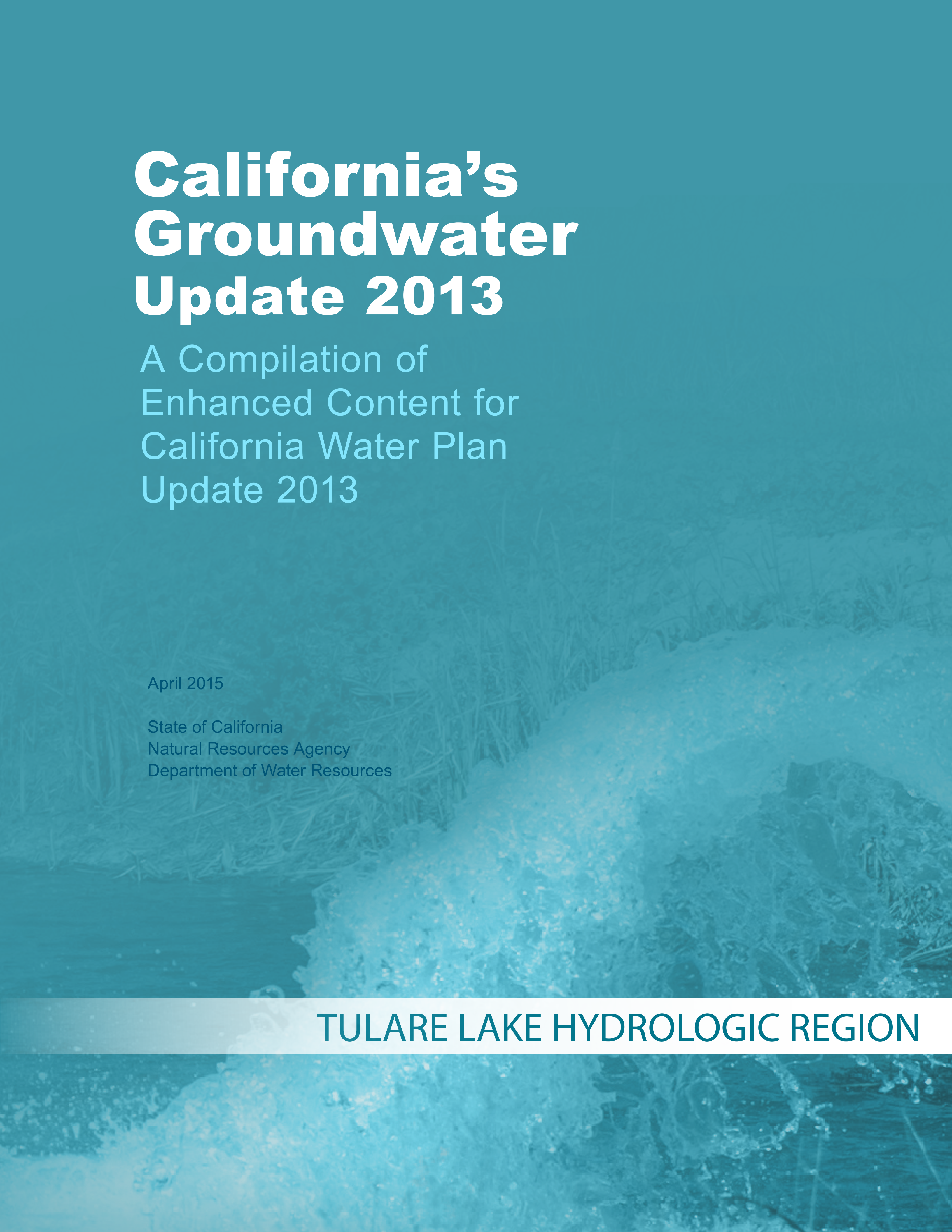

California's Groundwater Update 2013

A Compilation of Enhanced Content for California Water Plan Update 2013

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TULARE LAKE HYDROLOGIC REGION

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Acronyms and Abbreviations Used in This Chapter

AB	Assembly Bill
ACWA	Association of California Water Agencies
AWMP	agriculture water management plan
bgs	below ground surface
BMO	basin management objective
C2VSim	California Central Valley Groundwater-Surface Water Simulation Model
CASGEM	California Statewide Groundwater Elevation Monitoring
CDPH	California Department of Public Health
CVHM	Central Valley Hydrologic Model
CVP	Central Valley Project
CV-SALTS	Central Valley Salinity Alternatives for Long-Term Sustainability
CWP	California Water Plan
CWS	community water system
DAU	detailed analysis unit
DBCP	1,2-dibromo-3-chloropropane
DCE	dichloroethylene
GAMA	Groundwater Ambient Monitoring and Assessment
GIS	geographic information system
gpm	gallons per minute
gpm/ft	gallons per minute per foot
GPS	global positioning system
GWMP	groundwater management plan
HAL	health advisory level
InSAR	interferometric synthetic aperture radar
IRWM	integrated regional water management

ITRC	Irrigation Training and Research Center
KRCD	Kings River Conservation District
maf	million acre-feet
MCL	maximum contaminant level
NL	notification level
PA	planning area
PCE	tetrachloroethylene
RWMG	regional water management group
RWQCB	regional water quality control board
SB	Senate Bill
SB X7-6	California 2009 Comprehensive Water Package legislation
SB X7-7	Water Conservation Bill of 2009
SMCL	secondary maximum contaminant level
SWN	State Well Numbering
SWP	State Water Project
SWRCB	California State Water Resources Control Board
SWSD	Semitropic Water Storage District
taf	thousand acre-feet
TDS	total dissolved solids
TID	Tulare Irrigation District
Tulare Lake region	Tulare Lake Hydrologic Region
UNAVCO	university-governed consortium for geosciences research using geodesy
USBR	U.S. Bureau of Reclamation
USGS	U.S. Geological Survey
UWMP	urban water management plan
WWD	Westlands Water District

Chapter 9. Tulare Lake Hydrologic Region Groundwater Update

Introduction

The primary goal of the Tulare Lake Hydrologic Region (Tulare Lake region) groundwater update is to expand information about region-specific groundwater conditions for *California Water Plan Update 2013*, and to guide more informed groundwater management actions and policies. A second goal is to steadily improve the quality of groundwater information in future California Water Plan (CWP) updates to a level that will enable regional water management groups (RWMGs) to accurately evaluate their groundwater resources and implement management strategies that can meet local and regional water resource objectives within the context of broader statewide objectives. The final goal is to identify data gaps and groundwater management challenges meant to serve as guideposts for prioritizing future data collection and funding opportunities relevant to the region.

This regional groundwater update is not intended to provide a comprehensive and detailed examination of local groundwater conditions, or be a substitute for local studies and analysis. However, where information is readily available, the update does report some aspects of the regional groundwater conditions in greater detail.

The Tulare Lake region, depicted in Figure 9-1, covers about 16,800 square miles and includes all of Tulare and Kings counties, and most of Fresno and Kern counties. The hydrologic region is bordered to the east by the Sierra Nevada, to the west by the Coast Ranges, and to the south by the Tehachapi Mountains. To the north, the Tulare Lake region is separated from the San Joaquin River Hydrologic Region (San Joaquin region) by a rise in the San Joaquin Valley floor caused by an accumulation of San Joaquin River and the Kings River alluvial fan deposits. Although this drainage divide is the boundary between the San Joaquin and Tulare Lake regions, geographically the valley floor portion of the Tulare Lake region is considered part of the southern San Joaquin Valley. Major rivers draining into the Tulare Lake region include the Kings, Kaweah, Tule, and Kern, which extend from the Sierra Nevada headwaters in eastern Fresno and Tulare counties, to their termination at the former Tulare Lake and Buena Vista Lake beds.

The climate in the region is semi-arid to arid. The average annual precipitation on the valley floor ranges from about 6 to 11 inches. Approximately 95 percent of the precipitation falls between October and April. Moist winter conditions often cause tule fog blanketing the valley area.

The 2010 census information indicates an overall population of 2.27 million for the Tulare Lake region, with about 40 percent of the population overlying the Kings Groundwater Subbasin and about 31 percent overlying the Kern County Groundwater Subbasin.

Figure 9-1 Tulare Lake Hydrologic Region

Prepared by California Department of Water Resources for California's Groundwater Update 2013

The groundwater update for the Tulare Lake region provides an overview and assessment of the region's groundwater supply and development, groundwater use, monitoring efforts, aquifer conditions, and various management activities as well as challenges and successes associated with sustainable groundwater management. The regional update starts with a summary of findings based on the overview and assessment, groundwater data gaps and recommendations to further improve the overall sustainability of this valuable resource. This is followed by a comprehensive overview of the relevant groundwater topics.

Findings, Data Gaps, and Recommendations

The following information is specific to the Tulare Lake region and summarizes the findings, data gaps, and recommendations.

Findings

The bulleted items in this section are adopted from more comprehensive information presented in this chapter, and generally reflect information that was readily available through August 2012. Much of the groundwater information, including well infrastructure discussions, water supply analysis, change in groundwater in storage estimates, and groundwater management plan reviews, are new to this update of the CWP. The groundwater data presented in this document will be used as the foundation for the next update to the California Department of Water Resources' (DWR's) Bulletin 118 and CWP, with the goal of generating information that can be used to make informed decisions to sustainably manage California's groundwater resources. The following information highlights the groundwater findings for the Tulare Lake region.

Groundwater Supply and Development

- The Tulare Lake region contains 19 DWR Bulletin 118-2003-recognized alluvial groundwater basins and subbasins underlying approximately 8,400 square miles, or 50 percent of the hydrologic region (Figure 9-2 and Table 9-1).
- The total number of wells completed in the Tulare Lake region between 1977 and 2010 is approximately 54,322 and ranges from a high of 27,070 wells for Fresno County to a low of 4,150 wells for Kings County (Figure 9-3 and Table 9-3).
- Based on the California Statewide Groundwater Elevation Monitoring (CASGEM) Basin Prioritization completed in December 2013, seven basins or subbasins in the Tulare Lake region are identified as high priority, one basin is identified as medium priority, one subbasin is listed as low priority, and 10 basins or subbasins are listed as very low priority. The eight basins designated as high or medium priority account for 98 percent of the total average annual groundwater use and nearly 98 percent of the 2010 population living within the region's groundwater basin boundaries (Figure 9-6 and Table 9-4).

Groundwater Use and Aquifer Conditions

- The 2005-2010 average annual total water supply for the Tulare Lake region, based on planning area boundaries, is estimated at 11.6 million acre-feet (maf). Water demands in the region are met through a combination of local surface water supplies, State (State Water Project) and federal (Central Valley Project) surface water deliveries, groundwater, and reused/recycled water supplies (Figure 9-7).

- Groundwater contributes about 53 percent (6.2 maf) of the 2005-2010 average annual total water supply for the Tulare Lake region. Groundwater extraction in the region accounts for 38 percent of all the groundwater pumping in California — double the amount of the next largest hydrologic region groundwater user (Figure 9-7).
- Groundwater supplies, based on average annual estimates for 2005-2010, contribute 51 percent of the supply to meet the total agricultural water uses, 82 percent of the supply to meet total urban uses, and 37 percent of the supply to meet the total managed wetlands uses in the Tulare Lake region (Table 9-5).
- Between 2002 and 2010, annual groundwater extraction in the Tulare Lake region ranged between 3.5 maf in 2005 and 8.7 maf in 2009, and contributed between 32 percent and 70 percent of the annual water supply (Figure 9-8).
- Of the groundwater pumped on an annual basis between 2002 and 2010, 83 percent to 92 percent of the total groundwater extraction was used to meet agricultural uses (Figure 9-9).
- Depth to groundwater and groundwater elevation contours using spring 2010 data show that many parts of the southern San Joaquin Valley groundwater levels were at depths exceeding 650 feet below ground surface (bgs) (Figure 9-12 and Figure 9-13).
- Change in groundwater elevations between spring 2005 and spring 2010 show that many areas of the southern San Joaquin Valley experienced groundwater elevation declines in excess of 60 feet (Figure 9-15).
- A geographic information systems (GIS) tool developed by DWR indicated that between spring 2005 and spring 2010, the water table in the San Joaquin Valley portion of the Tulare Lake region declined by an average of 17.4 feet, which represented a loss of groundwater in storage between 3.6 maf and 8.8 maf (Figure 9-16 and Table 9-12).

Groundwater Monitoring Efforts

- A total of 3,342 wells are actively monitored for groundwater-level information in the Tulare Lake region as of July 2012, which is nearly twice as many as any other hydrologic region in the state (Figure 9-10 and Table 9-8).
- There are an estimated 354 community water systems (CWSs) in the Tulare Lake region with an estimated 1,229 active CWS wells; 329 of the CWS wells (27 percent) are identified as being affected by one or more chemical contaminants that exceed a maximum contaminant level (MCL). The affected wells are used by 146 CWSs in the region, with 110 of the 146 affected CWSs serving small communities.
- The most prevalent groundwater contaminants affecting community drinking water wells in the region are arsenic, nitrate, gross alpha particle activity, uranium, and DBCP. A total of 73 regional wells are affected by multiple contaminants (Tables 9-14, 9-15, 9-16, and 9-17).
- Land subsidence investigations in the southern San Joaquin Valley — elevation surveys along the California Aqueduct, borehole extensometer monitoring, satellite remote sensing using interferometric synthetic aperture radar (InSAR), continuous and conventional global positioning system (GPS) measurements, and spirit-leveling surveying — reveal that land subsidence is continuing to occur in areas where historical subsidence has been observed, and is also occurring in areas where no subsidence had previously been recorded. Recent studies indicate that land subsidence

rates of up to 1 foot per year have returned to groundwater basins that are highly reliant upon groundwater (Appendix F).

Groundwater Management and Conjunctive Management

- There are 26 groundwater management plans (GWMPs) within the Tulare Lake region that collectively cover 35 percent of the region and 69 percent of the Bulletin 118-2003 alluvial basin area.
- DWR's assessment of GWMPs in the Tulare Lake region determined that 17 of the 26 GWMPs have been developed or updated to include the legislative requirements of Senate Bill (SB) 1938 and are considered "active" for the purposes of the GWMP assessment.
- Five of the 17 GWMPs in the region, or 18 percent of the alluvial basin area, address all of the required components identified in California Water Code Section 10753.7 (Figure 9-24 and Table 9-18).
- Of the 89 agencies or programs identified as operating a conjunctive management or groundwater recharge program in California, 37 programs are located in the Tulare Lake region. The effort to fully characterize the region's conjunctive management programs was limited as numerous agencies were reluctant to make details about their groundwater recharge operations publically available (Appendix D).

Data Gaps

Data gaps in groundwater information are separated into the following three categories: data collection and analysis, basin assessments, and sustainable management. Where possible, the discussion of data gaps is specific to the Tulare Lake region; however, many of the identified data gaps are applicable to several or all hydrologic regions in California. Addressing these data gaps at both the local level and State agency level will help ensure that groundwater resources throughout California are better characterized and sustainably managed.

Data Collection and Analysis

Although the general characterization of the major alluvial aquifer systems in the Tulare Lake region is satisfactory, there is a need to further improve the characterization of many of the region's aquifers, especially those aquifers that serve disadvantaged communities. More complete hydrogeological data is necessary to better understand basin-wide and region-wide groundwater levels, groundwater quality, groundwater use, and the interaction between surface water and groundwater.

Information related to groundwater extraction, groundwater use, managed and natural recharge, and groundwater basin budgets in the Tulare Lake region is limited. Much of the related information presented in this report has been estimated primarily through water supply balance and land use information derived from DWR's land use surveys. Little or no information is known about the fractured-bedrock aquifers located outside the southern San Joaquin Valley and how they interact with the valley's alluvial aquifer systems.

Some local water agencies in the Tulare Lake region are collecting appropriate groundwater data, conducting necessary analyses, and are sustainably managing their basins by using the authorities they are given. However, locally collected and analyzed data, which could be used by RWMGs and State agencies to better characterize the groundwater basins in the Tulare Lake region, are generally not readily available.

Basin Assessments

Region-wide depth-to-groundwater information and annual estimates of change in groundwater in storage are not well understood for many of the groundwater basins in the Tulare Lake region.

Further degradation of groundwater quality in the Tulare Lake region is unavoidable without a plan for removing the accumulation of salts. In addition to salts, high levels of arsenic and nitrate concentrations have been reported throughout the region, and studies have concluded that nitrate problems will likely worsen in the coming decades.

Land subsidence investigations in the Tulare Lake region include various monitoring efforts, but because of the documented increase in the depth to water and the reduction of groundwater supplies in storage throughout the San Joaquin Valley, land subsidence will continue to occur in areas that have already experienced subsidence and in areas that have experienced increased groundwater pumping.

Approximately 42 percent of the state's conjunctive management programs (37 of 89) are located in the Tulare Lake region. The survey conducted as part of *California Water Plan Update 2013* was unable to collect comprehensive information about those programs; as a result, a general understanding of the effectiveness of the region's groundwater recharge and conjunctive management programs could not be determined. In addition, it was unknown at the time of data collection for this report whether local agencies have complied with the groundwater recharge mapping requirements of Assembly Bill (AB) 359, which went into effect on January 1, 2013.

Sustainable Management

The 17 active GWMPs in the Tulare Lake region that meet some, or all, of the SB 1938 groundwater management requirements, cover 49 percent of the alluvial groundwater basin area. More than 80 percent of the region's GWMPs address groundwater overdraft policies in their plans. From 2005 to 2010 the region depleted between 3.6 maf and 8.8 maf of its groundwater in storage from the areas that report groundwater elevation data from unconfined aquifers. A key gap to implementing sustainable groundwater management practices at the local level is the limited authority of some agencies to assess management fees, restrict groundwater extraction, and regulate land use in groundwater-short areas.

Recommendations

While much information is known about some of the groundwater basins in the Tulare Lake region, comprehensive information that could provide a realistic water budget to determine groundwater sustainability in the region is largely unknown. To better characterize and sustainably manage the region's groundwater resources, the following recommendations are made for the Tulare Lake region.

- Increase collection and analysis of groundwater level, quality, use, and extraction data, as well as information regarding the surface water-groundwater interaction in alluvial aquifers, to a level that allows for development of groundwater budgets, groundwater supply forecasting, and assessment of sustainable groundwater management practices.

- Increase data collection in fractured bedrock aquifers to determine the degree of interaction that the foothill communities have with the San Joaquin Valley aquifers.
- Increase land subsidence monitoring to quantify the permanent loss of groundwater in storage throughout the region that has been caused by excessive groundwater pumping.
- Continue to monitor groundwater quality throughout the region to better determine sources of natural and anthropogenic contamination and comply with all groundwater-quality protection strategies recommended by the Central Valley Regional Water Quality Control Board.
- Manage all high- and medium-priority groundwater basins as identified by the CASGEM Basin Prioritization process as per the standards set forth in California Water Code.
- DWR should work with local water managers in the region to fill in the gaps in the conjunctive management survey information to assess effectiveness of groundwater recharge and conjunctive management programs in the Tulare Lake region.
- DWR should work with local water managers in the region to ensure that the groundwater recharge mapping requirements of AB 359 are met.
- Ensure local agency goals, actions, and plans for sustainable groundwater management are compatible with, and roll-up to, a set of goals and actions established by the overlying integrated regional water management (IRWM) plan.
- Provide local and regional agencies the authority to assess fees, limit groundwater extraction, and restrict land use in groundwater-short areas as needed to better establish a path toward sustainable groundwater management.
- Develop annual groundwater management reports that summarize groundwater management goals, objectives, and performances measures; current and projected trends for groundwater extraction, groundwater levels, groundwater quality, land subsidence, and surface water-groundwater interaction; assessment of existing groundwater management practices; and proposed actions for improvements toward sustainable groundwater management.

Groundwater Supply and Development

This chapter provides an overview of the major aquifer systems that contribute groundwater to the regional supply, the well infrastructure used to develop these supplies, and an introduction to groundwater basin prioritization for the region.

Groundwater resources in the Tulare Lake region are supplied by alluvial aquifers and by fractured-rock aquifers. Alluvial aquifers are composed of sand and gravel, or finer-grained sediments, with groundwater stored within the voids, or pore space, among the alluvial sediments. Fractured-rock aquifers consist of impermeable granitic, metamorphic, volcanic, or hard sedimentary rocks, with groundwater being stored within fractures or other void spaces. The distribution and extent of alluvial and fractured-rock aquifers and water wells vary within the Tulare Lake region. A brief description of the alluvial aquifers for the region is provided in the following paragraphs. Additional information regarding alluvial and fractured-rock aquifers is available online from http://water.ca.gov/groundwater/bulletin118/index.cfm.

Alluvial Aquifers

DWR Bulletin 118-2003 identifies 19 alluvial groundwater basins and subbasins in the Tulare Lake region. The 19 basins and subbasins underlie approximately 8,400 square miles, or 50 percent of the hydrologic region. Most of the groundwater in the Tulare Lake region is stored in alluvial aquifers. A detailed description of aquifers within this hydrologic region is beyond the scope of this report. This section includes a brief summary of the major groundwater basins and aquifers within this hydrologic region. Figure 9-2 shows the locations of the alluvial groundwater basins and subbasins and Table 9-1 lists the names and numbers associated those basins and subbasins.

Groundwater extracted by wells located outside the alluvial basins is supplied largely from fractured-rock aquifers. In some cases, groundwater stored within a thin overlying layer of alluvial deposits or a thick soil horizon may also contribute to a well's groundwater supply.

Groundwater extraction from the alluvial aquifer portion of the Tulare Lake region accounts for approximately 38 percent of California's average annual groundwater extraction. The most heavily used groundwater basins in the region include six of the seven subbasins within the southern San Joaquin Valley Groundwater Basin: Kern County, Tule, Kings, Tulare Lake, Kaweah, and Westside. These six subbasins account for approximately 98 percent of the groundwater pumped in the Tulare Lake region.

The descriptions of alluvial aquifers in the Tulare Lake region is organized according to the major unconfined and confined aquifer systems within and outside the southern San Joaquin Valley Groundwater Basin, followed by a short overview of irrigation pump performance and aquifer susceptibility to land subsidence.

San Joaquin Valley Groundwater Basin

Aquifer systems within the southern San Joaquin Valley Groundwater Basin (5-22) portion of the Tulare Lake region consist mostly of continental sediments eroded from the nearby surrounding mountains and deposited in the valley. The alluvial aquifer system is a complex set of interbedded aquifers and aquitards that function regionally as a single water-yielding unit (Sneed 2001). The San Joaquin Valley aquifers are generally thick with groundwater wells extending to depths of more than 1,000 feet (Page 1986). The aquifers consist of gravel, sand, silt, and clay lenses, which become increasingly interbedded toward the center of the valley with fine-grained lakebed deposits (U.S. Geological Survey 2011). The maximum thickness of freshwater deposits is about 4,400 feet and occurs at the south end of the valley.

Figure 9-2 **Alluvial Groundwater Basins and Subbasins within the Tulare Lake Hydrologic Region**

Prepared by California Department of Water Resources for California's Groundwater Update 2013

Table 9-1 Alluvial Groundwater Basins and Subbasins in the Tulare Lake Hydrologic Region

Basin	Subbasin	Basin/Subbasin Name
5-22		San Joaquin Valley
	5-22.08	Kings
	5-22.09	Westside
	5-22.10	Pleasant Valley
	5-22.11	Kaweah
	5-22.12	Tulare Lake
	5-22.13	Tule
	5-22.14	Kern County
5-23		Panoche Valley
5-25		Kern River Valley
5-26		Walker Basin Creek Valley
5-27		Cummings Valley
5-28		Tehachapi Valley West
5-29		Castac Lake Valley
5-71		Vallecitos Creek Valley
5-80		Brite Valley
5-82		Cuddy Canyon Valley
5-83		Cuddy Ranch Area
5-84		Cuddy Valley
5-85		Mil Potrero Area

Principal water bearing formations that comprise the major aquifers in Tulare Lake region include Pliocene-Pleistocene-age Tulare and Kern River formations, older alluvium and terrace deposits, and recent alluvial and river sediments. Other water-bearing formations that are locally important in the Kaweah (5-22.11), Tulare Lake (5-22.12), Tule (5-22.13), and Kern County (5-22.14) groundwater subbasins include westward dipping sediments lying along the sloping face of the Sierran basement complex. These sediments included the Schenley sand member of the Kern River formation, and the Olcese and Santa Margarita formations, which provide fresh water from very deep wells (Rodner 1950; Hilton et al. 1963).

Although several highly productive coarse-grained aquifers exist in the San Joaquin Valley Groundwater Basin, fine-grained sediments comprise more than 50 percent of the valley fill deposits (Faunt 2005). Abundant deposits of fine-grained material of varying thickness and distribution combine over the larger aquifer area to restrict the vertical flow of groundwater. The upper few hundred feet of alluvial aquifer tends to remain unconfined, grading to semi-confined and highly confined conditions with increasing depth.

On a regional scale, the aquifer systems of the San Joaquin Valley Groundwater Basin can be divided into an upper unconfined to semi-confined aquifer, a series of geographically extensive confining clay layers, and a deep confined aquifer.

Unconfined to Semi-Confined Aquifers within the San Joaquin Valley

Alluvial deposits comprising the unconfined to semi-confined aquifers may be grouped into the Coast Range alluvium along the west side of the valley, Sierran alluvium on the east side of the valley, flood-basin deposits in the center of the valley (Faunt 2005), and buried river-channel deposits within the alluvial fan and Pleistocene river courses.

Coast Range Alluvium

Coast Range alluvium varies considerably by size and by location. Along stream channel reaches and upper alluvial fan areas, alluvial deposits are dominated by sand- and gravel-size sediments. Along the distal end of the alluvial fans, the grain size of the alluvial material grades to a finer mixture of silt and clay (Faunt 2005). Marine sediments, transported into San Joaquin Valley Basin aquifers from eroding sands and shale of the Temblor Range, contain a high portion of silt and clay, and a higher salt content (Davis 1961). Dissolved salts from Coast Range runoff over the alluvial marine deposits are dominated by calcium, sodium, chloride, and sulfate ions.

Sierran Alluvium

Sierran alluvium consists generally of coarse-grained sand and gravel deposits that have been transported by Sierra Nevada runoff into the valley, as far as the axis of the valley trough. Runoff from Sierra Nevada streams and rivers have a much lower concentration of dissolved salts and consist primarily of calcium, magnesium, and bicarbonate ions. Alluvial material from the Coast Range and Sierra Nevada come together along the axis of the San Joaquin Valley, forming inter-fingered alluvial deposits from the two source areas.

Flood-Basin Deposits

Flood-basin deposits lie mostly along the trough axis of the San Joaquin Valley. The organic rich deposits occur in the floodplain adjacent to the valley's river and stream channels, and within topographic lows associated with marshes, lakes, and ponds. Flood-basin deposits are dominantly silt and clay, with periodic lenses of sand that mark the former location of meandering stream beds.

Buried River Channel Deposits

The variable texture of the southern San Joaquin Valley Groundwater Basin's alluvial aquifers is partly a function of the location and size of the transporting rivers and streams. The high-energy flows can produce coarse-grained channel deposits measuring more than 0.5 mile wide, as much as 90 feet deep, and extending the length of the fluvial fan (Weissmann 2004). Changes in river flows associated with the buried river channel deposits are related to the Pleistocene glacial outwash cycles in the Sierra Nevada (Weissmann 2004). The buried channels create preferred pathways for groundwater movement between the shallow and deeper aquifer systems, and cause increases in groundwater velocity along these pathways. The Kings River Fan is one of the largest fluvial fans in the region. High-energy glacial outwash deposits along the Kings River Fan include those of the Modesto formation (Late Pleistocene), the Riverbank unit (Middle Pleistocene), and the Upper and Lower Turlock Lake formations (Early Pleistocene). High-permeability coarse-grained deposits can also be identified at depth in the southern San Joaquin Valley. The Pliocene-age coarse-grained basal units represent deposits from a pre-glaciation period (Weissmann et al. 2002).

Principal Confining Unit — Corcoran Clay

Fine-grained sediments comprise more than 50 percent of the valley fill deposits (Faunt 2005). Nearly continuous lake and/or marsh sediments have been present in the Tulare, Kern, and Buena Vista Lake beds since Pliocene and Pleistocene time. These lake and marsh sediments formed thick clay plugs in the lakebed areas. The largest of these clay plugs is in the Tulare Lake area. Now drained, the clay marks the presence of a succession of lakes that periodically spread from the Tulare Lake area, extending outward into greater- or lesser-size lakes. In the center of the spreading areas, the presence of thick (up to 3,000 feet) and extensive clay layers limit the amount of available groundwater for water supply. Six distinct lake clay layers have been identified in the geologic record. The clay layers are named in alphabetical order from A-clay (shallow and youngest) to F-clay (deepest and oldest).

The geographic extent and thickness of the clay layers provide a record of the interplay between the tectonic mountain building forces and climate variability. The Tulare Lake Bed is near the center of an area of structural downwarping with tectonic subsidence controlling the rate of sediment filling of the basin (Burow et al. 2004).

The largest of the ancestral lakes formed the E-clay, or Corcoran clay. The lake was geographically extensive, covering the western half of the San Joaquin Valley from the Kern Lake Bed north to an area north of Modesto (Faunt 2009). The Corcoran clay is up to 150 feet thick, occurs at a depth of about 250 feet bgs along State Route 99 near Goshen and Pixley, and at a depth of 800 feet bgs in the Tulare Lake Bed area (Croft 1972). The Corcoran clay is commonly described as “blue clay” on driller logs.

The Corcoran clay has formed a nearly impermeable flow barrier, separating the unconfined to semi-confined groundwater above from the confined groundwater below. Confining conditions are apparent by the marked differences in water levels between wells penetrating above and below the Corcoran clay. Presence of the confined aquifer was noted during early studies of groundwater in the valley by identifying areas of artesian wells (Mendenhall et al. 1916). The presence of the confining layers is reflected by significant water quality conditions between the unconfined/semi-confined aquifer and the confined aquifer. Where the Corcoran clay is present, groundwater quality from a salt content perspective is generally fresher below the clay layer.

Alluvial Aquifers outside the San Joaquin Valley

Several alluvial aquifers exist in groundwater basins outside the southern San Joaquin Valley portion of the Tulare Lake region. Although the overall groundwater supply of these aquifers is minor when compared with the groundwater supplies of the southern San Joaquin Valley Groundwater Basin, these aquifers serve as an important source of local groundwater supplies. Some of the more important outlying groundwater basins and subbasins include Pleasant Valley (5-22.10), Tehachapi Valley West (5-28), and Cummings Valley (5-27).

Pleasant Valley Groundwater Subbasin

Pleasant Valley Groundwater Subbasin (5-22.10) is located along the west side of the valley between the folded marine sediments of the Diablo Range. The eastern boundary of the subbasin abuts the Westside (5-22.09) and Tulare Lake (5-22.12) groundwater subbasins. The southern boundary abuts the Kern County Groundwater Subbasin (5-22.14). Major drainages entering the valley from the west include Los Gatos Creek, Warthan Creek, and Jacalitos Creek. Several ephemeral streams and creeks erode Tertiary marine shale and sandstone, dissolving and carrying the salt-laden water into the valley. Situated within the Pleasant Valley Groundwater Subbasin, Coalinga was once known as the town with three faucets (hot, cold, and drinking). At one time, Coalinga obtained its water supply from a combination of poor-quality (high total dissolved solids [TDS]) groundwater for hot and cold domestic water and potable water imported into the valley by rail tank car from nearby Hanford. Since the California Aqueduct was completed, Coalinga has been receiving an allotment of water, subsequently ending the need to import potable water from Hanford.

Groundwater in the Pleasant Valley Groundwater Subbasin is produced from a Holocene alluvial aquifer consisting of sand, gravel, and cobbles, interbedded with sandy clay, silt, and clay. Aquifer depth varies from a few feet to as much as 1,000 feet bgs (Schmidt 2000). Pleasant Valley lies in the rain shadow of the Coast Ranges and receives only 7 to 9 inches of precipitation per year — which severely limits aquifer recharge. Several similar but smaller alluvial valleys along the east side of the Coast Range also demonstrate aquifer quality impacts caused by recharge through salt-laden marine sediments. The influence of those surrounding marine sediments on the groundwater quality of several small drainages — with names like Devilwater Creek, Bitterwater Creek, Bitterwater Wells, and Sulphur Spring — is evident.

Tehachapi Valley

The Tehachapi Valley is located in the southeast portion of Kern County at the southern end of the Sierra Nevada in the Tehachapi Mountains. It is bordered on the north by the Sierra Nevada, on the south by the Tehachapi Mountains, on the west by foothills of the Bear Mountains, and on the east by Proctor Gap (*Tehachapi-Cummings County Water District v. City of Tehachapi*, 2010). Tehachapi Valley has been has been divided into two groundwater basins — the Tehachapi Valley West (5-28) and the Tehachapi Valley East (6-45), the latter being located in the Colorado River Hydrologic Region.

Topography in the area is variable, with the mountains surrounding the basin sloping moderately to steeply toward the valley floor. Sloping topography results in a relatively high gradient for an alluvial basin. Elevations of the valley floor range from 3,550 feet above mean sea level (msl) in the northwest to 5,000 feet above msl where the valley alluvium meets the bedrock of the basin boundary. The average annual safe yield of groundwater within the basin has been determined to be 5,500 acre-feet (*Tehachapi-Cummings County Water District v. City of Tehachapi*, 2010). The Tehachapi basins are also adjudicated basins that have contracted with the Kern County Water Agency for entitlements of 20,000 acre-feet of water from the State Water Project (SWP) to supplement groundwater supplies.

The valley fill consists of a heterogeneous mixture of alluvial sediments (clay, silt, sand, and gravel) eroded from the bedrock of the surrounding mountains (St. Clair and Kirk 2000). The sediments are thin around the basin rim and thicken toward the axis of the valley and overlay granitic bedrock. The base of permeable sediments exceeds a depth of 600 feet near the middle of the basin (Sorensen et al. 2009). The valley is cut by several faults, which have offset the alluvium. Several of the faults act as barriers to groundwater flow and have resulted in significant water-level differences on either side of the faults (St. Clair and Kirk 2000). Groundwater flow generally moves from the surrounding mountains toward the center of the valley and toward the northwest portion of the basin. Recharge occurs as a result of precipitation on the valley floor, streambed leakage, irrigation return flows, recharge of SWP water in conjunctive use programs, recharge from wastewater effluent, and other managed groundwater recharge operations. Outside the basin, hard-rock wells provide a portion of the water supply. In the basin, wells are typically drilled to depths of 300 to 500 feet bgs and consist of solid casing through the overburden and are screened or open below 25 to 100 feet bgs (Fram and Belitz 2012).

Cummings Valley Groundwater Basin

The Cummings Valley Groundwater Basin (5-27) is an adjudicated basin. It is bordered on the north by the southern Sierra Nevada and on the south by the Tehachapi Mountains. The northeast-southwest elongated basin is approximately 6 miles long and 4 miles wide and is surrounded on all sides and underlain by nearly impervious pre-Tertiary granitic bedrock.

The groundwater basin consists of alluvial sediments eroded from the surrounding Tehachapi and Sierra mountains. The aquifer consists of a heterogeneous mixture of clay, silt, sand, and gravel derived from the surrounding granitic mountains. Typical of alluvial settings, coarser material (sand, gravel, and cobbles) exists in the upper fans at the valley margins and finer-grained materials (clay and sandy clay) near the valley center. The thickness of the sediments varies from as little as 50 feet on the southwest side of the valley to 450 feet on the northeast side of the valley (Michael and McCann 1962).

The upper and lower portions of the aquifer are connected and considered a single aquifer system (Stetson 1969). The basin receives recharge from direct precipitation on the valley floor, from surface water flow from several small mountain streams, and from agricultural irrigation seepage. No groundwater flows into or out of the basin from adjacent alluvial basins (Sorensen et al. 2004). The average agricultural well yield in the basin ranges from 60 to 1,500 gallons per minute (gpm). Domestic wells range from 3 to 300 gpm. The Tehachapi-Cummings County Water District has a contract with Kern County Water Agency for 20,000 acre-feet of SWP supplies that may be used to supplement groundwater supplies in Tehachapi Valley East and Cummings basins (California Department of Water Resources 2006). The basin has adjudicated water rights, with an average annual safe yield of the groundwater basin, established by the judgment of the Cummings Valley Groundwater Basin, to be 4,090 acre-feet (*Tehachapi-Cummings County Water District v. Frank M. Armstrong).*

Irrigation Pump Performance

Irrigation well performance varies according to a number of factors, including drilling methods, casing size, perforated casing area, pump horsepower and type, and the hydrogeologic properties of the aquifer. Irrigation wells are periodically tested to identify optimum well production rates, pumping plant efficiency, and energy demands. Pump tests can also be used to help identify general aquifer characteristics and performance.

As part of the California Energy Commission's Public Interest Energy Research program, the Irrigation Training and Research Center (ITRC) at California Polytechnic State University analyzed electric irrigation pump test data for the Sacramento Valley, Salinas Valley, and San

Joaquin Valley groundwater basins (Burt 2011). In the southern San Joaquin Valley Groundwater Basin, about 9,000 irrigation pump test records were compiled and evaluated by ITRC. In addition to evaluating the pump test data for well efficiency requirements and energy requirements, the study also summarized the average flow rate, static groundwater level, and pumping drawdown for each groundwater basin. Using the compiled pump test results, the average specific capacity of wells within the groundwater basin was also estimated. Specific capacity is the measure of the pumping rate divided by the drawdown. Although a portion of the pumping well drawdown is related to well performance and inefficiencies, much of the drawdown and related specific capacity can be correlated to the aquifer's ability to freely transmit water. Pump test information from the ITRC study is shown in Table 9-2 and are presented in order of basin number. Average values shown in the table are weighted by input horsepower of the pump motor and grouped according to a given range of values.

Table 9-2 shows that the average groundwater pumping rates are lowest for the Kaweah and Tule groundwater subbasins, and highest for the Westside and Kern County groundwater subbasins. With more than 5,000 pump test records, the average pumping rates for the Kaweah Groundwater Subbasin range between 677 and 867 gpm. Average groundwater pumping rates for the Westside Groundwater Subbasin range between 1,249 gpm and 1,438 gpm, while pumping rates for Kern County Groundwater Subbasin range between 1,439 gpm and 1,629 gpm. The average pumping rate for the Kings, Pleasant Valley, and Tulare Lake groundwater subbasins all fall within the 1,058 gpm to 1,248 gpm range; however, only six pump test records were available for the Pleasant Valley Groundwater Subbasin.

Static groundwater levels, typically taken just prior to the pump test, are shallowest in the northeastern portion of the region in the Kings and Kaweah groundwater subbasins (113-175 feet bgs), and almost double in depth toward the south and west (207-337 feet bgs). Pumping drawdown values fall mostly within the 39- to 43-foot range. However, pumping drawdown results for the Tule Groundwater Subbasin tend to be significantly deeper (49-95 feet), while drawdowns in the Tulare Lake Groundwater Subbasin are lightly less (30-34 feet) than the region's average.

Specific capacity values were estimated based on the average range of pumping rates and drawdown values reported in the ITRC study. Higher specific capacity values typically correlate to higher aquifer permeability, or increases in the aquifer's ability to transmit water. Table 9-2 shows that specific capacity estimates for the Tulare Lake region range from a low of 9 gallons per minute per foot (gpm/ft) of drawdown in the Tule Groundwater Subbasin, to a high of 42 gpm/ft within the Tulare Lake and Kern County groundwater subbasins. Lower specific capacity values for the Westside basin are likely because of a combination of increases in fine-grained aquifer material and a decrease in the overall pumping plant efficiency reported in the ITRC study.

The trends identified in the ITRC report for the entire San Joaquin Valley indicate that the Tulare Lake region has greater depths to static water levels than what was reported for the San Joaquin River Hydrologic Region. The difference is up to two to three times lower in several subbasins. The average flow rates are generally lower on the eastern side of the valley than those on the west and south sides.

Table 9-2 Irrigation Pump Test Data for the Southern San Joaquin Valley Basin Portion of the Tulare Lake Hydrologic Region

Groundwater Basins		Number of Tests	Average Flow Rate[a] (gpm)	Average Static Water Level[b] (ft)	Average Drawdown[c] (ft)	Specific Capacity[d,e,f] (gpm/ft)
Subbasin Name	Subbasin Number					
Kings	5-22.08	1,248 - 1,414	1,058 - 1,248	144 - 175	39 - 43	25 - 32
Westside	5-22.09	161 - 220	1,249 - 1,438	176 - 206	39 - 43	29 - 32
Pleasant Valley	5-22.10	5 - 6	1,058 - 1,248	207 - 337	39 - 43	25 - 32
Kaweah	5-22.11	5,495 - 5,533	677 - 867	113 - 143	39 - 43	16 - 22
Tulare Lake	5-22.12	99 - 105	1,058 - 1,248	176 - 206	30 - 34	31 - 42
Tule	5-22.13	907 - 923	868 - 1,057	207 - 337	49 - 95	9 - 22
Kern County	5-22.14	896 - 948	1,439 - 1,629	207 - 337	39 - 43	33 - 42

Source: Data compiled from Irrigation Training and Research Center Report No. R11-004 (Burt. C., 2011)

Notes:

ft = feet; gpm = gallons per minute

[a] Averages are weighted by input horsepower and grouped according to a given range of values.

[b] Static water level measured in feet below ground surface.

[c] Drawdown = groundwater pumping level drawdown measured in feet below static water level

[d] Values are estimated from average data reported in ITRC study.

[e] Lower range specific capacity = average minimum gpm/average maximum drawdown (ft)

[f] Upper range specific capacity = average maximum gpm/average minimum drawdown (ft)

Land Subsidence and Aquifer Compaction

Land subsidence has detrimental effects on groundwater supply and development. Land subsidence resulting from aquifer compaction causes serious and costly damage to the gradient and flood capacity of conveyance channels, to water system infrastructure (including wells), and to farming operations. Pumping from beneath the Corcoran clay in the Tulare Lake region has resulted in artesian head decline and loss of aquifer water pressure. Declining aquifer pressure is thought to be the leading cause of aquifer compaction and land subsidence (Bull and Poland 1975) in the area. Interbedded deposits of fine-grained sediments within the Tulare Lake alluvial fan also create aquifer conditions conducive to subsidence. As aquifer pressures within the alluvial fan decrease, interbedded layers of sand, silts, and clays become increasingly compressed until, in the case of inelastic subsidence, it results in irreversible compaction of the aquifer, and permanent land surface subsidence and loss of aquifer storage capacity. More details on land subsidence for the Tulare Lake region are provided in the "Land Subsidence Monitoring," "Aquifer Conditions," and "Land Subsidence" sections of this chapter. Additional information on land subsidence is provided in Appendix F.

Fractured-Rock Aquifers

Fractured-rock aquifers are typically found in the mountain and foothill areas adjacent to the alluvial groundwater basins. Because of the highly variable nature of the void spaces within fractured-rock aquifers, wells drawing from fractured-rock aquifers tend to have less capacity and less reliability than wells drawing from alluvial aquifers. On average, wells drawing from fractured-rock aquifers yield less than 10 gpm. Although fractured-rock aquifers are less productive compared with the alluvial aquifers in the region, they are commonly the sole source of water supply and thus, are critically important for many communities. Information related to fractured-rock aquifers in the region was not developed as part of *California Water Plan Update 2013*.

Well Infrastructure

A key aspect to understanding the region's groundwater supply and development is identifying the age, distribution, and types of wells that have been completed in the region. A useful source of well information is the well completion reports, or well logs, submitted by licensed well drillers to DWR. Among other things, well logs identify well location, date of completion, and type of well use.

Well drillers have been required by law to submit well logs to the State since 1949. California Water Code Section 13751 requires drillers that construct, alter, abandon, or destroy a well to submit a well log to DWR within 60 days of the completed work. Confidentiality requirements (California Water Code Section 13752) limit access to the well logs to governmental agencies making studies, to the owner of a well, and to persons performing environmental cleanup studies.

Well logs submitted to DWR for water supply wells completed from 1977 through 2010 were used to evaluate the distribution and the uses of groundwater wells in the region. DWR does not have well logs for all the wells completed in the region, and for some well logs, information regarding well location or use is inaccurate, incomplete, ambiguous, or missing. Hence, some well logs could not be used in the evaluation. Even so, for a regional evaluation of well completion and distribution, the quality of the data is considered adequate and informative. Additional information regarding assumptions and methods of reporting well log information to DWR is provided in Appendix A.

The number and distribution of wells in the Tulare Lake region are grouped according to their location by county, and according to six most common well-use types: domestic, irrigation, public supply, industrial, monitoring, and other. Wells identified as "other" include the less common types of wells, such as stock wells, test wells, or unidentified wells (no information listed on the well log).

The number and type of wells listed by county are not necessarily indicative of the number and type of wells within the entire hydrologic region. Well log data for counties that fall within multiple hydrologic regions were assigned to the hydrologic region containing a majority of alluvial groundwater basins within the region. The Tulare Lake region includes significant portions of Fresno and Kern counties, and all of Kings and Tulare counties. A small portion of San Benito County is also within the Tulare Lake region. Well log information for San Benito County is provided in the Central Coast Hydrologic Region chapter of this report. Table 9-3 lists the number of well logs received by the DWR for wells completed in the Tulare Lake region from 1977 to 2010. Figures 9-3 and 9-4 illustrate the well data by use, for the individual region counties and the region as a whole.

Table 9-3 Number of Well Logs, by Well Use and By County for the Tulare Lake Hydrologic Region (1977-2010)

County	Total Number of Well Logs by Well Use						Total Well Records
	Domestic	Irrigation	Public Supply	Industrial	Monitoring	Other	
Fresno	15,957	5,050	743	45	1,092	4,183	27,070
Kern	5,182	1,603	305	58	970	2,009	10,127
Kings	1,536	1,549	86	19	410	550	4,150
Tulare	5,791	4,584	447	59	739	1,355	12,975
Total Well Records	**28,466**	**12,786**	**1,581**	**181**	**3,211**	**8,097**	**54,322**

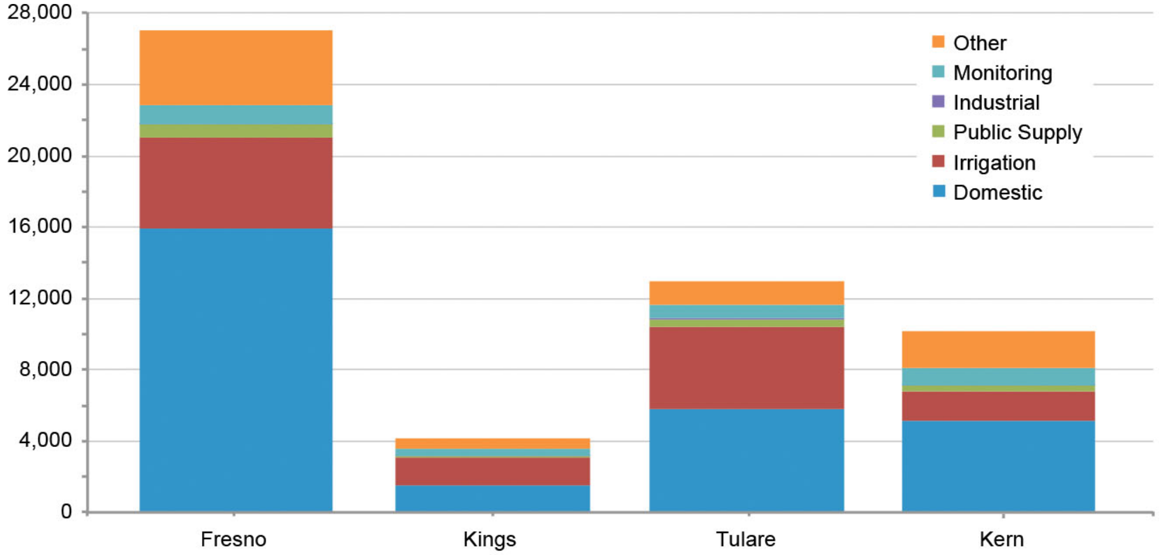
Table 9-3 and Figure 9-3 show that the distribution and number of wells vary widely by county and by use. The number of wells completed in the Tulare Lake region between 1977 and 2010 is approximately 54,322 and ranges from a high of 27,070 wells for Fresno County to a low of 4,150 wells for Kings County. The large proportion of wells in Fresno County (50 percent) is related in part to the high proportion of the region's population living in Fresno County (more than 40 percent of the Tulare Lake region's population lives in Fresno County). In most counties, rural domestic use wells make up the majority of well logs on file at DWR. For Kings County, the number of irrigation wells slightly exceeds the number of domestic wells for the 1977-2010 time frame. The lower number of domestic wells compared with irrigation wells in Kings County is most likely the result of the rural setting (7 percent of the region's population lives in Kings County) and the greater agricultural demand for groundwater.

Comparison of Tulare and Kern county well-log data indicates that domestic well numbers are relatively close; however, the number of irrigation wells in Tulare County is more than 2.5 times greater than the number of irrigation wells in Kern County. The higher number of irrigation wells in Tulare County is notable because both counties use approximately the same amount of groundwater for agriculture; however, water use estimates indicate Tulare County has about 15 percent greater reliance on groundwater supplies to meet agricultural uses.

Figure 9-4 shows the percentage breakdown of wells, by well use, for the Tulare Lake region between 1977 and 2010. The figure shows that domestic, irrigation, and monitoring wells account for slightly more than 80 percent of all wells installed in the region, with domestic wells comprising 52 percent and irrigation wells accounting for about 24 percent of the total number of well logs. Statewide, domestic and irrigation wells account for about 54 and 10 percent, respectively, of the total number of well logs. The larger percentage of Tulare Lake region irrigation wells, compared with the statewide average, is likely the result of the greater than average reliance on groundwater supplies to meet agricultural uses in the region. Monitoring wells account for about 6 percent of the total number of wells for the region, which is significantly lower than the statewide hydrologic region average of 24 percent. About 15 percent of the wells in the region fall into the "other" category.

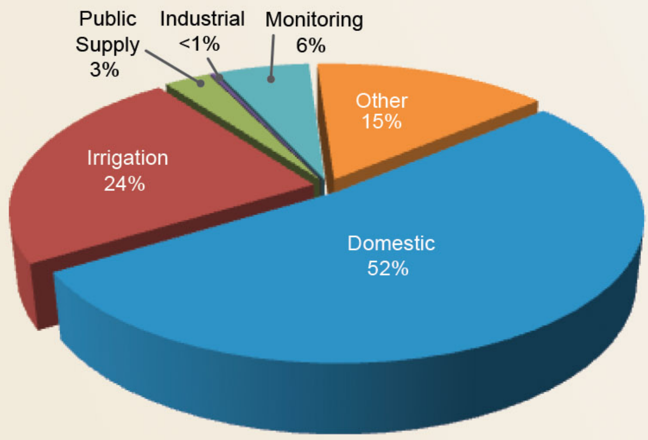
In addition to analyzing the number of wells by location and use, well logs were analyzed by well installation date (Figure 9-5). Evaluating the number and types of wells completed over time can

Figure 9-3 Number of Well Logs by County and Use for the Tulare Lake Hydrologic Region (1977-2010)



Prepared by California Department of Water Resources for California's Groundwater Update 2013

Figure 9-4 Percentage of Well Logs by Type of Use for the Tulare Lake Hydrologic Region (1977-2010)

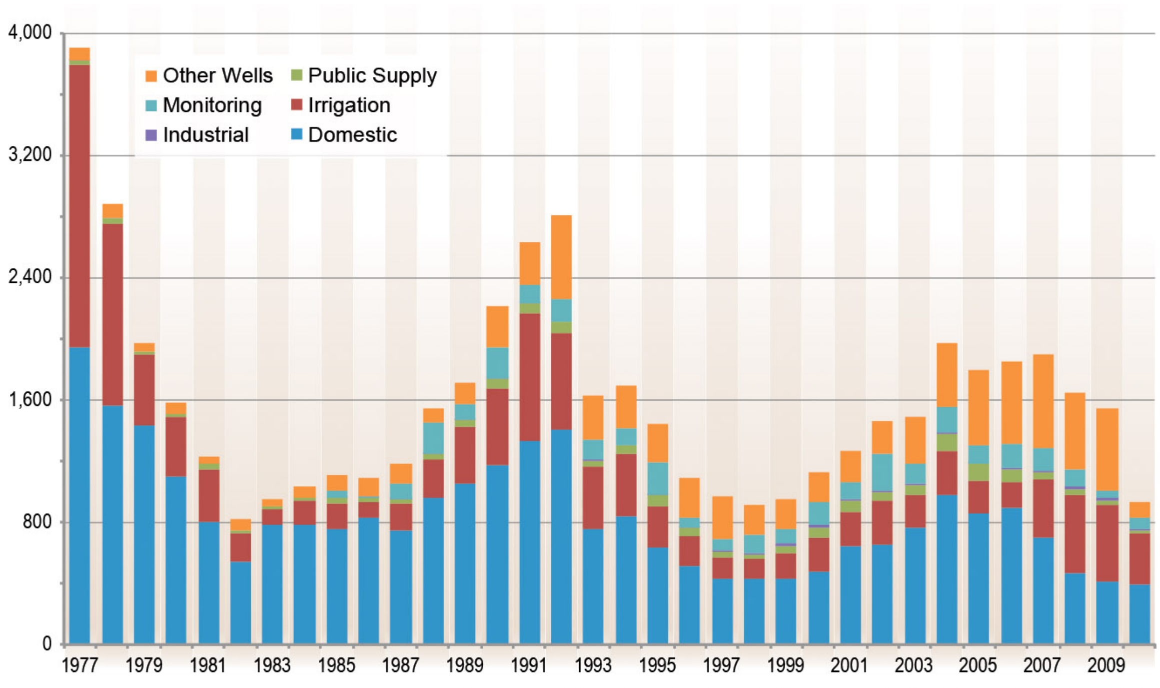


Tulare Lake Well Logs Summary by Well Type

Well Type	Number of Well Logs
Domestic	28,466
Irrigation	12,786
Public Supply	1,581
Industrial	181
Monitoring	3,211
Other	8,097
Total	**54,322**

Prepared by California Department of Water Resources for California's Groundwater Update 2013

Figure 9-5 **Number of Well Logs Filed per Year, by Well Use, for the Tulare Lake Hydrologic Region (1977-2010)**



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help offer a perspective on the average age of the existing well infrastructure and the general pattern of wells installed during various hydrologic and economic cycles.

Figure 9-5 shows a cyclic pattern of well installation. Multiple factors are known to affect the annual number and type of wells drilled. Some of these factors include the annual variations in climate, economy, agricultural cropping trends, or alternative water supply availability. New well construction in the Tulare Lake region between 1977 and 2010 ranged from about 800 (1982) to 3,900 (1977) wells per year, with an average of about 1,600 wells per year.

Installation trends for irrigation wells tend to more closely follow changes in annual weather conditions, cropping trends, and availability of alternate agricultural water supplies. Irrigation well installation in the Tulare Lake region ranged from a high of around 1,850 wells per year following the 1976-1977 drought, to a low of 102 wells following the wet water year of 1983. The annual installation rate for irrigation wells stayed at approximately 140 wells per year during the wet years of the mid-1980s before increasing again to an average of 530 wells per year during the 1989-1994 drought. Approximately 500 irrigation wells per year were drilled during the 2008-2009 drought and related reduction in surface water deliveries. The DWR well log database does not differentiate between new irrigation wells installed and the deepening of existing wells; for that reason, some of the irrigation well logs may be attributed to the deepening of existing irrigation wells. Much of the irrigation well infrastructure installed during the late 1970s and early 1980s is still in use today.

Similar to irrigation well installation, domestic well construction also responds to changes in climatic conditions. Moreover, variations in domestic well drilling activity can be attributed to the economy and associated fluctuations in residential housing construction. The increase in domestic well drilling from 2001 to 2006 in the Tulare Lake region is likely because of increases in housing construction during this time. Similarly, the decline in domestic well drilling from 2007 to 2010 is likely because of the economic downturn and related drop in housing construction. A portion of the lower number of well logs recorded for 2010 could also be the result of delays in receiving and processing of well driller logs (see Appendix A for additional information). As with irrigation wells, a portion of the new well logs submitted for domestic wells may involve the deepening of existing domestic wells because of declining groundwater levels in the hydrologic region.

Monitoring wells in the Tulare Lake region were first recorded in significant numbers in 1987, when slightly more than 100 wells were installed. The number of monitoring well installations in the mid- to late-1980s are likely associated with federal underground storage tank programs signed into law in the mid-1980s. In 1984, the State of California Underground Storage Tank Program took effect. The program provided partial reimbursement of expenses associated with the cleanup of leaking underground storage tanks and quickly resulted in an increase in the installation of groundwater-quality monitoring wells. Beginning in 1987, changes in California Water Code Section 13751 required well drillers to begin submitting well logs for monitoring well completions. Well logs typically do not distinguish between monitoring wells are installed as part of a groundwater clean-up project versus those installed primarily to collect changes in groundwater levels. However, information on the well logs supports a conclusion that the majority of the monitoring wells are completed for use in environmental assessments related to leaking underground storage tanks, waste disposal sites, and hazardous chemical spills.

Monitoring well installation peaked at 236 wells in 2002. Since 1987, monitoring well installation in the region has averaged approximately 131 wells per year. Overall, the total number and average number of monitoring well records for the region appears to be low, considering the number of remedial action sites within the region by the California State Water Resources Control Board (SWRCB) (http://geotracker.waterboards.ca.gov/).

CASGEM Basin Prioritization

As part of the California 2009 Comprehensive Water Package legislation (SB X7-6), DWR implemented the CASGEM program. The SB X7-6 groundwater monitoring legislation added Part 2.11 to Division 6 of the California Water Code (Section 10920 et seq.), which established provisions and requirements for local agencies to develop and conduct groundwater-level monitoring programs. The legislation requires DWR to identify the extent of groundwater elevation monitoring within each of the alluvial groundwater basins defined under Bulletin 118-2003 and to prioritize those basins to help identify, evaluate, and determine the need for additional groundwater-level monitoring. The basin prioritization process directs DWR to consider, to the extent available, all of the following data components.

1. The population overlying the basin.
2. The rate of current and projected growth of the population overlying the basin.
3. The number of public supply wells that draw from the basin.

4. The total number of wells that draw from the basin.
5. The irrigated acreage overlying the basin.
6. The degree to which persons overlying the basin rely on groundwater as their primary source of water.
7. Any documented impacts on the groundwater within the basin, including overdraft, subsidence, saline intrusion, and other water quality degradation.
8. Any other information determined to be relevant by the department.

Using groundwater reliance as the leading indicator of basin priority, DWR evaluated California's 515 groundwater basins identified in Bulletin 118-2003 and categorized them into four prioritization groups: high, medium, low, and very low.

The CASGEM Basin Prioritization for the Tulare Lake region is listed in Table 9-4 and shown in Figure 9-6. A full listing of the CASGEM groundwater basin prioritization is provided in Appendix B. Groundwater extraction in the Tulare Lake region represents more than one-third of the statewide average annual total withdrawal. CASGEM basin prioritization results for the Tulare Lake region indicate that seven of the 19 basins are identified as high priority, with one basin identified as medium priority, one basin listed as low priority, and the remaining 10 basins listed as very low priority. The eight basins designated as high or medium priority include 98 percent of the annual groundwater use and nearly 98 percent of the 2010 population living within the region's groundwater basin boundaries.

Although the primary intent of basin prioritization is to assist DWR in implementing the CASGEM program, based on the comprehensive set of data included in the analysis, the basin prioritization effort is also a valuable tool to help evaluate, focus, and align limited resources toward the implementation of effective groundwater management practices, as well as improving the reliability and sustainability of groundwater resources in the region. In the Tulare Lake region, implementation of sustainable groundwater resource management should initially be focused on the eight basins listed in Table 9-4 as having a high or medium priority.

Table 9-4 CASGEM Prioritization for Groundwater Basins in the Tulare Lake Hydrologic Region

Basin Priority	Count	Basin/Subbasin Number	Basin Name	Subbasin Name	2010 Census Population
High	1	5-22.11	San Joaquin Valley	Kaweah	271,700
High	2	5-27	Cummings Valley	NA	7,665
High	3	5-22.13	San Joaquin Valley	Tule	108,660
High	4	5-22.08	San Joaquin Valley	Kings	906,544
High	5	5-22.14	San Joaquin Valley	Kern County	700,323
High	6	5-22.12	San Joaquin Valley	Tulare Lake	125,701
High	7	5-22.09	San Joaquin Valley	Westside	27,285
Medium	1	5-28	Tehachapi Valley West	NA	17,313
Low	1	5-22.10	San Joaquin Valley	Pleasant Valley	34,213
Very Low	10	See Appendix B			
Total	**19**	**Population of Tulare Lake Region Groundwater Basin Area: 2,216,590**			

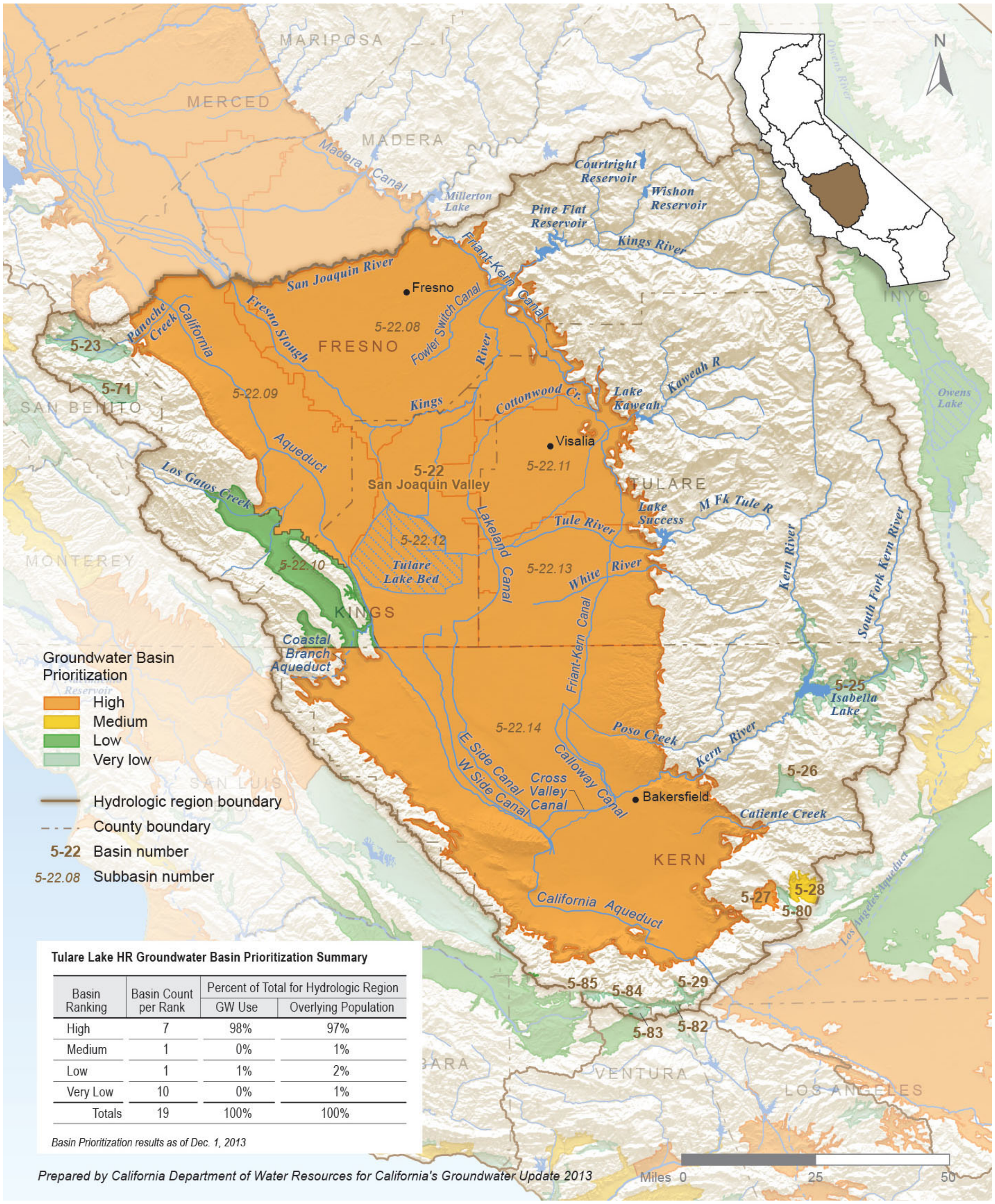
Notes:

Basin priority ranking as of December 2013.

Senate Bill X7-6 (SB X7-6; Part 2.11 to Division 6 of the California Water Code Section 10920 et seq.) requires, as part of the California Statewide Groundwater Elevation Monitoring program, The California Department of Water Resources to prioritize groundwater basins to help identify, evaluate, and determine the need for additional groundwater-level monitoring by considering available data that include the population overlying the basin, the rate of current and projected growth of the population overlying the basin, the number of public supply wells that draw from the basin, the total number of wells that draw from the basin, the irrigated acreage overlying the basin, the degree to which persons overlying the basin rely on groundwater as their primary source of water, any documented impacts on the groundwater within the basin, including overdraft, subsidence, saline intrusion, and other water quality degradation, and any other information determined to be relevant by the California Department of Water Resources.

Using groundwater reliance as the leading indicator of basin priority, the California Department of Water Resources evaluated California’s 515 alluvial groundwater basins and categorized them into four groups — high, medium, low, and very low.

Figure 9-6 CASGEM Groundwater Basin Prioritization for the Tulare Lake Hydrologic Region



Tulare Lake HR Groundwater Basin Prioritization Summary

Basin Ranking	Basin Count per Rank	Percent of Total for Hydrologic Region	
		GW Use	Overlying Population
High	7	98%	97%
Medium	1	0%	1%
Low	1	1%	2%
Very Low	10	0%	1%
Totals	19	100%	100%

Basin Prioritization results as of Dec. 1, 2013

Prepared by California Department of Water Resources for California's Groundwater Update 2013

Groundwater Use

The amount and timing of groundwater extraction, along with the location and type of groundwater use, are fundamental components for developing a groundwater basin budget and identifying effective options for groundwater management. While some types of groundwater uses are reported for some California basins, the majority of groundwater users are not required to monitor, meter, or record their annual groundwater extraction amounts. Groundwater use estimates for this report are based on water supply and balance information derived from DWR land use surveys and from groundwater use information voluntarily provided to DWR by water purveyors or other State agencies.

Groundwater extraction estimates derived from land and water use methods typically assume that local surface water supplies are first used to meet local water demands. Once surface water supplies have been fully allocated, if crop demand and water balance information indicates that additional water supplies are needed, groundwater supplies are then applied until the full water use is met and the overall supply and use for the area is balanced. For agricultural areas employing conjunctive management practices, which may involve optimally using surface water and groundwater supplies, accurate estimates of annual groundwater extraction using the land and water use method can be challenging.

DWR water supply and balance data are collected and analyzed by hydrologic regions, which largely correspond to watershed boundaries. The land and water use data is first compiled and analyzed by detailed analysis units (DAUs). Water supply and balance data for DAUs are then compiled into larger planning areas, then into hydrologic regions, and finally into a statewide water supply and balance estimate. To assist local resource planning, DWR also generates water supply and balance information by county. Although some local groundwater management groups independently develop groundwater extraction estimates for their groundwater basins, DWR does not currently generate groundwater extraction information by groundwater basin area.

Water use is reported by water year (October 1 through September 30) and categorized according to urban, agriculture, and managed wetlands uses. Reference to *total water supply* for a region represents the sum of surface water, groundwater, and reused/recycled water supplies. Reused/recycled water supplies also include desalinated water supplies. Reporting of groundwater supply information is presented by planning area, county, and type of use. Additional information on water use analysis is provided in Appendix A and in Appendix C.

2005-2010 Average Annual Groundwater Supply

With a 2005-2010 average annual extraction volume of 6,185 thousand acre-feet (taf), groundwater use in the Tulare Lake region accounts for 38 percent of all the groundwater pumping in California — double the amount of the next largest hydrologic region groundwater user.

Water demands in the Tulare Lake region are met through a combination of local surface water supplies, federal (Central Valley Project [CVP]) and State (SWP) surface water deliveries, groundwater, and reused/recycled water supplies. The 2005-2010 average annual total water supply for the region is estimated at 11,636 taf. Local groundwater resources play a significant

Table 9-5 Average Annual Total Water Supply Met by Groundwater, By Planning Area and Type of Use, for the Tulare Lake Hydrologic Region (2005-2010)

Tulare Lake Hydrologic Region		Agriculture Use Met by Groundwater		Urban Use Met by Groundwater		Managed Wetlands Use Met by Groundwater		Total Water Use[a] Met by Groundwater	
PA Number	PA Name	taf	%[b]	taf	%[b]	taf	%[b]	taf	%[b]
701	Western Uplands	0.3	100%	2.0	100%	0.0	0%	2.3	100%
702	San Luis West Side	598.5	41%	7.5	42%	0.0	0%	606.0	41%
703	Lower Kings-Tulare	1,429.0	69%	44.5	100%	1.1	4%	1,474.6	69%
704	Fresno - Academy	56.8	11%	204.5	78%	0.0	0%	261.2	34%
705	Alta - Orange Cove	417.2	45%	59.3	97%	0.0	0%	476.5	48%
706	Kaweah Delta	1,492.6	59%	112.8	97%	3.2	100%	1,608.7	61%
707	Uplands	32.6	97%	14.3	76%	0.0	0%	46.9	89%
708	Semitropic - Buena Vista	622.7	54%	17.7	74%	24.7	55%	665.0	54%
709	Kern Valley Floor	322.0	40%	31.9	97%	0.0	0%	353.9	42%
710	Kern Delta	580.3	42%	109.7	68%	0.0	0%	690.0	45%
2005-2010 Annual Average HR Total		**5,551.8**	**51%**	**604.1**	**82%**	**28.9**	**37%**	**6,184.8**	**53%**

Notes:

HR = hydrologic region; PA = planning area; taf = thousand acre-feet

[a] Total water use = groundwater + surface water + reuse

[b] Percent use is the percentage of the total water supply that is met by groundwater, by type of use.

2005-2010 precipitation equals 93 percent of the 30-year average for the Tulare Lake Hydrologic Region.

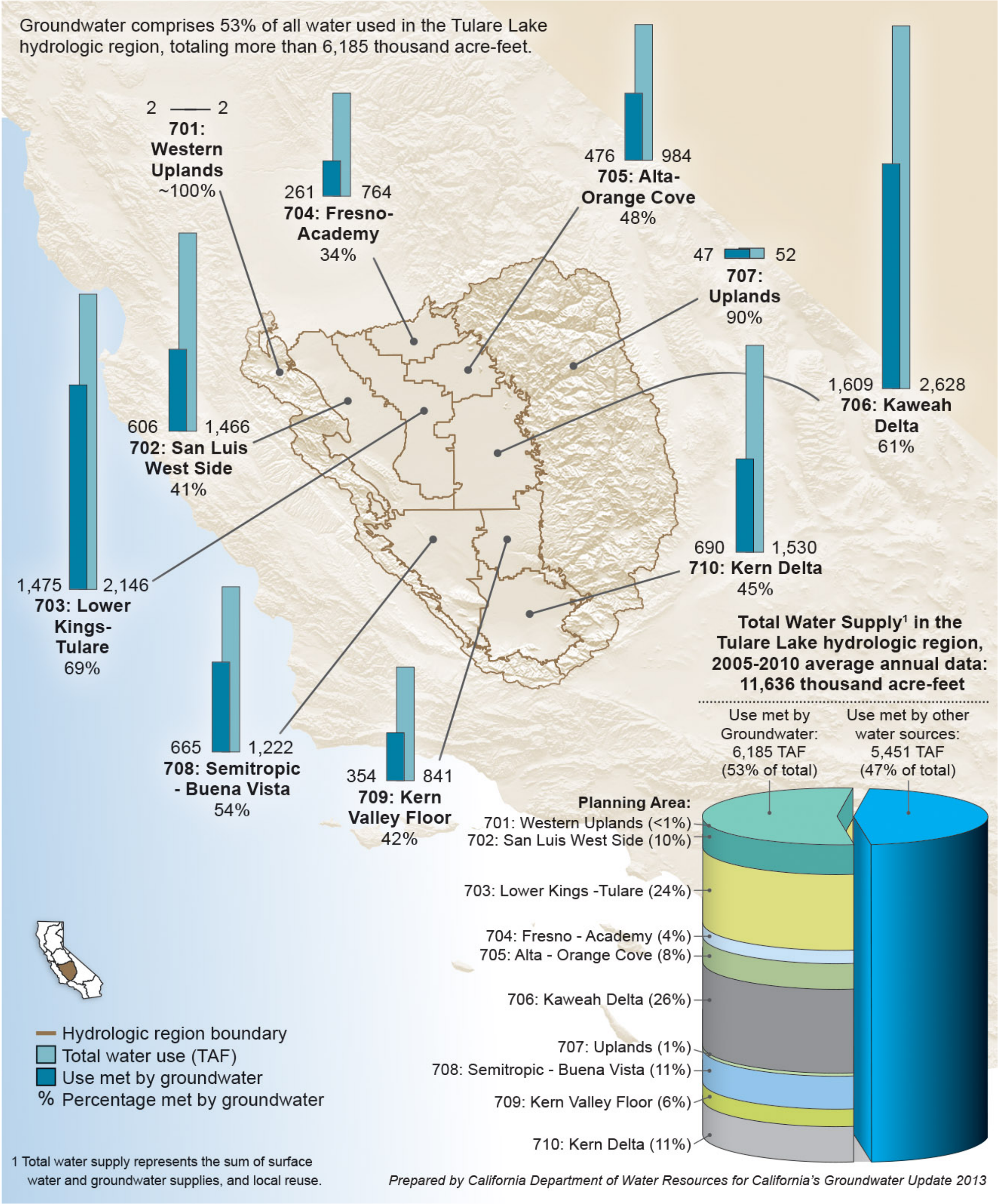
role in meeting annual water demands for the Tulare Lake region. Groundwater contributes about 53 percent to the total overall supply, approximately 20 percent is met by local projects, 15 percent is met by the CVP, and about 8 percent met by the SWP.

The Tulare Lake region includes 10 planning areas. Table 9-5 lists the 2005-2010 average annual total water supply met by groundwater, by planning area and by type of use. The 2005-2010 precipitation for the region was about 93 percent of the 30-year average. Dry conditions and substantial regulatory cutback of imported surface water between 2007 and 2009 significantly increased the agricultural demand for groundwater during these years. Table 9-5 shows the quantity and percentage of groundwater contributing to the total water supply for the region. Figure 9-7 displays the 2005-2010 average annual groundwater extraction, the average total supply, the distribution of groundwater use by planning area.

Table 9-5 shows that, on average, groundwater supplies contribute 53 percent (6,185 taf) of the total water supply within the Tulare Lake region. By type of use, groundwater contributes 51 percent of the total annual agricultural water supply, 82 percent of the total urban water supply, and 37 percent of the managed wetlands total supply.

Two of the largest groundwater users in the region, the Lower Kings-Tulare Planning Area (PA) and Kaweah Delta PA, rely on about 3,083 taf of combined groundwater pumping to meet 69 percent and 61 percent, respectively, of their total agricultural water supply and 100 percent

Figure 9-7 Groundwater Use and Total Water Supply Met by Groundwater, by Planning Area, for the Tulare Lake Hydrologic Region (2005-2010)



1 Total water supply represents the sum of surface water and groundwater supplies, and local reuse.

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and 97 percent, respectively, of their total urban supply. The annual pumping volume and reliance on groundwater supplies is also high for the San Luis West Side PA, Kern Delta PA, Alta-Orange Cove PA, and Semitropic-Buena Vista PA. Groundwater status reports from groundwater management groups overlying many of these planning areas acknowledge that the average annual groundwater extraction commonly exceeds safe aquifer yield. The smallest groundwater user by planning area, Western Uplands, is 100-percent reliant on groundwater to meet urban and agricultural water needs.

Half of the planning areas in the Tulare Lake region rely on groundwater to meet 97 percent or more of their total urban water supply. The three largest urban groundwater users (Fresno-Academy PA, Kaweah Delta PA, and Kern Delta PA) comprise 71 percent of all urban groundwater extraction in the region and together rely on groundwater for 81 percent of their total urban water supply. Groundwater supplies meet 37 percent of the region’s managed wetlands needs, with about 85 percent of the groundwater use for managed wetlands (24.7 taf) occurring in the Semitropic-Buena Vista PA.

A percentage breakdown of the Tulare Lake region’s groundwater extraction, by planning area and by the type of use, is shown in Table 9-6. The table shows that approximately 90 percent of the groundwater extraction in the Tulare Lake region is for agricultural use. The two largest planning areas in the Tulare Lake region, the Lower Kings-Tulare PA and Kaweah Delta PA, apply about 97 and 93 percent, respectively, of their total groundwater extraction toward agricultural use. Groundwater for urban use is limited to 10 percent of the region’s total groundwater extraction, with two (Fresno-Academy and Western Uplands) of the 10 planning areas pumping more groundwater for urban than agricultural uses. Nine of 10 planning areas in the Tulare Lake region apply less than 1 percent of the total planning area groundwater extraction toward managed wetlands use.

Groundwater supply and use was also calculated by county. Tulare and Kings counties are fully within the Tulare Lake region, while Kern and Fresno counties are partially within the region. County boundaries do not align with planning area or hydrologic region boundaries, so groundwater use based on county areas will vary from regional estimates using planning areas shown in Table 9-5. Tables showing groundwater supply and use for all 58 California counties are provided in Appendix C.

Table 9-7 lists the 2005-2010 average annual groundwater extraction by county, by type of use, and by the percentage that groundwater contributed to the total water supply of the four-county area. The table shows that groundwater contributes from 48 to 61 percent of the total water supply within the individual four county areas and, although the vast majority of groundwater extraction occurred for agricultural use, groundwater supplies contributed 51 percent of the total agricultural water supply for the four-county area in the Tulare Lake region. In contrast, groundwater supplies for urban use in the four-county area amounted to less than 11 percent of the overall groundwater supply, but contributed 81 percent of the total water supply for urban use. Overall, the four-county area relied on groundwater for 52 percent (6,391 taf) of its total water supply.

Table 9-6 Average Annual Total Water Supply Met by Groundwater, By Planning Area and Type of Use, for the Tulare Lake Hydrologic Region (2005-2010)

Tulare Lake Hydrologic Region		Groundwater for Agriculture Use	Groundwater for Urban Use	Groundwater for Managed Wetlands Use	Groundwater Use by PA
PA Number	**PA Name**	**%[a]**	**%[a]**	**%[a]**	**%[b]**
701	Western Uplands	13%	87%	0%	<1%
702	San Luis West Side	99%	1%	0%	10%
703	Lower Kings-Tulare	97%	3%	0%	24%
704	Fresno - Academy	22%	78%	0%	4%
705	Alta - Orange Cove	88%	12%	0%	8%
706	Kaweah Delta	93%	7%	0%	26%
707	Uplands	69%	31%	0%	<1%
708	Semitropic - Buena Vista	94%	3%	4%	11%
709	Kern Valley Floor	91%	9%	0%	6%
710	Kern Delta	84%	16%	0%	11%
2005-2010 Annual Average HR Total		**90%**	**10%**	**0%**	**100%**

Notes:

HR = hydrologic region; PA = planning area

[a] Percent use is average annual groundwater use by planning area and type of use, compared with the total groundwater use for the Tulare Lake Hydrologic Region.

[b] Percentage of hydrologic region total groundwater use.

Table 9-7 Average Annual Total Water Supply Met by Groundwater by County and by Type of Use for the Tulare Lake Hydrologic Region (2005-2010)

County	Agriculture Use Met by Groundwater		Urban Use Met by Groundwater		Managed Wetlands Use Met by Groundwater		Total Water Use Met by Groundwater	
	taf	**%[a]**	**taf**	**%[a]**	**taf**	**%[a]**	**taf**	**%**
Fresno	1,657.6	45%	272.4	80%	1.1	4%	1,931.0	48%
Kern	1,549.2	46%	185.6	72%	24.7	55%	1,759.5	48%
Kings	939.8	58%	39.6	94%	0.0	0%	979.4	59%
Tulare	1,587.1	59%	131.3	98%	3.2	100%	1,721.6	61%
2005-2010 Annual Average Total	5,733.6	51%	628.9	81%	29.0	37%	6,391.4	52%

Notes**:**

taf = thousand acre-feet

[a] Percent use is the percentage of the total water supply that is met by groundwater, by type of use.

2005-2010 precipitation equals 93 percent of the 30-year average for the Tulare Lake Hydrologic Region.

Change in Annual Groundwater Use

Changes in annual amount and type of groundwater use may be related to a number of factors, such as changes in surface water availability, urban and agricultural growth, economic fluctuations, and water use efficiency practices. Agricultural cropping trends for the Tulare Lake region show a significant shift away from annual crops using surface water, toward high-value permanent crops reliant on groundwater. In the 1970s, less than 5 percent of the Semitropic Water Storage District (SWSD) agricultural lands were in permanent crops. In 2012, more than half the agricultural acreage was planted with permanent crops (Semitropic Water Storage District 2012). The trends toward increased permanent crop planting versus annual crop planting, leads to an increase in the annual demand for groundwater, regardless of the water year type.

Figure 9-8 illustrates the 2002-2010 water supply trend for the Tulare Lake region. The right side of Figure 9-8 illustrates the total water supply volume by supply type (groundwater, surface water, and reused/recycled water), while the left side shows the percentage of the overall water supply that is met by those sources of water. The center column in both figures identifies the water year along with the corresponding amount of precipitation, as a percentage of the previous 30-year average for the hydrologic region.

Between 2002 and 2010, the total annual water supply for the Tulare Lake region remained relatively stable (Figure 9-8). The total water supply during the 9-year period averaged 11,625 taf with a fluctuation of about 7 percent — between a low of 10,654 taf in 2005, to a high of 12,388 taf in 2009. However, the percentage to which groundwater or surface water contributed to the total supply during this same period was widely variable. Periodic cutbacks in Tulare Lake region surface water deliveries during the period analyzed have resulted in large fluctuations in the annual amount of groundwater pumping required to meet demand. Groundwater extraction during the 2002-2010 period averaged 6,396 taf. During the wet water years of 2005 and 2006, groundwater extraction was reduced to 3,504 taf and 3,588 taf, respectively. During the dry years of 2008 and 2009, groundwater extraction in the Tulare Lake region was 8,397 taf and 8,711 taf, respectively. The fluctuation in the annual water supply shown in Figure 9-8 points to a limited surface water supply reliability for the Tulare Lake region and highlights the value of applying conjunctive water management practices to meet local demands during times of reduced surface water supply.

Figure 9-9 shows the 2002-2010 groundwater supply trend by urban, agricultural, and managed wetland uses in the Tulare Lake region. The right side of Figure 9-9 illustrates the annual volume of groundwater extraction by type of use; the left side shows the percentage of groundwater extraction by type of use. The percentage of groundwater extracted from the Tulare Lake region to meet agricultural water supply ranged from a low of 83 percent in 2005 and 2006, to a high of 92 percent in 2008 and 2009. Figure 9-9 also illustrates how, in areas of high water demand, small changes in the percentage of groundwater demand can result in large changes to the volume of groundwater extraction. For example, between 2005 and 2009, the amount of groundwater applied to agricultural use increased from 83 to 92 percent. The increase of 9 percentage points in

Figure 9-8 **Annual Surface Water and Groundwater Supply Trend for the Tulare Lake Hydrologic Region (2002-2010)**

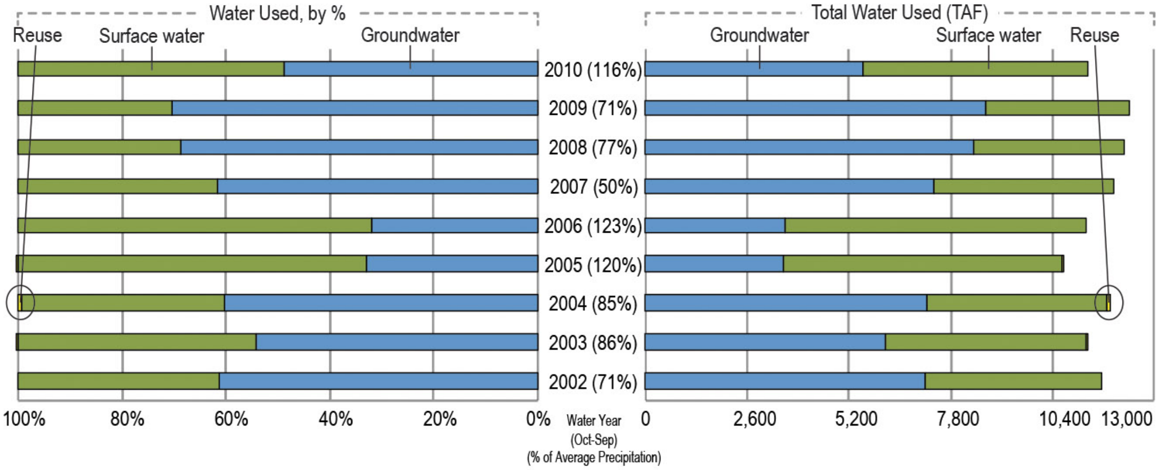

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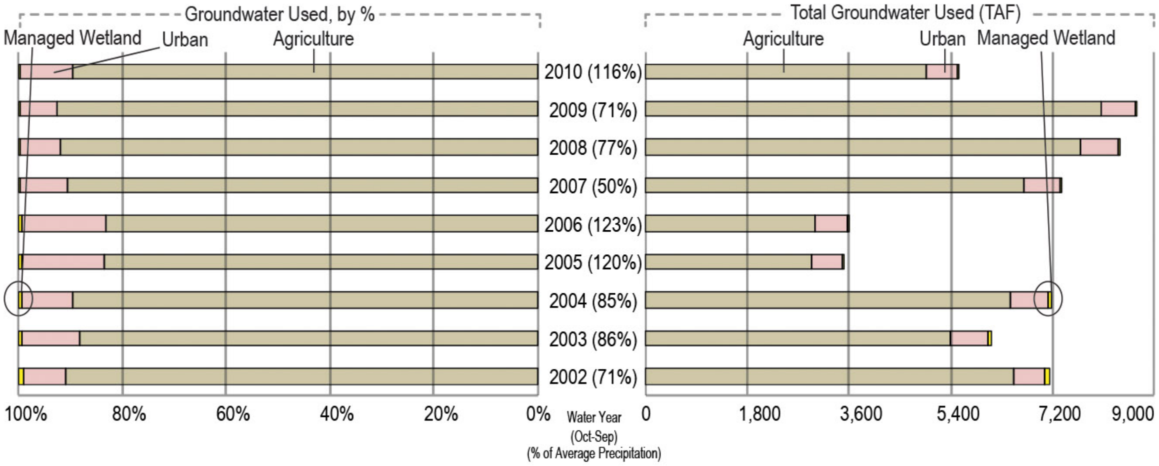
Figure 9-9 **Annual Groundwater Supply Trend by Type of Use for the Tulare Lake Hydrologic Region (2002-2010)**



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groundwater for agricultural use resulted in a doubling of the total annual groundwater extraction, from 3,504 taf in 2005 to 8,711 taf in 2009. This 250 percent increase in the Tulare Lake region groundwater extraction between wet and dry years represents more groundwater than is annually extracted by all of the remaining Central Valley groundwater basins combined.

Groundwater pumping to meet urban water needs remained fairly stable during the 2002 to 2010 period. Urban groundwater use ranged from a low of about 552 taf in 2005 to a high of about 686 taf in 2004, or between 7 percent (in 2009) and 16 percent (in 2005 and 2006) of the total amount of groundwater for the region. Compared with agricultural and urban uses, the application of groundwater supplies for managed wetlands use in the region is fairly minor. Groundwater for managed wetlands use ranged from 26 taf to 66 taf; however, during the2002-2010 period, groundwater contributed between 32 and 54 percent of the total managed wetlands water use.

Groundwater Monitoring Efforts

Groundwater resource monitoring and evaluation is essential to understanding groundwater conditions, as well as identifying and implementing sustainable resource management practices. California Water Code Section 10753.7 requires local agencies seeking State funds administered by DWR to prepare and implement GWMPs that include monitoring of groundwater levels, groundwater quality degradation, inelastic land subsidence, and changes in surface water flow and quality that directly affect groundwater levels or quality. The protocols associated with groundwater monitoring can vary greatly, depending on the local conditions; but overall, monitoring protocols should be designed to generate information that promotes efficient and effective groundwater management.

This section summarizes some of the groundwater level, groundwater quality, and land subsidence monitoring activities within the Tulare Lake region. The summary includes publically available groundwater data compiled by DWR, SWRCB, California Department of Public Health (CDPH), and the U.S. Geological Survey (USGS). Information regarding the groundwater monitoring methods, assumptions, and data availability is provided in Appendix A.

Groundwater-Level Monitoring

State and federal agencies with groundwater-level monitoring programs in the region include DWR and USGS. Groundwater-level monitoring is also performed by CASGEM-designated monitoring entities, as well as local cooperators that measure, or contract others to measure, groundwater levels. Groundwater-level information presented in this section is publically available through DWR or USGS online information systems. Privately collected and locally maintained groundwater-level information is not included in this analysis. The groundwater-level information in this section includes only active monitoring wells, or those wells that have been measured since January 1, 2010, and monitoring groups that have entered data into the CASGEM or USGS online databases as of July 2012. Because monitoring programs are frequently adjusted to meet changing demands and management actions, groundwater-level information presented for the Tulare Lake region may not represent the most current information available. Updated groundwater-level information may be obtained online from the DWR CASGEM program Web site (http://www.water.ca.gov/groundwater/casgem/), and through the USGS National Water Information System (http://waterdata.usgs.gov/nwis).

A list of the number of monitoring wells by monitoring agencies, cooperators, and CASGEM-designated monitoring entities is provided in Table 9-8. The locations of Tulare Lake monitoring wells, by monitoring entity and monitoring well type, are shown in Figure 9-10. Tulare Lake region has, by far, the largest number of groundwater-level monitoring wells of California's 10 hydrologic regions. Table 9-8 shows that 3,342 wells are actively monitored for groundwater-level information in the Tulare Lake region, which is nearly twice as many as in any other hydrologic region in the state. The DWR monitoring network consists of 268 wells covering five basins, with the majority of wells being split between the Kings and Kern County groundwater subbasins. The U.S. Bureau of Reclamation (USBR) monitoring network consists of 104 wells, 91 of which are located in the Kings Groundwater Subbasin. Four of the USBR monitoring wells are located outside the Bulletin 118-2003 alluvial groundwater basins. The USGS monitors

Table 9-8 Groundwater-Level Monitoring Wells by Monitoring Entity for the Tulare Lake Hydrologic Region

State and Federal Agencies	Number of Wells
California Department of Water Resources	268
U.S. Geological Survey	4
U.S. Bureau of Reclamation	104
Total State and Federal Wells	**376**
Monitoring Cooperators	**Number of Wells**
Fresno Irrigation District	48
James Irrigation District	26
Alta Irrigation District	114
Buena Vista Water Storage District	19
California Water Service Company	12
Cawelo Water District	46
Exeter Irrigation District	51
Fresno, City of	79
Ivanhoe Irrigation District	38
Kings County Water District	118
Lakeside Irrigation Water District	45
Lewis Creek Water District	9
Liberty Water District	43
Lindmore Irrigation District	142
Lindsay-Strathmore Irrigation District	17
Orange Cove Irrigation District	34
Pixley Irrigation District	24
Porterville Irrigation District	12
Riverdale Irrigation District	13
San Joaquin, Southern, Municipal Utility District	10
Saucelito Irrigation District	13
Tule River Association	30
Tule River, Lower, Irrigation District	129
Total Cooperator Wells	**1,072**
CASGEM Monitoring Entities	**Number of Wells**
Westlands Water District	1,043
Arvin-Edison Water Storage District	197
Consolidated Irrigation District	8
Deer Creek & Tule River Authority	47

CASGEM Monitoring Entities	Number of Wells
Delano-Earlimart Irrigation District	7
Kaweah Delta Water Conservation District	205
Kern County Water Agency Improvement District No. 4	4
Kern River Fan Group	34
Kern Water Bank Authority	15
Kern-Tulare Water District	5
Kings River Conservation District	101
Semitropic Water Storage District	46
Shafter-Wasco Irrigation District	44
Tulare Irrigation District	138
Total CASGEM Monitoring Entities Wells	**1,894**
Total Tulare Lake Hydrologic Region Monitoring Wells	**3,342**

Notes:
CASGEM = California Statewide Groundwater Elevation Monitoring
Table includes groundwater-level monitoring wells having publically available online data.
Table represents monitoring information as of July 2012.

groundwater levels in four wells within the Westside Groundwater Subbasin. In addition to the State and federal agency monitoring efforts, 23 cooperators and 14 CASGEM monitoring entities combined to monitor a total of 2,966 wells in nine of the Tulare Lake region's groundwater basins and subbasins.

As part of the CASGEM Basin Prioritization process, seven high-priority basins and one medium-priority basin were identified for the Tulare Lake region. A list of the high- and medium-priority basins for the Tulare Lake region, along with a breakdown of the number of groundwater-level monitoring wells, is provided in Table 9-9. The monitoring data in Table 9-9 includes only those wells that were entered into the CASGEM system as of July 2012. Table 9-9 shows that only the Cummings Valley (high priority) and Tehachapi Valley West (medium priority) groundwater basins do not have monitoring wells entered into the CASGEM system.

Most of the groundwater-level monitoring networks include a variety of well use types. The groundwater-level monitoring wells are categorized by the types of well use that include irrigation, domestic, observation, public supply, or other. Groundwater-level monitoring wells identified as "other" include a combination of the less common well types, such as stock wells, test wells, industrial wells, or unidentified wells (no type of well listed on the well log). Wells listed as "observation" also include those wells described by drillers in the well logs as "monitoring" wells. Some of the domestic and irrigations wells used for groundwater-level monitoring include actively operated wells and some consist of older inactive or unused wells.

In the Tulare Lake region, well depths tend to be deeper than other hydrologic regions. Declining groundwater levels, poor quality shallow aquifers, and highly productive deeper confined aquifer zones all contribute to the need for deeper well construction in the Tulare Lake region, when

Table 9-9 Groundwater-Level Monitoring Wells within the CASGEM High- and Medium-Priority Basins for Tulare Lake Hydrologic Region

Basin/Subbasin Number	Basin Name	Subbasin Name	Basin Priority	Number of Groundwater Level Monitoring Wells[a,b]
5-22.11	San Joaquin Valley	Kaweah	High	642
5-27	Cummings Valley	-	High	0
5-22.13	San Joaquin Valley	Tule	High	276
5-22.08	San Joaquin Valley	Kings	High	652
5-22.14	San Joaquin Valley	Kern County	High	555
5-22.12	San Joaquin Valley	Tulare Lake	High	142
5-22.09	San Joaquin Valley	Westside	High	1,058
5-28	Tehachapi Valley West	-	Medium	0

Notes:

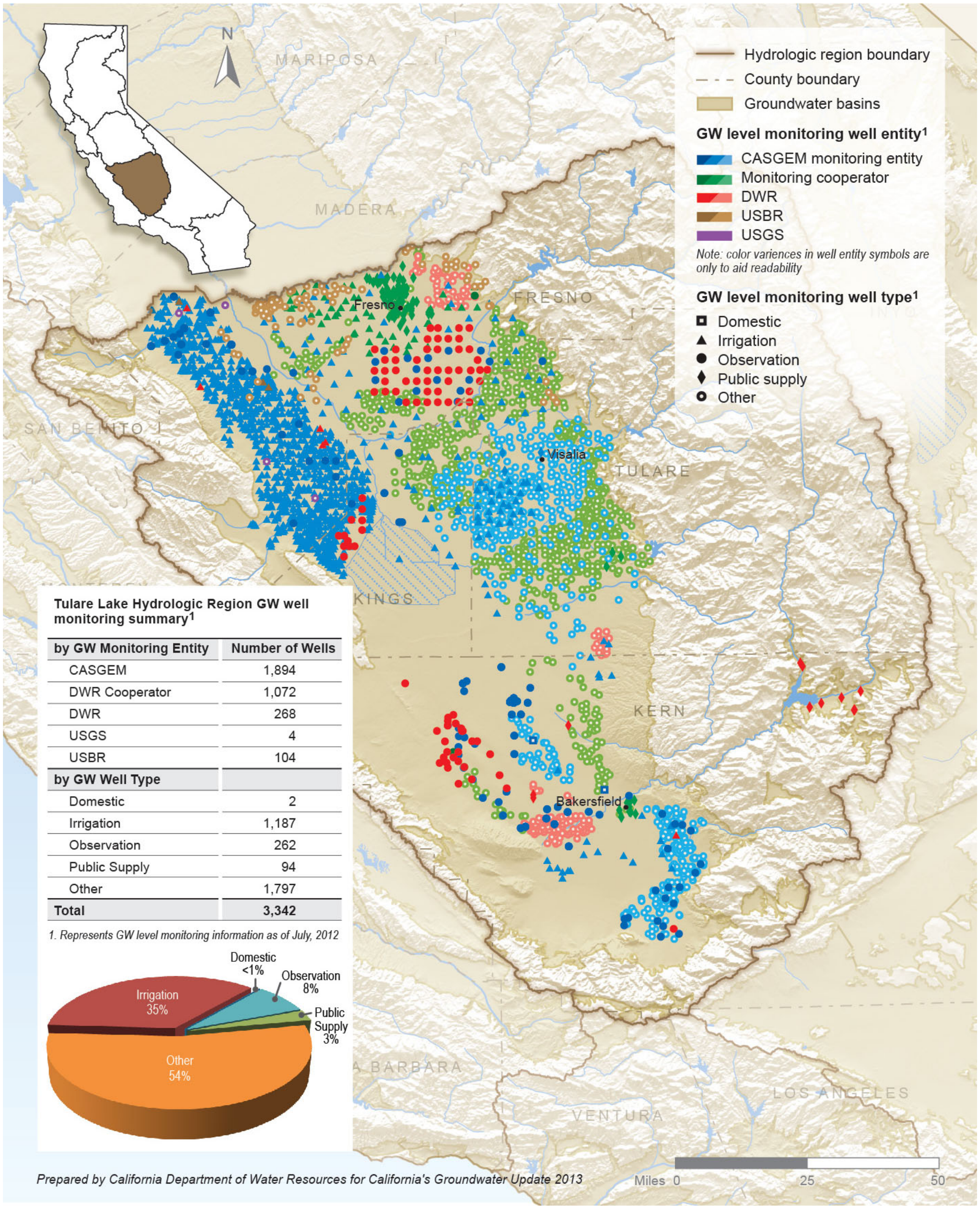
[a] Includes monitoring wells entered into the California Statewide Groundwater Elevation Monitoring or the U.S. Geological Survey online databases as of July 2012.

[b] Total of 3,325 wells monitored as of July 2012.

compared with other hydrologic regions. In general, domestic wells tend to be relatively shallower and screened in the upper portion of the aquifer system, while irrigation wells tend to be constructed deeper within the aquifer system. As a result, groundwater-level data collected from domestic wells typically represent shallow aquifer conditions, while groundwater-level data from irrigation wells represent middle-to-deep aquifer conditions. Some observation wells are constructed as a nested or clustered set of dedicated monitoring wells, designed to characterize groundwater conditions at specific and discrete intervals in the aquifer system.

Figure 9-10 graphically displays groundwater-level monitoring wells by use and includes a table listing the number of wells by use. The figure shows that many of these wells are concentrated in the Westside, Kings, Kaweah, and Kern County groundwater subbasins, and to a lesser degree in the Tule and Tulare Lake groundwater subbasins and Kern River Valley Groundwater Basin. A percentage breakdown of the groundwater-level monitoring wells by use, illustrated by the pie chart in Figure 9-10, indicates that wells identified as “other” account for more than 54 percent of the groundwater-level monitoring wells in the region. Irrigation and observation wells comprise 35 percent and 8 percent of the monitoring wells, respectively, while public supply wells account for 3 percent. Only two domestic wells are part of the groundwater-level monitoring grid for the Tulare Lake region.

Figure 9-10 Monitoring Well Location by Agency, Monitoring Cooperator, and CASGEM Monitoring Entity for the Tulare Lake Hydrologic Region



Tulare Lake Hydrologic Region GW well monitoring summary[1]

by GW Monitoring Entity	Number of Wells
CASGEM	1,894
DWR Cooperator	1,072
DWR	268
USGS	4
USBR	104
by GW Well Type	
Domestic	2
Irrigation	1,187
Observation	262
Public Supply	94
Other	1,797
Total	**3,342**

1. Represents GW level monitoring information as of July, 2012

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Groundwater Quality Monitoring

Groundwater quality monitoring is an important aspect of effective groundwater basin management and is one of the required groundwater management planning components under California Water Code Section 10753.7. Groundwater quality monitoring and assessment evaluates current conditions, can be used to establish groundwater quality thresholds, and can help guide management decisions. Without sufficient groundwater quality monitoring it is almost impossible to determine if groundwater problems exist, or to forecast the potential for problems that may warrant management actions. Many local, regional, and State agencies have statutory responsibility or authority to collect water quality and water use/level data and information; however, monitoring is inconsistent throughout the state, with significant regional variation in parameters monitored, monitoring frequency, and data availability. In spite of these inconsistencies, there are excellent examples of groundwater monitoring programs being implemented at the local, regional, and State levels.

A number of the existing groundwater-quality monitoring activities were initiated as part of the Groundwater Quality Monitoring Act of 2001, which implemented goals to improve and increase the statewide availability of groundwater-quality data. A comprehensive presentation of the Tulare Lake region groundwater-quality monitoring activities is beyond the scope of this report. A summary of the regional groundwater-quality monitoring activities and information is provided in this section.

Regional and statewide groundwater-quality monitoring information and data are available to the public on DWR's Water Data Library (http://www.water.ca.gov/waterdatalibrary/), the SWRCB's Groundwater Ambient Monitoring and Assessment (GAMA) Program Web site (http://www.waterboards.ca.gov/gama/geotracker_gama.shtml), and on the SWRCB's GeoTracker GAMA Web site (http://geotracker.waterboards.ca.gov/). The GAMA program was created in 2000 by the SWRCB to better understand California's groundwater quality issues. The GAMA program was later expanded, as part of the Groundwater Quality Monitoring Act of 2001, resulting in a publicly accepted plan to monitor and assess groundwater quality in basins that account for more than 95 percent of the state's groundwater use. The GAMA Web site includes a description of the GAMA program and also provides links to published GAMA documents and related reports.

GeoTracker GAMA is an online groundwater information system that provides the public with access to groundwater quality data. The data is geographically displayed and includes analytical tools and reporting features to assess groundwater quality conditions. GeoTracker GAMA allows users to search for more than 60 million standardized analytical test results from more than 200,000 wells and contains more than 125 million data records. These data records were obtained from different sources such as regional water quality control board (RWQCB) cleanup sites, CDPH, Department of Pesticide Regulation, DWR's Water Data Library, USGS GAMA Priority Basin Project, SWRCB GAMA Domestic Well Project, and Lawrence Livermore National Laboratory GAMA Special Studies projects. In addition to groundwater quality data, GeoTracker GAMA contains more than 2.5 million depth-to-groundwater measurements from DWR and the RWQCBs. GeoTracker GAMA also contains hydraulically fractured oil and gas well information from the California Division of Oil, Gas, and Geothermal Resources.

Groundwater quality data in DWR's Water Data Library primarily includes baseline minerals, metals, and nutrient data associated with regional monitoring. Table 9-10 lists agency-specific groundwater quality information. Additional information regarding assessment and reporting of groundwater quality information is listed in the "Aquifer Conditions" section of this chapter.

Table 9-10 Sources of Groundwater Quality Information for the Tulare Lake Hydrologic Region

Agency	Links to Information
State Water Resources Control Board http://www.waterboards.ca.gov/	**Groundwater** • Communities that Rely on a Contaminated Groundwater Source for Drinking Water http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/index.shtml • Nitrate in Groundwater: Pilot Projects in Tulare Lake Basin/Salinas Valley http://www.waterboards.ca.gov/water_issues/programs/nitrate_project/index.shtml • Hydrogeologically Vulnerable Areas http://www.waterboards.ca.gov/gama/docs/hva_map_table.pdf • Aquifer Storage and Recovery http://www.waterboards.ca.gov/water_issues/programs/asr/index.shtml • Central Valley Salinity Alternatives for Long-Term Sustainability (CV-Salts) http://www.waterboards.ca.gov/centralvalley/water_issues/salinity/ **Groundwater Ambient Monitoring and Assessment (GAMA)** http://www.waterboards.ca.gov/gama/index.shtml • GeoTracker GAMA (Monitoring Data) http://www.waterboards.ca.gov/gama/geotracker_gama.shtml • Domestic Well Project http://www.waterboards.ca.gov/gama/domestic_well.shtml • Priority Basin Project http://www.waterboards.ca.gov/water_issues/programs/gama/sw_basin_assesmt.shtml • Special Studies Project http://www.waterboards.ca.gov/water_issues/programs/gama/special_studies.shtml • California Aquifer Susceptibility Project http://www.waterboards.ca.gov/water_issues/programs/gama/cas.shtml **Contaminant Sites** • Land Disposal Program http://www.waterboards.ca.gov/water_issues/programs/land_disposal/ • Department of Defense Program http://www.waterboards.ca.gov/water_issues/programs/dept_of_defense/ • Underground Storage Tank Program http://www.waterboards.ca.gov/ust/index.shtml • Brownfields http://www.waterboards.ca.gov/water_issues/programs/brownfields/

Agency	Links to Information
California Department of Public Health http://www.cdph.ca.gov/Pages/DEFAULT.aspx	**Division of Drinking Water and Environmental Management** • Drinking Water Source Assessment and Protection (DWSAP) Program http://www.cdph.ca.gov/certlic/drinkingwater/Pages/DWSAP.aspx • Chemicals and Contaminants in Drinking Water http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Chemicalcontaminants.aspx • Chromium-VI http://www.cdph.ca.gov/certlic/drinkingwater/Pages/Chromium6.aspx • Groundwater Replenishment with Recycled Water http://www.cdph.ca.gov/HealthInfo/environhealth/water/Pages/Waterrecycling.aspx
Department of Water Resources http://www.water.ca.gov/	**Groundwater Information Center** http://www.water.ca.gov/groundwater/index.cfm • Bulletin 118 Groundwater Basins http://www.water.ca.gov/groundwater/bulletin118/gwbasins.cfm • California Statewide Groundwater Elevation Monitoring (CASGEM) http://www.water.ca.gov/groundwater/casgem/ • Groundwater-Level Monitoring http://www.water.ca.gov/groundwater/data_and_monitoring/gw_level_monitoring.cfm • Groundwater Quality Monitoring http://www.water.ca.gov/groundwater/data_and_monitoring/gw_quality_monitoring.cfm • Well Construction Standards http://www.water.ca.gov/groundwater/wells/standards.cfm • Well Completion Reports http://www.water.ca.gov/groundwater/wells/well_completion_reports.cfm
Department of Toxic Substances Control http://www.dtsc.ca.gov/	**EnviroStor** http://www.envirostor.dtsc.ca.gov/public/
Department of Pesticide Regulation http://www.cdpr.ca.gov/	**Groundwater Protection Program** http://www.cdpr.ca.gov/docs/emon/grndwtr/index.htm • Well Sampling Database http://www.cdpr.ca.gov/docs/emon/grndwtr/gwp_sampling.htm • Groundwater Protection Area Maps http://www.cdpr.ca.gov/docs/emon/grndwtr/gwpa_maps.htm
U.S. Environmental Protection Agency http://www.epa.gov/safewater/	**Storage and Retrieval (STORET) Environmental Data System** http://www.epa.gov/storet/
United States Geological Survey http://ca.water.usgs.gov/	**Water Data for the Nation** http://waterdata.usgs.gov/nwis

Land Subsidence Monitoring

Land subsidence has been shown to occur in areas experiencing a significant decline in groundwater levels. When groundwater is extracted from aquifers in sufficient quantity, the groundwater level is lowered and the water pressure, which supports the sediment grains structure, decreases. A decrease in water pressure causes more weight from the overlying sediments to be supported by the sediment grains within the aquifer. In unconsolidated deposits, the increased weight from overlying sediments may compact the fine-grained sediments and permanently decrease the porosity of the aquifer and the ability of the aquifer to store water. The partial collapse of the aquifer results in the subsidence of the land surface overlying the aquifer. Elastic land subsidence is the reversible and temporary fluctuation of the earth's surface in response to seasonal periods of groundwater extraction and recharge. Inelastic land subsidence is the irreversible and permanent decline in the earth's surface resulting from the collapse or compaction of the pore structure within the fine-grained portions of an aquifer system (U.S. Geological Survey 1999).

Land subsidence investigations in the southern San Joaquin Valley and Tulare Lake areas include various monitoring efforts such as elevation surveys along the California Aqueduct, borehole extensometer monitoring, satellite remote sensing studies using InSAR, continuous and conventional GPS measurements, and spirit-leveling surveying (U.S. Geological Survey, California Water Science Center) (http://ca.water.usgs.gov/projects/central-valley/land-subsidence-monitoring-network.html). In addition, monitoring of ground surface elevation associated with non-land subsidence studies, such as periodic highway elevation surveys, can also result in data that is useful for monitoring land subsidence. A summary of these land subsidence monitoring activities is provided in this section. Additional efforts to expand or develop land subsidence monitoring at the subbasin level is currently being implemented by several local groundwater management planning entities (Kings River Conservation District 2012). An overview of the results and findings associated with these land subsidence monitoring activities is provided under the "Aquifer Conditions" section of this chapter. Additional information regarding land subsidence in California is provided in Appendix F.

California Aqueduct Elevation Surveys

DWR performs periodic elevation surveys along the California Aqueduct to measure land subsidence effects along the canal and guide maintenance repairs as needed. Previous surveys were summarized by the USGS (Ireland 1986) that included elevation profiles along the canal for 1966, 1968, 1971, 1972, 1975, 1977, 1978 and 1981. DWR surveys compare elevations along portions of the aqueduct in Fresno and Kings counties for 2000, 2006, and 2009. The results of the DWR aqueduct elevation monitoring are provided in the "Aquifer Conditions" section of this chapter.

Borehole Extensometer Monitoring

A borehole extensometer is designed to act as benchmark anchored to a geologically stable portion of the lower aquifer. They are typically drilled and constructed using slip-joints to connect the borehole casing at periodic intervals. The slip-joints allow for vertical movement of the aquifer without collapse or damage to the extensometer casing. A concrete plug is placed in the bottom of the casing to serve as a stable benchmark. Steel pipe is then installed inside the extensometer casing and connected with a counterweight at the surface to limit compression of the pipe and allow it to carefully rest on the concrete plug, or benchmark. The steel pipe serves to transfer elevation readings from lower aquifer benchmark to the surface, where instrumentation is installed to continuously record very small movements in the aquifer. Extensometers are also commonly equipped to continuously monitor groundwater levels in one or more aquifer zones.

Most of the borehole extensometers in the Tulare Lake region were constructed in the 1950s and 1960s during the planning and construction of the State and federal water projects. After completion of the water projects and the importation of surface water, it was commonly thought that the threat of land subsidence had largely been mitigated. As a result, land subsidence investigations became less of a priority and the borehole extensometer monitoring wells fell into disrepair. In 2009, the USGS evaluated 12 of the inactive borehole extensometers for potential repair and reuse (Sneed 2011). Four extensometers were selected to be rehabilitated. These extensometers include: 12S/12E-16H2, 14S/13E-11D6, 18S/16E-33A1, and 20S/18E-6D1. Other active extensometers currently being monitored include the 25S/22E-35B1 (Semitropic Water Storage District Extensometer) and 30S/25E-16L monitored by DWR.

Figure 9-11 shows the location of the seven active borehole extensometers. Table 9-11 provides information for both the active and inactive extensometers in the southern San Joaquin Valley. Because of the small number of borehole extensometers in the San Joaquin River Hydrologic Region (one active and one inactive), the extensometer information for the San Joaquin and Tulare Lake regions have been combined in Figure 9-11 and Table 9-11. Results from the borehole extensometer monitoring are provided in the “Aquifer Conditions” section of this chapter.

Figure 9-11 Borehole Extensometer Locations for the San Joaquin Valley Portion of the Tulare Lake Hydrologic Region

Table 9-11 Borehole Extensometer Information for the San Joaquin Valley Portion of the Tulare Lake Hydrologic Region

State Well Number	HR	GW Basin	County	Latitude	Longitude	Well Depth	Initial Start of Data Record	Post-Rehab Start of Record
Active								
12S/12E-16H2	SJR	5.22-07	Merced	36.890	120.655	1,000	5/19/1958	2/27/2012
13S/15E-35D5	TL	5.22-07	Fresno	36.760	-120.311	440	5/13/1966	2002
14S/13E-11D6	TL	5-22.09	Fresno	36.733	-120.532	1358	1/1/1961 to 1974	4/6/2012
18S/16E-33A1	TL	5-22.09	Fresno	36.327	-120.230	1029	3/10/1965	3/2/2012
20S/18E-6D1	TL	5-22.09	Fresno	36.226	-120.065	1007	1/1/1965	4/5/2012
5S/22E-35B1	TL	5-22.14	Kern	35.710	-119.535	880	2010	
30S/25E-16L5	TL	5-22.14	Kern	35.318	-119.297	780	6/1/1994	
Inactive[a]								
13S/12E-20D1	SJR	5.22-07	Madera	36.790	-120.689	681	Abandoned 1974	
14S/12E-12H1	TL	5-22.09	Fresno	36.731	-120.605	913	1/10/1965[b]	
14S/13E-26N1	TL	5-22.09	Fresno	36.678	-120.529		1945[b]	
15S/13E-11D2	TL	5-22.09	Fresno	36.646	-120.529	958	1/1/1965[b]	
15S/14E-14J1	TL	5-22.09	Fresno	36.622	-120.408	1010	Abandoned 1971	
15S/16E-31N3	TL	5-22.09	Fresno	36.575	-120.276	596	3/23/1967[b]	
16S/15E-34N1 to N42	TL	5-22.09	Fresno	36.495	-120.329	503, 703, 1096, 2000	9/25/1958[b]	
17S/15E-14Q1	TL	5-22.09	Fresno	36.445	-120.308	2315	11/4/1969[b]	
17S/15E-21N1	TL	5-22.09	Fresno	36.430	-120.354		1955[b]	
18S/19E-20P1	TL	5-22.09	Kings	36.345	-119.934	578	3/24/1967[b]	
19S/16E-23P2	TL	5-22.09	Fresno	36.256	-120.205	2200	1/2/1960 Abandoned 1974	
20S/18E-11Q1, Q2, Q3	TL	5-22.09	Fresno	36.198	-119.982	710, 845, 1930	7/24/1964[b]	
22S/27E-30D2	TL	5-22.13	Tulare	35.992	-119.104	1246	8/13/1970[b]	
23S/25E-16N1, N3, N4	TL	5-22.13	Tulare	35.922	-119.284	250, 430, 760	6/24/1959[b]	
24S/26E-34F1	TL	5-22.13	Tulare	35.800	-119.155	1510	1/21/1959[b]	
24S/26E-36A2	TL	5-22.13	Tulare	35.804	-119.108	2200	5/12/1959[b]	
25S/26E-1A2	TL	5-22.14	Kern	35.790	-119.117	875	4/6/1959 Abandoned 1978	

State Well Number	HR	GW Basin	County	Latitude	Longitude	Well Depth	Initial Start of Data Record	Post-Rehab Start of Record
Inactive								
26S/23E-16H2, H3	TL	5-22.14	Kern	35.668	-119.492	355, 1002	8/17/1978[b]	
32S/28E-20Q1	TL	5-22.14	Kern	35.123	-118.992	970	4/11/1963 Abandoned 1975	
12N/21W-34Q1[c]	TL	5-22.14	Kern	35.078	-119.106	810	6/20/1960 Abandoned 1974	
11N/21W-3B1 (SB BLM)	TL	5-22.14	Kern	35.076	-119.105	1480	4/12/1963[b]	

Notes:

HR = hydrologic region; SJR = San Joaquin River; TL = Tulare Lake; GW = groundwater; SB BLM = Santa Barbara Baseline and Meridian

[a] Inactive extensometers are not in use because of disrepair.

[b] Uncertain date when extensometer readings were terminated.

The U.S. Geological Survey online information for active extensometers can be found at: http://waterdata.usgs.gov/ca/nwis/inventory.

USGS InSAR Monitoring

InSAR is a remote sensing tool that uses satellite radar signals to measure deformation of the Earth's crust at a high degree of spatial detail and measurement resolution (U.S. Geological Survey 2000). By bouncing radar signals off the ground surface from the same point in space, but at different times, the radar satellite can measure the change in distance between the satellite and ground as the land surface uplifts or subsides. Under optimum conditions, the measurement resolution of InSAR monitoring is estimated to be 5 to 10 millimeters (U.S. Geological Survey 2003).

In cooperation with DWR and the USBR, the USGS is evaluating 2007 to 2011 InSAR survey data for evidence of subsidence in the San Joaquin River and Tulare Lake regions. Results of the InSAR investigation are provided in the "Aquifer Conditions" section of this chapter.

Caltrans Highway Elevation Monitoring

Caltrans periodically resurveys their network of existing benchmarks along key sections of highways. In 2004, Caltrans surveyed a section of State Route 198 across the San Joaquin Valley from the Diablo Range to Visalia. Prior surveys along this section of State Route 198 have been done at approximately 16-year intervals. Although the surveys are typically limited to the highway right-of-way and likely miss some of the larger land subsidence areas, the highway survey data have identified significant subsidence between survey intervals. Results from the Caltrans State Route 198 survey is provided in the "Aquifer Conditions" section of this chapter.

GPS Array Monitoring

A university-governed consortium for geosciences research using geodesy (UNAVCO) operates the Plate Boundary Observatory and uses precision GPS monitoring sites for western United States plate tectonics studies. The UNAVCO GPS stations provide continuous monitoring of the land surface elevation providing a potential direct measurement of subsidence. There are 13 GPS stations in the San Joaquin Valley. Several of these are close to the edge of the valley and provide only partial insight into the regional magnitude of subsidence, while others lie outside of areas susceptible to subsidence. However, a number of UNAVCO stations provide important information regarding changes in the land surface over time. Results from the UNAVCO GPS monitoring are provided in the "Aquifer Conditions" section of this chapter.

Aquifer Conditions

Aquifer conditions and groundwater levels change in response to varying supply, demand, and weather conditions. During years of normal or above normal precipitation, or during periods of low groundwater use, aquifer systems tend to recharge and respond with rising groundwater levels. Direct and in-lieu recharge programs in the Tulare Lake region take advantage of increased runoff and surface water deliveries during years of normal and above normal precipitation and help further raise groundwater levels. As a result, if groundwater levels rise sufficiently, they reconnect to surface water systems, contributing to the overall base flow or directly discharging onto the ground surface via wetlands, seeps, and springs. For much of the Tulare Lake region, the groundwater table has been disconnected from surface water systems for decades and provides no contribution to base flow.

During dry years or periods of increased groundwater use, seasonal groundwater levels tend to fluctuate widely, 50 feet or more in some locations (Semitropic Water Storage District 2012), and depending on the annual amount of natural and managed recharge, may respond with a long-term decline in groundwater levels, both locally and regionally. Excessive lowering of groundwater levels requires owners of impacted wells to deepen wells or lower pumps to regain access to groundwater. Lowering of groundwater levels also impacts the surface water-groundwater interaction by increasing infiltration rates, capturing groundwater flow that would otherwise have contributed to the base flow of surface water systems, and by reducing groundwater discharge to surface water systems. Extensive lowering of groundwater levels can also result in land subsidence caused by the dewatering, compaction, and loss of storage within finer grained aquifer systems.

In 1980, DWR Bulletin 118-80 identified five of the seven southern San Joaquin Valley groundwater subbasins (Kings, Kaweah, Tulare Lake, Tule, and Kern County), as being subject to critical conditions of overdraft. More than 30 years later, Tulare Lake groundwater supplies still account for about 38 percent of all groundwater extraction in California, double the groundwater extraction of the next highest hydrologic region, and contribute more than half the total annual water supply for the Tulare Lake region. In addition, reduced surface water supply reliability, and a recent agricultural shift toward more permanent crop planting, has further increased the demand for groundwater. Although significant efforts have been made by local groundwater management entities to reduce overdraft conditions in the region, a number of the GWMPs, and more recent studies for the five key southern San Joaquin Valley basins, acknowledge that groundwater overdraft conditions continue today.

The following overview of Tulare Lake region aquifer conditions includes a regional description of groundwater occurrence and movement, estimates of spring 2005 to spring 2010 change in groundwater in storage, an overview of groundwater quality conditions, and a discussion of the effects of groundwater withdrawal on land subsidence. Additional information regarding the methods and assumptions associated with aquifer condition data is provided in Appendix A.

Groundwater Occurrence and Movement

In the simplest of terms, groundwater comes from infiltration of precipitation and of water from streams, canals, and other surface water systems, and moves from areas of higher to lower elevation. Under predevelopment conditions, the occurrence and movement of groundwater was largely controlled by the surface and the subsurface geology, the size and distribution of the natural surface water systems, the average annual hydrology, and the regional topography. Many decades of high-volume groundwater extraction to sustain the agricultural and urban land uses in the Tulare Lake region has considerably affected the natural occurrence and movement of groundwater. Areas of high groundwater extraction tend to redirect and capture groundwater underflow that may otherwise have contributed to nearby surface water systems, leading to varying degrees of surface water depletion. Thousands of high-capacity wells screened over multiple aquifer zones also lend themselves to vertical aquifer mixing, which can additionally alter natural groundwater flow conditions. In addition, infiltration along miles of unlined water conveyance canals, percolation of applied irrigation water, and direct recharge programs create significant groundwater recharge areas where none previously existed.

Groundwater occurrence and movement in the Tulare Lake region were evaluated using spring 2005 to spring 2010 groundwater-level data to develop contour maps. Springtime groundwater levels typically depict the highest groundwater levels of the year and a time when annual groundwater demands are at a minimum. It is also a time when aquifer recharge from winter rainfall and snowmelt runoff is at or near the annual maximum.

Groundwater contour maps provide a snapshot of groundwater conditions at a particular point in time, or between two particular time periods. Groundwater levels are affected by a number of variables, so the depth-to-water maps and groundwater elevations maps should be considered regional approximations — with potentially varying local conditions.

Groundwater contour maps were developed using groundwater-level data that is publically available online from DWR's Water Data Library (http://www.water.ca.gov/waterdatalibrary/), and DWR's CASGEM system (http://www.water.ca.gov/groundwater/casgem/). Additional groundwater-level information for the Tulare Lake region is publically available from the USGS National Water Information System (http://waterdata.usgs.gov/nwis/gw), and some groundwater management groups in the region. Groundwater contour maps for the Tulare Lake region are also generated by DWR's South Central Region Office and by various groundwater management groups in the region. The following is a list of additional sources for Tulare Lake region groundwater contour maps.

- **DWR South Central Region Office:** http://www.water.ca.gov/groundwater/data_and_monitoring/south_central_region/GroundwaterLevel/gw_level_monitoring.cfm
- **Kings River Conservation District:** http://www.krcd.org/water/groundwater_management/annual_report.html
- **Kaweah Delta Water Conservation District**: http://www.kdwcd.com/kdwcdweb_005.htm
- **Semitropic Water Storage District:** http://www.semitropic.com/pdfs/Semitropic%20Draft%20GW%20Management%20Plan_10%201%202012.pdf
- **Improvement District No. 4:** http://www.water.ca.gov/urbanwatermanagement/2010uwmps/CA%20Water%20Service%20Co%20-%20Bakersfield/Appendix%20K%20-%20ID-4%20ROWC.pdf

The following sections provide an overview of the Tulare Lake region's depth-to-groundwater, groundwater elevation, and long-term groundwater-level trends associated with changing hydrologic conditions and local management actions. Additional information regarding the assumptions and methods associated with groundwater contours and change in storage estimates are provided in Appendix A and Appendix E.

Depth to Groundwater

Prior to the import of surface water supplies into the Tulare Lake region in the late 1960s, groundwater levels for much of the region were dropping at a rate of about 8 to 10 feet per year, with seasonal fluctuations approaching 100 feet (Semitropic Water Storage District 2012). In the decade following the import of surface water supplies, groundwater levels began a dramatic period of recovery and, in some areas, recovered as much as 200 feet between 1967 and 1974.

Since then, a combination of drought conditions, diversion of surface water for environmental uses, an increasing population, and the trend toward more permanent crops have led to a renewed reliance on groundwater pumping and subsequent decline of groundwater levels. In 2008-2009, groundwater levels in many Tulare Lake region basins reached historic lows, raising concerns over renewed subsidence, declining groundwater ecosystem services, and, for smaller farming operations in the region, suggesting that the cost of groundwater pumping for agricultural use may become unaffordable.

Understanding the local depth to groundwater provides a better awareness of the potential interaction between groundwater and surface water systems, the relationship between land use and groundwater levels, the potential for land subsidence, groundwater contributions to the local ecosystems, and the costs associated with well installation and groundwater extraction.

Under predevelopment aquifer conditions, changes in the depth to groundwater will generally correlate with ground surface elevation. For example, with increasing ground surface elevation there is a corresponding increase in the depth to groundwater. In high-use basins or in conjunctively managed basins, the correlation between depth to water and ground surface elevation will eventually start to breakdown and show significant variability over areas having little change in ground surface elevation.

Figure 9-12 is a spring 2010 depth-to-groundwater contour map for the Tulare Lake region. The contour lines represent areas having similar spring 2010 depth-to-groundwater measurements. Contour lines were developed only for those areas having sufficient groundwater-level data and only for those aquifers characterized by unconfined to semi-confined groundwater conditions. Areas having sufficient spring 2010 groundwater-level data to develop depth-to-groundwater contours are highlighted in Figure 9-12 by color-ramped contours and are identified as "Reporting Areas." Alluvial basin areas not covered with color-ramped contours are identified as "Non-Reporting Areas," because of a lack of sufficient groundwater-level data. Because of the largely confined nature of the Westside Subbasin aquifer systems, no contours were developed for this area. Depth-to-groundwater contours were not developed for the Tulare Lake lakebed area because of thick clay layers limiting groundwater production and limited availability of groundwater-level data.

Figure 9-12 shows that the depth to groundwater in the northeastern one-third of the region (Kings and Kaweah groundwater subbasins), is shallowest along the valley floor adjacent to the Sierra Nevada foothills. Groundwater recharge along the eastside drainages, such as the Kings River, helps maintain spring 2010 groundwater levels at 20 to 60 feet bgs. Seepage from the Friant-Kern Canal likely also contributes to shallower groundwater levels along the eastern Kings Groundwater Subbasin. Moving west toward the axis of the valley, groundwater levels deepen to more than 250 feet bgs along the western edge of the Kings Groundwater Subbasin, areas identified as Management Area A and Management Area B in the Kings River service area (Kings River Conservation District 2012).

Farther to the south in the Kaweah Groundwater Subbasin, recharge along the eastern edge of the valley and in areas adjacent to the Kaweah and Tule rivers results in shallower groundwater depths in the 30 to 50 feet bgs range. Moving to the west, as groundwater extraction for urban and agricultural uses increases, the depth-to-groundwater contours becomes increasingly irregular and variable. Figure 9-12 shows depth to groundwater increasing to about 150 feet bgs near the cities of Lindsay and Tulare. Tulare is entirely dependent on groundwater supplies to meet urban demands. Because of poor quality groundwater, Lindsay augments its groundwater with surface water supplies from the Friant-Kern Canal during the summer months, periods of high demand, or during maintenance to the surface water distribution system. Poor quality groundwater currently limits further groundwater use by Lindsay.

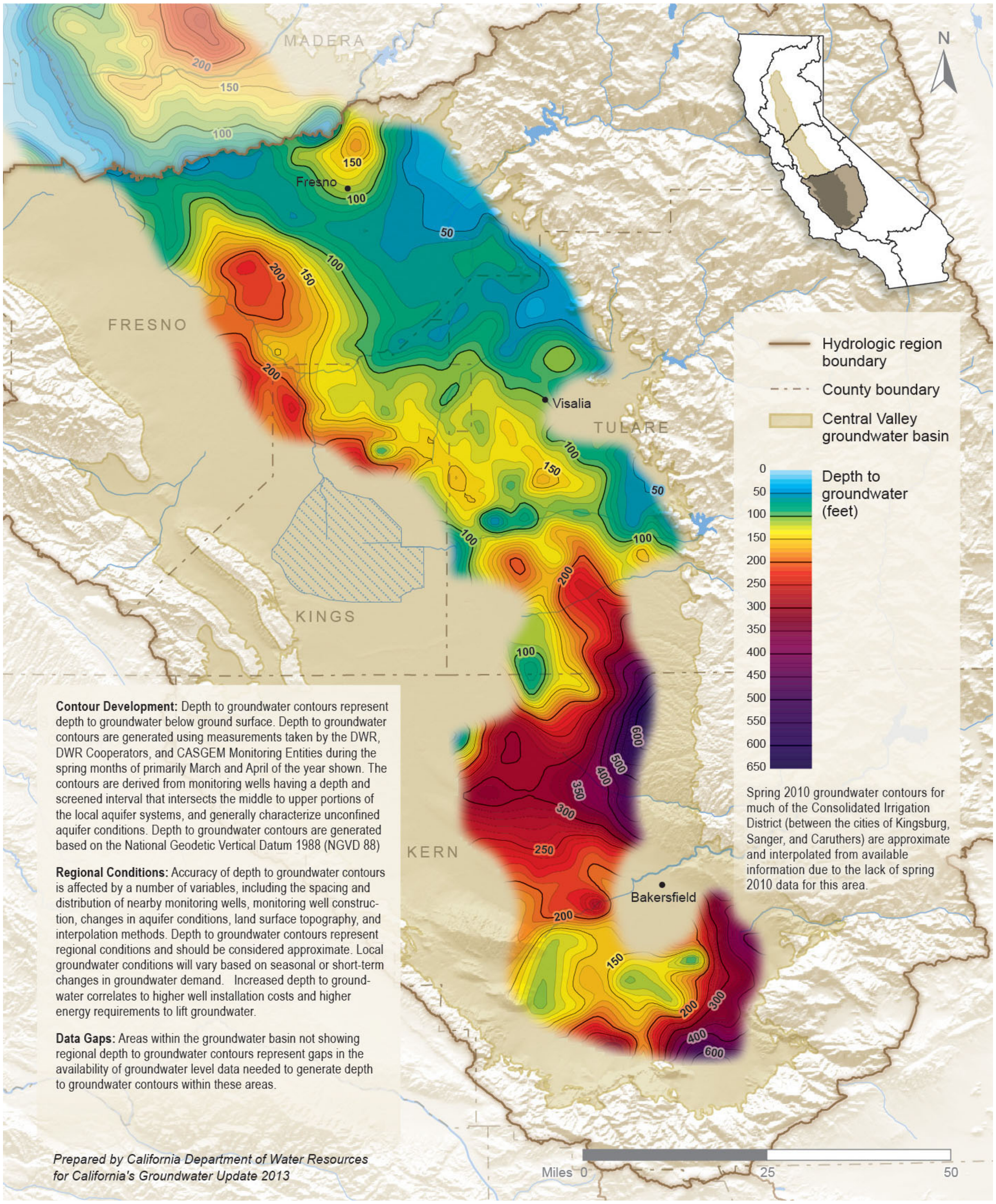
In the Tule and Kern County groundwater subbasins, availability of surface water for irrigation has created a more complex distribution of groundwater depths. For areas in the Tule and Kern County groundwater subbasins that receive surface water, groundwater levels range from 200 to 300 feet bgs. For groundwater-dependent areas along the east side of the Friant-Kern Canal, the depth to groundwater ranges from 450 to 600 feet bgs. In the southern and southeastern portion of the Kern County Groundwater Subbasin, the depth to groundwater becomes more variable and complicated because of nearby groundwater pumping, variably imported surface water, and large groundwater banking projects. A significant rise in ground surface topography toward the surrounding mountains results in depths to groundwater of 300 to 500 feet bgs, or more, along the edges of the valley.

Groundwater Elevations

Groundwater elevation contours, which provide a good regional estimate of the occurrence and movement of groundwater in the Tulare Lake region, were developed using data publically available through DWR’s Water Data Library. The library contains data collected by DWR and other State, federal, and private cooperators. Under predevelopment conditions, the groundwater elevations typically follow a muted version of the overlying topography. The direction of groundwater flow follows a path perpendicular to the groundwater contours — moving from areas of higher to lower elevation. In aquifer recharge areas, groundwater flow lines tend to diverge from the area in a radial flow pattern. In aquifer discharge areas, or in areas characterized by pumping depressions of the groundwater table, the groundwater flow lines will tend to converge toward the center of the discharge or pumping area. Using similar principles, groundwater elevation contours along gaining stream reaches (streams where groundwater contributes to the base flow) will show a groundwater flow-line pattern that converges upon the stream. Along losing stream reaches (streams that lose water to the aquifer), the groundwater contours will show a groundwater flow-line pattern that diverges from the stream.

Figure 9-13 is a spring 2010 groundwater elevation contour map for the southern San Joaquin Valley Groundwater Basin portion of the Tulare Lake region. Groundwater movement direction is shown as a series of arrows along the groundwater flow path. Note that these flow direction arrows do not provide information regarding vertical flow within the local aquifer system. Similar to the spring 2010 depth-to-groundwater contours, groundwater elevation contours lines in Figure 9-13 were developed only for those areas having sufficient groundwater-level data and for those aquifers characterized by unconfined to semi-confined groundwater conditions. Because of the largely confined nature of the Westside Groundwater Subbasin aquifer and the lack of unconfined aquifer data, no contours were developed for this area. Groundwater elevation contours were not developed for the Tulare Lake lakebed area because of thick clay layers limiting groundwater production, and the lack of groundwater-level data in the area.

Figure 9-12 **Spring 2010 Depth to Groundwater Contours for the Tulare Lake Hydrologic Region**



Spring 2010 groundwater contours for much of the Consolidated Irrigation District (between the cities of Kingsburg, Sanger, and Caruthers) are approximate and interpolated from available information due to the lack of spring 2010 data for this area.

Contour Development: Depth to groundwater contours represent depth to groundwater below ground surface. Depth to groundwater contours are generated using measurements taken by the DWR, DWR Cooperators, and CASGEM Monitoring Entities during the spring months of primarily March and April of the year shown. The contours are derived from monitoring wells having a depth and screened interval that intersects the middle to upper portions of the local aquifer systems, and generally characterize unconfined aquifer conditions. Depth to groundwater contours are generated based on the National Geodetic Vertical Datum 1988 (NGVD 88)

Regional Conditions: Accuracy of depth to groundwater contours is affected by a number of variables, including the spacing and distribution of nearby monitoring wells, monitoring well construction, changes in aquifer conditions, land surface topography, and interpolation methods. Depth to groundwater contours represent regional conditions and should be considered approximate. Local groundwater conditions will vary based on seasonal or short-term changes in groundwater demand.   Increased depth to groundwater correlates to higher well installation costs and higher energy requirements to lift groundwater.

Data Gaps: Areas within the groundwater basin not showing regional depth to groundwater contours represent gaps in the availability of groundwater level data needed to generate depth to groundwater contours within these areas.

Prepared by California Department of Water Resources for California's Groundwater Update 2013

Figure 9-13 shows that the spring 2010 groundwater movement is generally from the eastern edge of the basin to the axis of the valley. Groundwater pumping and recharge activities tend to alter the spacing, pattern, and overall variability of groundwater elevation contours for some areas. In areas receiving little or no surface water, large pumping centers have developed pumping cones-of-depression, drawing water levels to below sea level. The spring 2010 pumping depressions along the western edge of the Kings and Kaweah subbasins tend to capture groundwater from adjacent areas and prevent groundwater from moving in a normal down-gradient direction. Additional pumping depressions are observed in other subbasins; however, the extent and depth of these depressions are not as large. Several local groundwater management groups have begun to address the ongoing groundwater-level declines by implementing conjunctive management programs that include groundwater banking, water exchange programs, and importation of alternative water supplies.

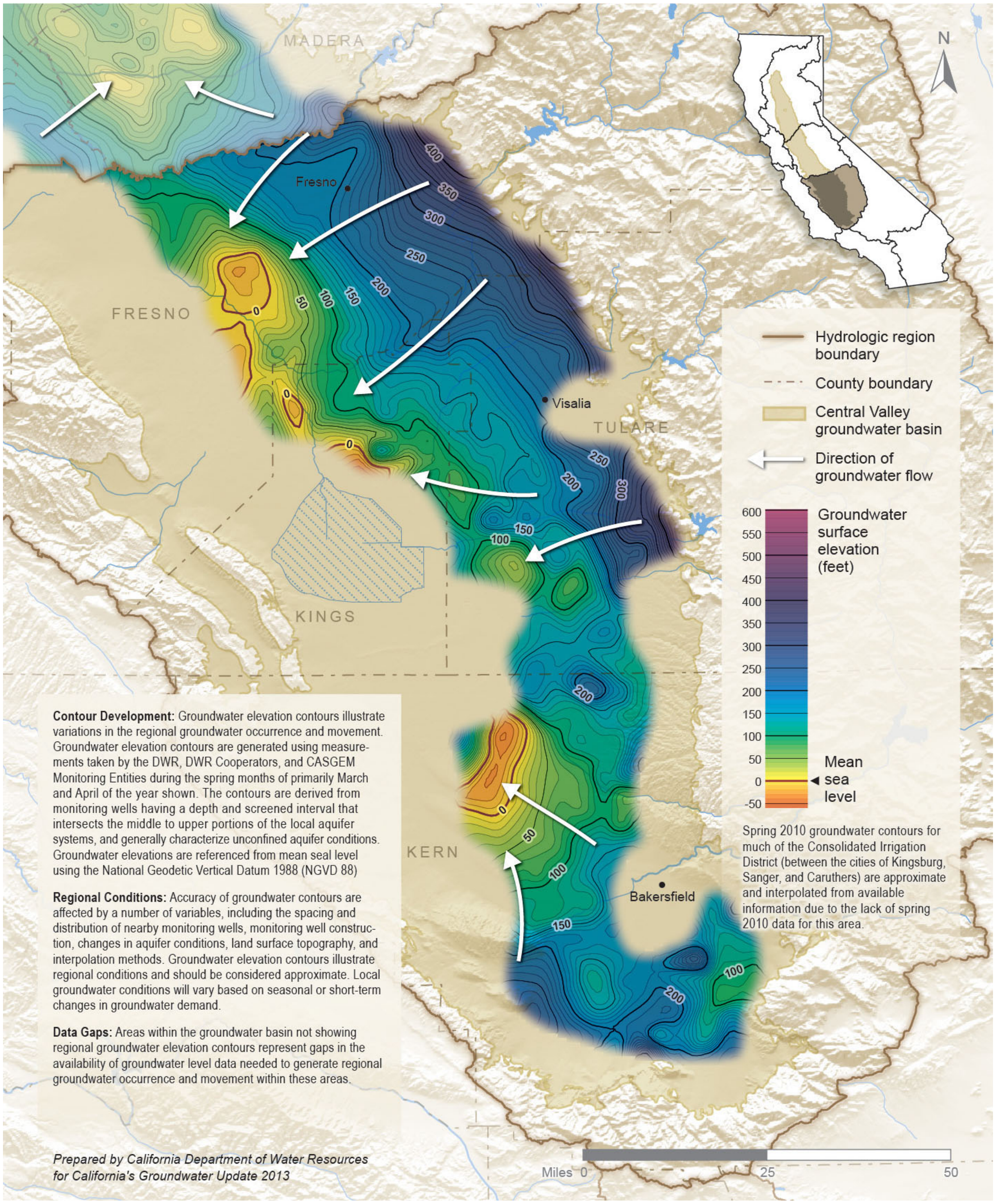
Although groundwater contours were not developed for the west side of the hydrologic region (Westside, Tulare Lake, and Kern County subbasins), the direction of groundwater movement along the west side is generally from the Diablo Range eastward toward the axis of the valley. The influence of recharge from the west side streams is much less than that of the rivers emanating from the Sierra Nevada. Figure 9-13 illustrates several patterns of groundwater recharge associated with key surface water systems flowing into the San Joaquin Valley. In particular, recharge areas can be seen along the larger rivers, such as the San Joaquin, Kings, and Tule.

Groundwater-Level Trends

Depth-to-water measurements collected from a particular well over time can be plotted to create a hydrograph. Hydrographs assist in the presentation and analysis of seasonal and long-term groundwater-level variability and trends over time. Because of the highly variable nature of the aquifer systems within each groundwater basin, and because of the variable nature of annual groundwater extraction, recharge, and surrounding land use practices, the hydrographs selected to depict long-term groundwater-level trends do not necessarily capture the extensive variability in regional aquifer conditions. The hydrographs were selected to help tell a story of how the local aquifer systems respond to changing groundwater extractions and resource management practices. The hydrographs are identified according to the State Well Numbering (SWN) system. The SWN identifies a well by its location using the U.S. Public Land Survey System of township, range, and section. More information on the SWN system is provided in DWR's Water Facts No. 7 information brochure (http://www.water.ca.gov/pubs/conservation/waterfacts/numbering_water_wells_in_california__water_facts_7_/water_facts_7.pdf).

Figure 9-14 shows five selected tell-a-story hydrographs in the Tulare Lake region, including a brief explanation of the hydrograph "story." More detailed information about the hydrographs is provided in the following text.

Figure 9-13 Spring 2010 Groundwater Elevation Contours for the Tulare Lake Hydrologic Region



Contour Development: Groundwater elevation contours illustrate variations in the regional groundwater occurrence and movement. Groundwater elevation contours are generated using measurements taken by the DWR, DWR Cooperators, and CASGEM Monitoring Entities during the spring months of primarily March and April of the year shown. The contours are derived from monitoring wells having a depth and screened interval that intersects the middle to upper portions of the local aquifer systems, and generally characterize unconfined aquifer conditions. Groundwater elevations are referenced from mean seal level using the National Geodetic Vertical Datum 1988 (NGVD 88)

Regional Conditions: Accuracy of groundwater contours are affected by a number of variables, including the spacing and distribution of nearby monitoring wells, monitoring well construction, changes in aquifer conditions, land surface topography, and interpolation methods. Groundwater elevation contours illustrate regional conditions and should be considered approximate. Local groundwater conditions will vary based on seasonal or short-term changes in groundwater demand.

Data Gaps: Areas within the groundwater basin not showing regional groundwater elevation contours represent gaps in the availability of groundwater level data needed to generate regional groundwater occurrence and movement within these areas.

Spring 2010 groundwater contours for much of the Consolidated Irrigation District (between the cities of Kingsburg, Sanger, and Caruthers) are approximate and interpolated from available information due to the lack of spring 2010 data for this area.

Prepared by California Department of Water Resources for California's Groundwater Update 2013

Hydrograph 15S18E30L001M

Figure 9-14a is a hydrograph for well 15S18E30L001M located near Raisin City, approximately 10 miles southwest of Fresno in the Kings Groundwater Subbasin and in the Lower Kings-Tulare PA. The hydrograph for this well demonstrates a persistent decline in groundwater levels during the last 50 years for the western Kings Groundwater Subbasin. Well 15S18E30L001M is screened in the unconfined to semi-confined portion of the aquifer. The area surrounding the well is predominantly agricultural land use, characterized by a mix of permanent crops (vines and tree fruit) and row crops. Groundwater-level measurements were first recorded in 1921 and have since been measured on approximately a semi-annual basis.

The hydrograph for well 15S18E30L001M shows that groundwater levels remained more or less stable during the 1920s and 1930s. After World War II, agriculture land use reliant on groundwater intensified and water levels began a steady decline, with groundwater elevations reaching sea level around 1973, prior to the 1977 drought. Seasonal fluctuation during this time ranged from about 5 to 15 feet.

Groundwater levels generally remained seasonally stable during the 10-year period of above normal precipitation between 1978 and 1988, before declining approximately another 50 feet during the 1989-1994 drought. Groundwater levels showed some increase during the wet years of the late 1990s, but have since continued declining by approximately 25 feet, to an elevation of about 136 feet below sea level.

Groundwater in this portion of the Kings Groundwater Subbasin is replenished by subsurface inflow from surrounding areas and recharge from rainfall and infiltration of applied irrigation water. With improved efficiencies of applied irrigation water, recharge to aquifer from applied water has decreased substantially. The decline of groundwater levels for this area since 1940 is approximately 300 feet, with more than 75 feet of decline since 1990. During the 2008-2009 drought, groundwater extraction for the Lower Kings-Tulare PA averaged 2.0 million acre-feet. The 2005 to 2010 average groundwater extraction for this area was about 1.5 million acre-feet.

The hydrograph for this well clearly demonstrates the imbalance between aquifer recharge and groundwater extraction for this portion of the Kings Groundwater Subbasin, and the unsustainability of relying on groundwater resources at the existing level of groundwater extraction and management practices. The Kings Groundwater Subbasin is designated as a CASGEM high-priority basin.

Hydrograph 20S23E12A001M

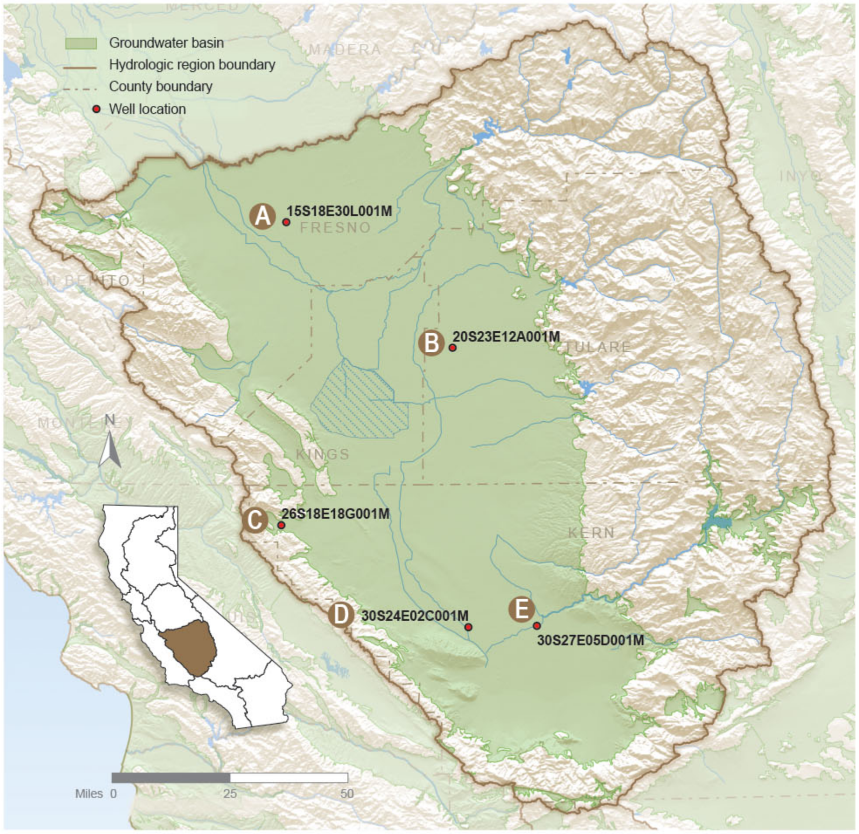
Figure 9-14b is a hydrograph for well 20S23E12A001M located 5 miles west of Tulare, along the western edge of the Kaweah Groundwater Subbasin and Kaweah Delta PA. The hydrograph for this well illustrates the local aquifer response to changes in groundwater recharge and extraction because of changes in precipitation and surface water supply deliveries for the Kaweah Groundwater Subbasin. Well 20S23E12A001M is currently used for agricultural irrigation and is screened in the unconfined to semi-confined portion of the aquifer. Land use surrounding the well is characterized by permanent agricultural crops (vines and fruit trees), row crops, and dairies

Figure 9-14 Groundwater Hydrographs for the Tulare Lake Hydrologic Region, Page 1

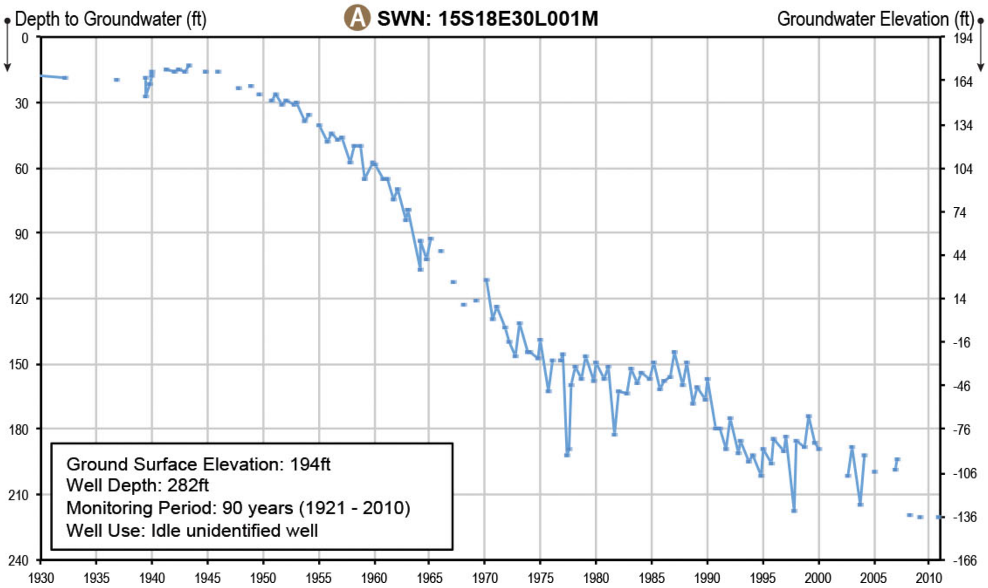
Aquifer response to changing demand and management practices

Hydrographs were selected to help tell a story of how local aquifer systems respond to changing groundwater demand and resource management practices. Additional detail is provided within the main text of the report.

Regional locator map

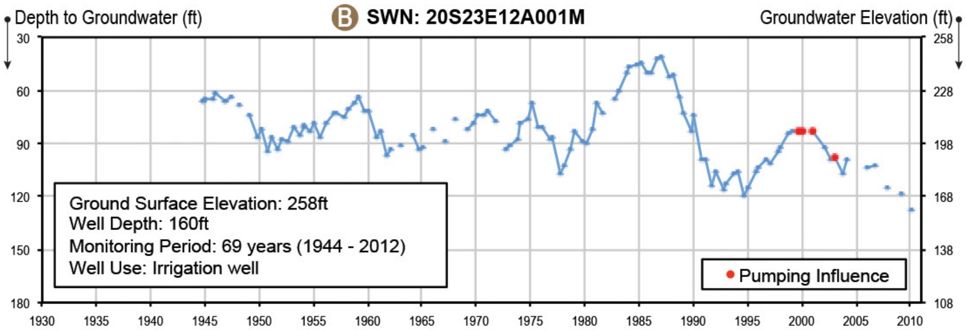


A Hydrograph 15S18E30L001M: shows an imbalance between aquifer recharge and groundwater extraction as a result of unsustainable reliance on the local groundwater resources.



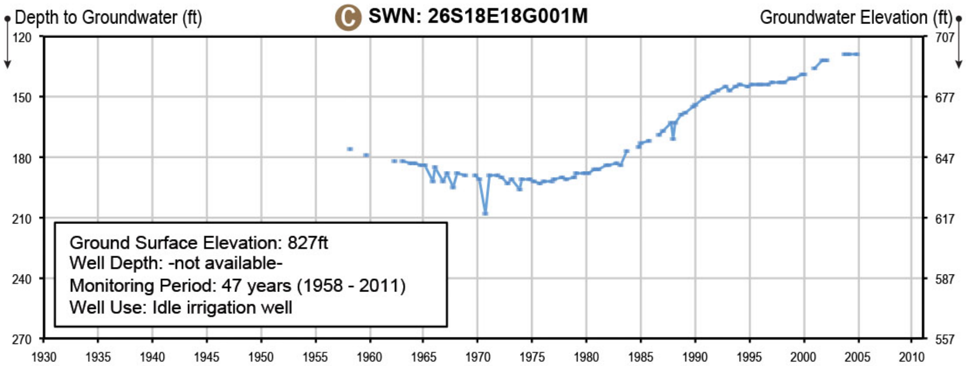
Ground Surface Elevation: 194ft
Well Depth: 282ft
Monitoring Period: 90 years (1921 - 2010)
Well Use: Idle unidentified well

Figure 9-14 Groundwater Hydrographs for the Tulare Lake Hydrologic Region, Page 2



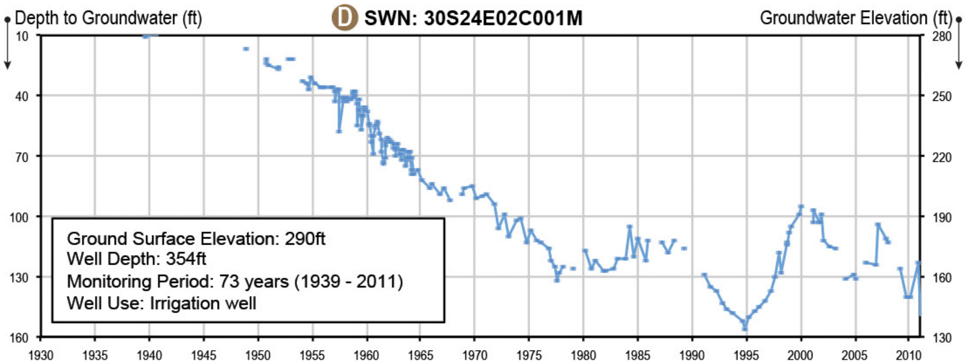
Ground Surface Elevation: 258ft
Well Depth: 160ft
Monitoring Period: 69 years (1944 - 2012)
Well Use: Irrigation well

B Hydrograph 20S23E12A001M: illustrates the local aquifer response to changes in aquifer recharge and groundwater extraction, due to changes in precipitation and surface water supply deliveries.

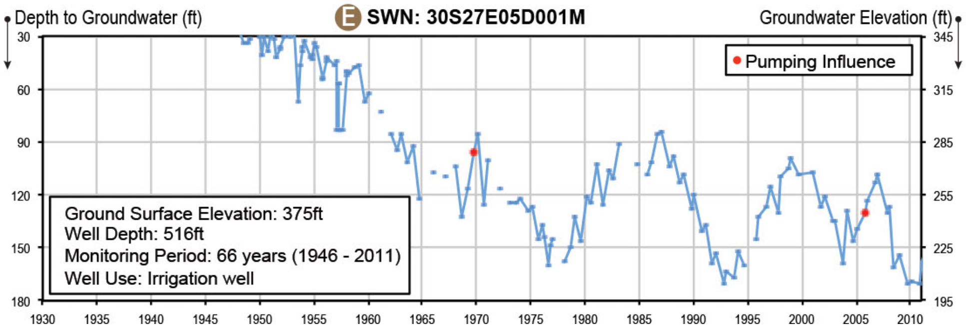


Ground Surface Elevation: 827ft
Well Depth: -not available-
Monitoring Period: 47 years (1958 - 2011)
Well Use: Idle irrigation well

C Hydrograph 26S18E18G001M: highlights recovering groundwater levels associated with the introduction of imported surface water from the California Aqueduct, which resulted in decreasing groundwater demand and facilitating in-lieu groundwater recharge.



Ground Surface Elevation: 290ft
Well Depth: 354ft
Monitoring Period: 73 years (1939 - 2011)
Well Use: Irrigation well



Ground Surface Elevation: 375ft
Well Depth: 516ft
Monitoring Period: 66 years (1946 - 2011)
Well Use: Irrigation well

D, E Hydrographs 30S24E02C001M and 30S27E05D001M: illustrate the successful stabilization of sharply declining groundwater levels through conjunctive management of surface water and groundwater supplies.

served by the Tulare Irrigation District (TID). Groundwater-level measurements were first recorded in 1944 and were measured on approximately a semi-annual basis through 2007. No measurements were recorded in 2008 and only spring monitoring was conducted in 2009 and 2010.

TID receives surface water supplies from the CVP via the Friant-Kern Canal. Historically, surface water deliveries have provided about half of TID's total water supply, with the remaining half provided by groundwater extraction (Tulare Irrigation District personal communication). Local aquifers are recharged predominantly through precipitation, canal seepage, and infiltration from applied irrigation water. During the 2008-2009 drought, groundwater extraction for the Kaweah Delta PA averaged about 2.1 million acre-feet. The 2005 to 2010 average groundwater extraction for this area is about 1.7 million acre-feet.

The hydrograph for well 20S23E12A001M shows several patterns of increasing and decreasing groundwater levels in response to periods of above normal (early to mid-1980s and late 1990s) and below normal (1976-77 and 1987-1994) precipitation. More recent declines in groundwater levels are attributed to increased groundwater demand because of surface water supply cutbacks. Starting about 2007, the surface water supply from the CVP was reduced by 15 to 20 percent because of the San Joaquin River water rights court settlement (Tulare Irrigation District personal communication). During this time, the percentage of total water supply met by groundwater for the Kaweah Delta PA increased from about 36 percent in 2005, to about 82 percent in 2007. The total water supply met by groundwater remained at approximately 75 percent during 2008 and 2009, prior to declining to about 50 percent in

2010. The hydrograph in Figure 9-14b indicates that recent increases in groundwater pumping appears to have tipped the groundwater budget toward net aquifer depletion rather than recharge, resulting in rapidly declining groundwater levels between 2007 and 2009.

Hydrograph 26S18E18G001M

Figure 9-14c is a hydrograph for well 26S18E18G001M which is located along the western edge of the Kern County Groundwater Subbasin and the Semitropic-Buena Vista PA. The hydrograph for this well illustrates the positive effects of in-lieu recharge associated with increases in imported surface water supply and reduced groundwater demand. Well 26S18E18G001M is an inactive agricultural irrigation well screened in the unconfined to semi-confined portion of the aquifer, which consists of eroding marine sediments from the surrounding mountains. Land use surrounding the well is characterized by permanent agricultural crops (orchards) and annual row crops. Groundwater-level measurements were first recorded in 1958 and have been measured on a semi-annual basis through 2004. No measurements have been recorded since 2004.

Groundwater recharge in this area is derived from streams flowing through the upland marine sediments and infiltrating poor quality water into the underlying aquifer. Prior to receiving imported surface water from the California Aqueduct, some farms in the area used groundwater to meet agricultural demand, despite the poor quality. Construction of the California Aqueduct has increased the quality and water supply reliability of water applied for agricultural uses. The hydrograph in Figure 9-14c shows that in-lieu recharge associated with imported surface water supply and reduced groundwater demand has resulted in about 65 feet of groundwater-level recovery since the mid-1970s.

Hydrograph 30S24E02C001M

Figure 9-14d is a hydrograph for well 30S24E02C001M located near the base of the Elk Hills approximately 12 miles west of Bakersfield in the Kern County Groundwater Subbasin and the Kern Delta PA. The hydrograph for this well illustrates the successful stabilization of sharply declining groundwater levels through implementation of in-lieu and managed groundwater recharge projects via conjunctive management practices. Well 30S24E02C001M is an irrigation well that is constructed in an unconfined to semi-confined portion of the aquifer, overlying the confined aquifer beneath the Corcoran clay. Land use surrounding the well is a combination of permanent agricultural crops (orchards) and annual row crops. Groundwater-level measurements were first recorded in 1939 and have continued to be monitored on a semi-annual basis.

Post-World War II expansion of agriculture in this portion of the region resulted in increased demand on groundwater and a corresponding steady 120-foot decline of groundwater levels through 1978, regardless of the precipitation or water year type. Construction of the California Aqueduct in the mid-1970’s stabilized groundwater levels as farmers switched from groundwater to lower-cost surface water. Between 1988 and 1994, a combination of lower-than-normal precipitation, increased population growth, and expanding agricultural requirements for water, resulted in renewed groundwater extraction and an additional 25-foot decline in groundwater levels. Since 1995, groundwater levels have been strongly influenced by the construction and operation of several large groundwater banking projects such as the Kern Water Bank, the Pioneer groundwater banking projects, and the Buena Vista Water Storage District. Above normal precipitation and groundwater recharge activities resulted in groundwater levels rebounding almost 30 feet. During the last 10 years, groundwater levels have again declined. Current groundwater management practices are working to help stabilize groundwater levels through implementation of wet year groundwater banking and dry year pumping.

Hydrograph 30S27E05D001M

Figure 9-14e is a hydrograph for well 30S27E05D001M located in western Bakersfield, in the Kern County Groundwater Subbasin and the Kern Delta PA. Similar to hydrograph for well 30S24E02C001M, well 30S27E05D001M also illustrates the power of conjunctive management as an effective tool for stabilizing declining groundwater levels and improving aquifer sustainability. Well 30S27E02C001M is a municipal supply well for Bakersfield. The well is constructed in an unconfined to semi-confined portion of the aquifer and overlies the confined aquifer beneath the Corcoran clay. Land use surrounding the well is predominantly urban residential. The Kern River is located to the north of the well, and the California State University, Bakersfield, campus is just south of the well. Groundwater-level measurements were first recorded in 1946 and have continued to be monitored on a semi-annual basis.

Post-World War II expansion of agricultural in this portion of the region resulted in increased demand on groundwater and a corresponding, steady, 140-foot decline of groundwater levels through 1978, regardless of the precipitation or water year type. Construction of the California Aqueduct and the Cross Valley Canal in the mid-1970s stabilized groundwater levels as farmers switched from groundwater to lower-cost surface water. During this time, Improvement District

No. 4 was created to more fully utilize the imported surface water and provide a supplemental water supply for Bakersfield. Improvement District No. 4 was designed and developed to conjunctively manage the municipal water supply by using surface water to either replenish the underlying groundwater aquifer, or deliver for municipal water use, and to pump groundwater during years of surface water supply cutbacks. Surface water cutbacks during the 1987 and 1994 droughts, followed by a 1994-1998 El Nino wet weather pattern, provided opportunities to conjunctively manage the municipal water supply. The hydrograph for well 30S27E05D001M shows a 40-foot groundwater-level decline and recovery during this operational period. Surface water supply cutbacks during the 2007-2009 drought resulted in a period of heavy groundwater pumping from the groundwater banks in Kern County, and a subsequent 40-foot decline in groundwater levels. The 2010 groundwater-level data show some recovery as groundwater recharge operations began to replenish the aquifer in this area. Total water demands for this area have remained relatively stable during the last 10 years. During this time, municipal and industrial uses have increased while the agricultural uses have decreased (Improvement District No. 4, 2010).

Change in Groundwater Storage

Change in groundwater in storage is the difference in groundwater volume between two different time periods. Change in groundwater in storage is calculated by multiplying the difference in groundwater elevation between two time periods, by the overlying basin area, and by the average specific yield (or volume of pore space from which water may be extracted).

Evaluating the annual change in groundwater in storage over a series of years helps identify aquifer responses to changes in hydrology, land use, and groundwater management. If the change in groundwater in storage is negligible over a period represented by average hydrologic and land use conditions, the basin is considered to be in equilibrium. Declining groundwater levels and reduction of groundwater in storage during years of average hydrology and land use does not always indicate basin overdraft or unsustainable management — some additional investigation is typically required. Use of groundwater in storage during years of diminishing surface water supply, followed by active recharge of the aquifer when surface water or other alternative supplies become available, is a recognized and acceptable approach to conjunctively managing a groundwater basin. Additional information regarding risk and benefits of conjunctive management in California can be found in *California Water Plan Update 2013*, Volume 3, Chapter 9, “Conjunctive Management and Groundwater Storage.”

Annual and cumulative change of groundwater in storage for the San Joaquin Valley portion of the Tulare Lake region was calculated between 2005 and 2010 using spring groundwater elevation monitoring data, a range of specific yield values for the unconfined aquifer, and a standardized GIS data processing tool. Spring groundwater levels were used because of the tendency toward aquifer stability during the spring months. Beginning the change in storage calculation in 2005, a relatively average water year, allows for better comparison of the annual and cumulative change in storage values in subsequent years.

One key piece of data required to calculate the change in the amount of groundwater in storage is the aquifer specific yield information. Data from two vetted models were assessed for use in the change in groundwater in storage tool; the 2013 DWR California Central Valley Groundwater-Surface Water Simulation Model (C2VSim) and the 2009 USGS Central Valley Hydrologic Model (CVHM). These models have compiled and developed specific yield data for the Central Valley in a format readily useable in GIS. Based on data included in C2VSim and CVHM, minimum and maximum specific yield values of 0.07 and 0.17 were determined to be a good approximation of the range of aquifer storage parameters for the unconfined aquifers in the Central Valley. As with the groundwater elevation contour maps, groundwater basins having insufficient data to annually contour and compare the year-to-year changes in groundwater elevations were identified as “Non-Reporting” areas. Change in groundwater in storage was not estimated for these areas.

A standardized GIS tool was developed by DWR to generate annual groundwater elevation contours and subsequent change in storage estimates. The primary goal of the using a standardized GIS tool was to implement a repeatable and transparent process for compiling groundwater elevation data and determining change in storage estimates. The GIS tool is intended to be for basin scale assessment of change in groundwater in storage and is not intended for local scale project analysis.

Change in groundwater in storage was calculated using groundwater-level data that is publically available online from DWR’s Water Data Library (http://www.water.ca.gov/waterdatalibrary/), and DWR’s CASGEM system (http://www.water.ca.gov/groundwater/casgem/). Additional groundwater-level information for the Tulare Lake region is publically available from the USGS National Water Information System (http://waterdata.usgs.gov/nwis/gw), and some groundwater management groups in the region.

Change in groundwater in storage estimates using groundwater-level data is also being developed by various groundwater management groups in the region. Change in groundwater in storage estimates have also been estimated for the Tulare Lake region using regional and local-scale groundwater modeling. A detailed comparison of the various methods and sources of change in groundwater in storage estimates is beyond the scope of this report. Additional information regarding the methods and assumptions for calculating change in groundwater in storage is provided in Appendix E.

Spring 2005 to Spring 2010 Change in Groundwater in Storage

Figure 9-15 is a spring 2005 to spring 2010 change in groundwater elevation contour map for the southern San Joaquin Valley portion of the Tulare Lake region. The colored contours in Figure 9-15 represent lines of equal change in groundwater elevation between spring 2005 and spring 2010. Figure 9-15 shows an overall decline in groundwater levels for much of the region. Groundwater levels show the least amount of decline along the east side of valley and the northern Kings Subbasin. Isolated locations showing 40- to 50-foot increases in 2005-2010 groundwater levels largely correspond to nearby recharge basins within the Kaweah and Tule groundwater subbasin areas. The largest decline in groundwater levels is along the axis of the valley, in the western Kings, Kaweah, and Tule groundwater subbasins, and in the Kern County Groundwater Subbasin. The maximum decline in 2005-2010 groundwater levels in these areas ranges from 40 to 90 feet. Although contours do not extend into the Westside Groundwater

Table 9-12 Annual Change in Groundwater in Storage for the San Joaquin Valley Portion of the Tulare Lake Hydrologic Region (Spring 2005-Spring 2010)

Period Spring - Spring	Average Change in Groundwater Elevation (feet)	Estimated Change in Groundwater in Storage (taf)	
		Assuming Specific Yield = 0.07	Assuming Specific Yield = 0.17
2005-2006	7.0	1,457	3,539
2006-2007	1.1	237	576
2007-2008	-15.4	-3,213	-7,802
2008-2009	-7.7	-1,600	-3,886
2009-2010	-2.5	-517	-1,256
2005-2010 (total)	**-17.4**	**-3,636**	**-8,829**
Reporting Area:	**2,981,955 acres**		
Non-Reporting Area:	**2,018,490 acres**		

Notes:
taf = thousand acre feet
Groundwater elevation and change in storage estimates are calculated within reporting area only.

Subbasin, the pattern and degree of 2005-2010 groundwater-level change in adjacent basins indicates that groundwater levels in the Westside Groundwater Subbasin have likely declined by similar amounts.

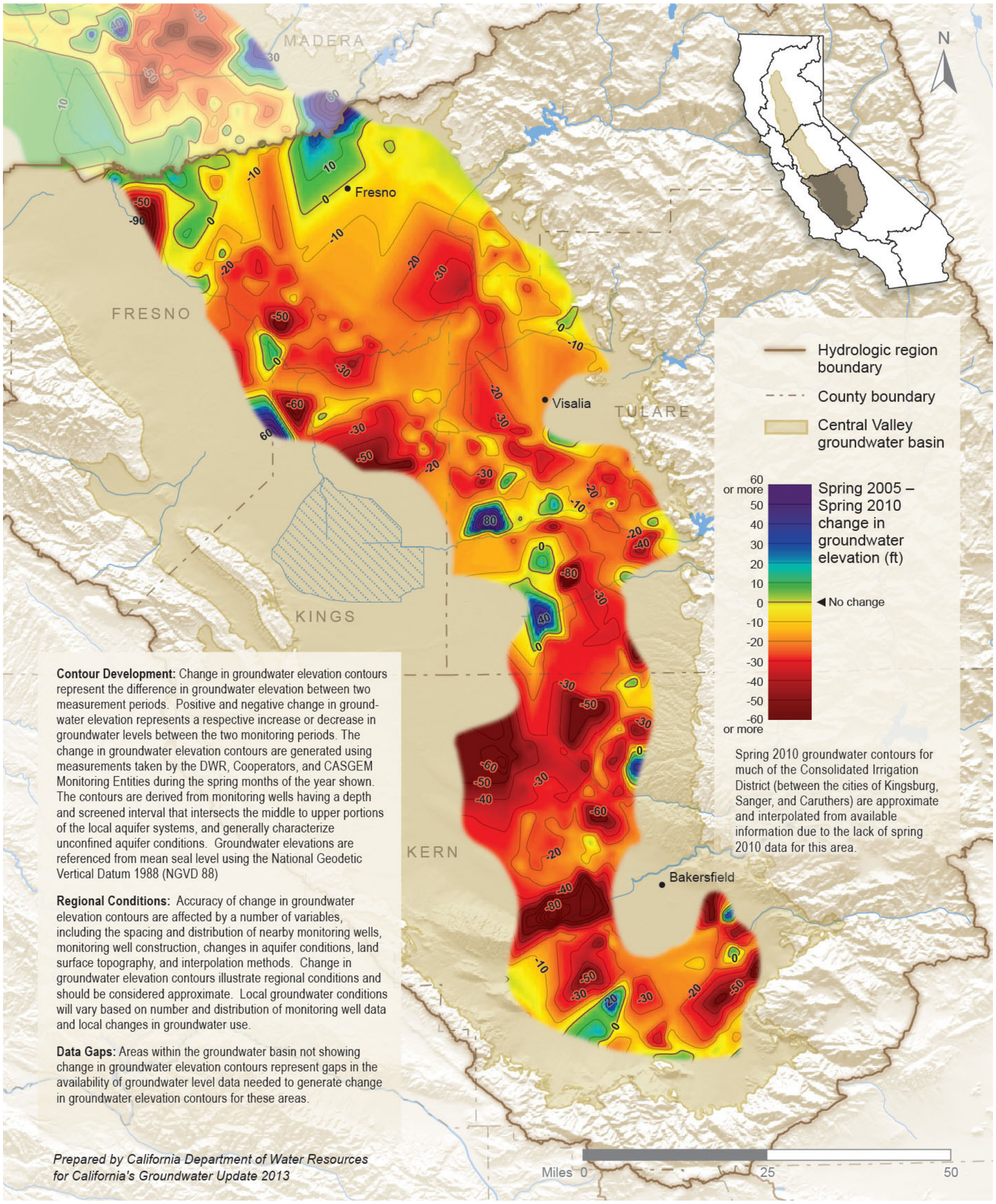
Table 9-12 lists the average annual change in groundwater elevation and the estimated range of groundwater in storage change, based on the minimum (0.07) and maximum (0.17) estimates of specific yield values. Table 9-12 also shows the reporting and non-reporting areas used to calculate the change in groundwater in storage for the Tulare Lake region. Figure 9-16 is a bar chart depicting the annual and cumulative (2005-2010) change in groundwater in storage associated with the average change in groundwater levels listed in Table 9-12 and illustrated in Figure 9-15. The bottom of Figure 9-16 shows the generalized water year type (wet, normal, below normal, dry, and critically dry) for the region. Tables and figures similar to Table 9-12 and Figure 9-16 have been developed for several groundwater subbasins in the Tulare Lake region and are provided in Appendix E.

Table 9-12 and Figure 9-16 show that the average annual change in groundwater elevation and related change in groundwater in storage generally corresponds with the annual precipitation or water year type (wet, normal, below normal, dry, and critically dry). The 2005-2006 period is identified as a wet year, while the subsequent four years are characterized as dry, critically dry, dry, and below normal. Table 9-12 shows an increase in groundwater levels for the 2005-2006 and 2006-2007 periods, followed by a large decline in groundwater levels for the 2007-2008 period, and a lesser decline for the 2008-2009 and 2009-2010 periods. The spring 2005-spring 2010 cumulative region-wide average groundwater-level decline is estimated at 17.4 feet.

Figure 9-16 shows that the annual variability in change in groundwater in storage for the region is significant. The single-year maximum increase in groundwater in storage occurred during the 2005-2006 period and ranged between 1,457 taf and 3,539 taf. The maximum single-year decline in groundwater in storage occurred during the 2007-2008 period and ranged between 3,213 taf and 7,802 taf. The 2007-2008 reduction of groundwater in aquifer storage is estimated to be 50 to 122 percent of the 2005-2010 average annual groundwater extraction for the region (Table 9-5). The cumulative decline in groundwater in storage during the 2005-2010 time period is estimated between 3,635 taf and 8,829 taf. These numbers represent 57 percent to 140 percent of the Tulare Lake region's 2005-2010 average annual groundwater extraction and 22 percent to 54 percent of the average groundwater extraction for the entire state. The large annual variation in estimated change in groundwater in storage points to the high reliance on groundwater and the active conjunctive management practices that occur in this region.

Change in groundwater levels, and associated changes in groundwater in storage, are also estimated by the Kings River Conservation District (KRCD) for the Kings River service area. The Kings River service area closely approximates the Kings Groundwater Subbasin area. The KRCD 2009-2011 annual groundwater report states that the majority of the basin during the 2003-2011 time period had generalized declines in groundwater elevations of as much as 20 feet, with limited areas of recovery in the southwest corner of the Kings Groundwater Subbasin (Kings River Conservation District 2012). The decrease in groundwater in storage during the 2003-2011 time period was estimated by KCRD to be 1,200 taf (Kings River Conservation District 2012). The 2005-2010 change in groundwater in storage for the Kings Groundwater Subbasin conducted as part of this report was estimated between 720 taf and 1,700 taf. Although the time period and areas are slightly different, there appears to be a general agreement between the two estimates of change in groundwater in storage.

Figure 9-15 Change in Groundwater Elevation Contour Map for the San Joaquin Valley Portion of the Tulare Lake Hydrologic Region (Spring 2005-Spring 2010)



Contour Development: Change in groundwater elevation contours represent the difference in groundwater elevation between two measurement periods. Positive and negative change in groundwater elevation represents a respective increase or decrease in groundwater levels between the two monitoring periods. The change in groundwater elevation contours are generated using measurements taken by the DWR, Cooperators, and CASGEM Monitoring Entities during the spring months of the year shown. The contours are derived from monitoring wells having a depth and screened interval that intersects the middle to upper portions of the local aquifer systems, and generally characterize unconfined aquifer conditions. Groundwater elevations are referenced from mean seal level using the National Geodetic Vertical Datum 1988 (NGVD 88)

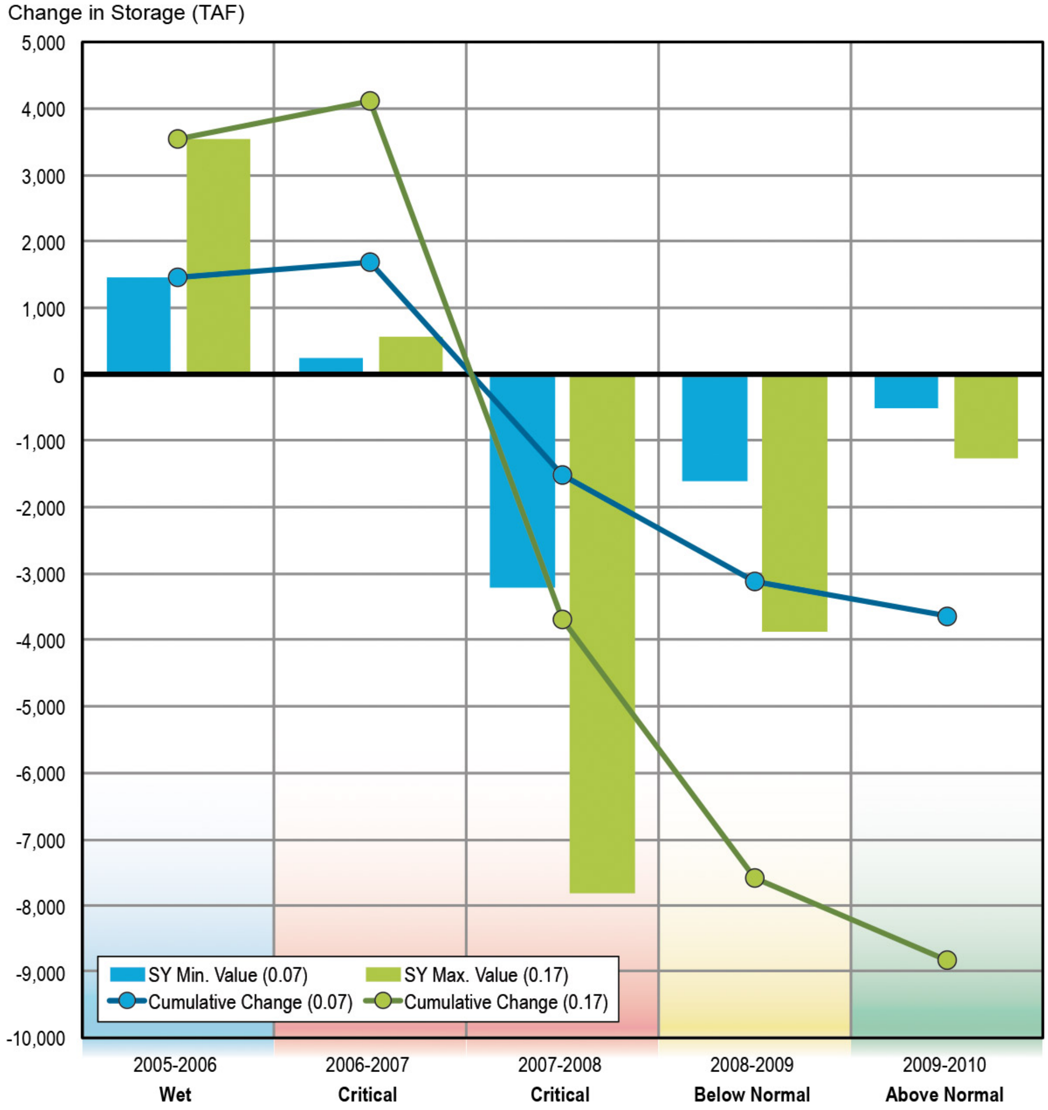
Regional Conditions: Accuracy of change in groundwater elevation contours are affected by a number of variables, including the spacing and distribution of nearby monitoring wells, monitoring well construction, changes in aquifer conditions, land surface topography, and interpolation methods. Change in groundwater elevation contours illustrate regional conditions and should be considered approximate. Local groundwater conditions will vary based on number and distribution of monitoring well data and local changes in groundwater use.

Data Gaps: Areas within the groundwater basin not showing change in groundwater elevation contours represent gaps in the availability of groundwater level data needed to generate change in groundwater elevation contours for these areas.

Spring 2010 groundwater contours for much of the Consolidated Irrigation District (between the cities of Kingsburg, Sanger, and Caruthers) are approximate and interpolated from available information due to the lack of spring 2010 data for this area.

Prepared by California Department of Water Resources for California's Groundwater Update 2013

Figure 9-16 **Annual Change in Groundwater in Storage for the San Joaquin Valley Portion of the Tulare Lake Hydrologic Region (Spring 2005-Spring 2010)**



Note: TAF = thousand acre feet

Groundwater Quality

In general, groundwater quality throughout the Tulare Lake region is suitable for most urban and agricultural uses. Groundwater quality in shallower aquifers generally contains higher concentrations of anthropogenic contaminants, such as nitrates and pesticides. The shallower part of the aquifer is generally younger water, indicating that it is recently recharged water. Shallower wells, such as private domestic supply wells, may provide better indication of pollutants from current land use activities. Pollutants from current land use activities may eventually impact deeper wells such as public supply wells (Burow 2008). The following chemical contaminants affect groundwater use in the Tulare Lake, and at times require treatment.

- TDS or salinity.
- Arsenic.
- Nitrate.
- Organic compounds.

The areas of high TDS content are primarily along the west side of the San Joaquin Valley and along the trough of the valley. High TDS content of west side water is caused by recharge of stream flow originating from marine sediments in the Coast Range. High TDS content along the valley axis is the result of concentration of salts caused by evaporation and poor drainage. In the central and west side portions of the valley, where the Corcoran clay confining layer exists, water quality is generally better beneath the clay than above it.

The degradation of groundwater quality in the Tulare Lake region by salts is unavoidable without a plan for removing salts from the basin. Some of the salt load is primarily the result of natural processes within the basin, but some occurs because of water imported from other basins to supply agricultural irrigation water. Natural processes include salt loads leached from the soils by precipitation, valley floor runoff, and native surface waters. Other sources of salts include imported water, soil leached by irrigation, animal and human wastes, fertilizers and other soil amendments, municipal use, industrial wastewaters, and oil field wastewaters. These salt sources all contribute to increases in salinity and should be managed to the extent practicable to reduce the rate of groundwater quality degradation (Central Valley Regional Water Quality Control Board 2004).

High levels of arsenic occur locally and appear to be associated with lakebed areas. Elevated arsenic levels have been reported in the Tulare Lake, Kern Lake and Buena Vista lake bed areas. The highest nitrate concentrations are in the alluvial fan areas of the eastern Tulare Lake region. On a regional scale, nitrate contamination is primarily the result of agricultural fertilizers and animal waste applied to cropland, as reported in a 2012 University of California, Davis study (Harter et al. 2012). The study concluded that nitrate problems will likely worsen in the coming decades. Organic contaminants can be broken into two categories, agricultural and industrial. Agricultural pesticides and herbicides have been detected throughout the valley, but primarily along the east side where soil permeability is higher and depth to groundwater is shallower. The most notable agricultural contaminant is 1,2-dibromo-3-chloropropane (DBCP), a now-banned soil fumigant and known carcinogen once used extensively on grapes. Industrial organic contaminants include tetrachloroethylene (PCE), trichloroethylene (TCE), dichloroethylene (DCE), and other solvents. They are found in groundwater near airports, industrial areas, and landfills.

Several State and federal GAMA-related groundwater quality reports that help assess and outline the groundwater quality conditions for the Tulare Lake region are listed in Table 9-13.

Groundwater Quality at Community Drinking Water Wells

The SWRCB recently completed a report to the Legislature, *Communities that Rely on a Contaminated Groundwater Source for Drinking Water*. The report focused on chemical contaminants found in active groundwater wells used by CWSs. A CWS is defined under the California Health and Safety Code (Section 116275) as a “public water system that serves at least 15 service connections used by yearlong residents or regularly serves at least 25 yearlong residents of the area served by the system.” CWSs serve the same group of people, year round, from the same group of water sources. The findings of this report reflect the raw, untreated groundwater quality and do not necessarily reflect the final quality of groundwater delivered to these communities.

In the Tulare Lake region, there are an estimated 354 CWSs, with an estimated 1,229 active CWS wells. Table 9-14 shows that 329 of the 1,229 CWS wells (27 percent) are identified as being affected by one or more chemical contaminants that exceed an MCL. The affected wells are used by 146 CWSs in the region, with 110 of the 146 affected CWSs serving small communities which commonly require financial assistance to construct water treatment facilities or alternative solutions to meet drinking water standards (Table 9-15). The most prevalent groundwater contaminants affecting community drinking water wells in the region include arsenic, nitrate, gross alpha particle activity, uranium, and DBCP (Table 9-16). In addition, a total of 73 regional wells are affected by multiple contaminants.

While most large CWSs are able to construct, operate, and maintain a water treatment system to remove or reduce groundwater contaminants below drinking water standards, small CWSs often cannot afford the high cost to operate and maintain a treatment system. For that reason,, some are unable to provide drinking water that meets primary drinking water standards. As of February 2013, there were 59 small CWSs in the Tulare Lake region that violated a primary drinking water standard primarily because of groundwater contaminants. Twenty-nine of these small CWSs are affected by nitrate and 24 are affected by arsenic (California Department of Public Health 2013).

Chromium-VI is another groundwater contaminant that is expected to affect many community water systems when a state MCL is adopted by CDPH. In 2011, the State Office of Environmental Health Hazard Assessment set a public health goal for chromium-VI at 0.02 ppb. Chromium-VI is found to occur naturally in the environment at low levels, and there are also areas of contamination in the state resulting from historic industrial use such as manufacturing of textile dyes, wood preservation, leather tanning, and anti-corrosion coatings (California Department of Public Health 2012). The SWRCB’s *Communities that Rely on a Contaminated Groundwater Source for Drinking Water* report indicated that 1,378 of the 2,803 active community water system wells had two or more detections for chromium-VI above 1 ppb. When the chromium-VI MCL is implemented, it is expected to affect many California water systems. Additional information on chromium-VI from the SWRCB and CDPH is available on Table 9-10.

Table 9-13 GAMA Groundwater Quality Reports for the Tulare Lake Hydrologic Region

Data Summary Reports

- Southeast San Joaquin Valley
  http://www.waterboards.ca.gov/gama/docs/se_sanjoaquin_dsr351.pdf
- Western San Joaquin Valley
  http://pubs.usgs.gov/ds/706/_
- Kern County
  http://pubs.usgs.gov/ds/337/_
- Sierra Regional
  http://www.waterboards.ca.gov/gama/docs/dsr_sierra_regional.pdf_
- Southern Sierra
  http://www.waterboards.ca.gov/gama/docs/southsierra_data_summary.pdf

Assessment Reports

- Status and Understanding of Groundwater Quality in the Tahoe-Martis, Central Sierra, and Southern Sierra Study Units, 2006-2007, California GAMA
  http://pubs.usgs.gov/sir/2011/5216/

Fact Sheets

- Groundwater Quality in the Kern County Subbasin
  http://pubs.usgs.gov/fs/2011/3150/_
- Groundwater Quality in the Southeast San Joaquin Valley
  http://pubs.usgs.gov/fs/2011/3151/_
- Groundwater Quality in the Southern Sierra Nevada
  http://pubs.usgs.gov/fs/2012/3011/

Domestic Well Project

- Tulare County Focus Area
  http://www.waterboards.ca.gov/gama/domestic_well.shtml#tularecfa

Other Relevant Reports

- Nitrate in Groundwater: Pilot Projects in Tulare Lake Basin/Salinas Valley
  http://www.waterboards.ca.gov/water_issues/programs/nitrate_project/index.shtml_
- Communities that Rely on a Contaminated Groundwater Source for Drinking Water
  http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/index.shtml

Note:
GAMA = Groundwater Ambient Monitoring and Assessment Program

Table 9-14 Community Drinking Water Wells that Exceed a Primary Maximum Contaminant Level Prior to Treatment in the Tulare Lake Hydrologic Region

Well Information	Community Water System[a] Wells
Number of Affected Wells[b]	329
Total Wells in the Region	1,229
Percentage of Affected Wells[b]	27%

Source: State Water Resources Control Board's report to the Legislature, *Communities that Rely on a Contaminated Groundwater Source for Drinking Water* (2013).

Notes:

[a] Community water system is a public water system that serves at least 15 service connections used by year-long residents or regularly serves at least 25 year-long residents of the areas served by the system (Health and Safety Code Section 116275).

[b] Affected wells exceeded a primary maximum contaminant level prior to treatment at least twice from 2002 to 2010. Gross alpha levels were used as a screening assessment only and did not consider uranium correction.

Table 9-15 Community Drinking Water Systems that Rely on Contaminated Groundwater Wells in the Tulare Lake Hydrologic Region

System Information	Community Water Systems[a]		
	Number of Affected Water Systems[b]	Total Water Systems in the Region	Percentage of Affected Water Systems[b]
Small Systems Population ≤ 3,300	110	297	37%
Medium Systems Population 3,301 –	12	22	55%
Large Systems Population > 10,000	24	35	69%
Total	**146**	**354**	**41%**

Source: State Water Resources Control Board's report to the Legislature, *Communities that Rely on a Contaminated Groundwater Source for Drinking Water* (2013).

Notes:

[a] Community water system is a public water system that serves at least 15 service connections used by year-long residents or regularly serves at least 25 year-long residents of the areas served by the system (Health and Safety Code Section 116275).

[b] Affected water systems are those with one or more wells that exceed a primary maximum contaminant level prior to treatment at least twice from 2002 to 2010. Gross alpha levels were used as a screening assessment only and did not consider uranium correction.

State small water systems are not included in the above totals. These systems serve between 5 to 14 service connections and do not regularly serve water to more than 25 people. In general, state small water systems are regulated by local county environmental health departments.

Table 9-16 Contaminants Affecting Community Drinking Water Systems[a] in the Tulare Lake Hydrologic Region

Principal Contaminant (PC)	Number of Affected Water Systems[b] (PC exceeds the Primary MCL)	Number of Affected Wells[c,d,e,f] (PC exceeds the Primary MCL)
Arsenic	62	131
Nitrate	54	75
Gross alpha particle activity	46	78
Uranium	21	29
1,2-Dibromo-3-chloropropane (DBCP)	17	61
Fluoride	7	15
Tetrachloroethylene (PCE)	7	10
Perchlorate	4	4
Trichloroethylene (TCE)	2	7
Ethylene dibromide (EDB)	2	4
Benzene	2	3
Aluminum	1	2
Antimony	1	1
cis-1,2-Dichloroethylene	1	1

Source: State Water Resource Control Board's report to the Legislature*, Communities that Rely on a Contaminated Groundwater Source for Drinking Water* (2013).

Notes:

MCL = maximum contaminant level

[a] Community water system is a public water system that serves at least 15 service connections used by year-long residents or regularly serves at least 25 year-long residents of the areas served by the system (Health and Safety Code Section 116275).

[b] Affected wells exceeded a primary maximum contaminant level prior to treatment at least twice from 2002 to 2010. Gross alpha levels were used as a screening assessment only and did not consider uranium correction.

[c] Affected water systems are those with one or more wells that exceed a primary maximum contaminant level prior to treatment at least twice from 2002 to 2010. Gross alpha levels were used as a screening assessment only and did not consider uranium correction.

[d] Fifty-six wells are affected by two contaminants.

[e] Fifteen wells are affected by three contaminants.

[f] Two wells are affected by four contaminants.

Groundwater Quality — GAMA Priority Basin Project

The GAMA Priority Basin Project was initiated to provide a comprehensive baseline of groundwater quality in the state and to assess deeper groundwater basins that account for more than 95 percent of all groundwater used for public drinking water supply. The GAMA Priority Basin Project has defined 35 groundwater basin groups, called study groups, in California. The project is being implemented by the SWRCB, the USGS, and the Lawrence Livermore National Laboratory.

The GAMA Priority Basin Project tests for constituents that are a concern in public supply wells. The list of constituents includes:

- Field parameters.
- Organic constituents.
- Pesticides.

- Constituents of special interest.
- Inorganic constituents.
- Radioactive constituents.
- Microbial constituents.

For the Tulare Lake region, the USGS has completed data summary reports for the following study units:

- Southeast San Joaquin Valley.
- Western San Joaquin Valley.
- Kern County.
- Sierra Nevada.
- Southern Sierra Nevada.
- South Coast Interior Basins.

Three of the six study units reside entirely in the Tulare Lake region (Southeast San Joaquin Valley, Kern County, and Southern Sierra Nevada) and the other three study units cover multiple hydrologic regions. These include the Sierra Nevada Study Unit with wells in the Sacramento River, San Joaquin River, Tulare Lake, and North Lahontan hydrologic regions; the Western San Joaquin Study Unit with wells in the San Joaquin River and Tulare Lake hydrologic regions; and the South Coast Interior Basins Study Unit with wells in the San Francisco Bay, Central Coast, and Tulare Lake hydrologic regions.

For comparison purposes only, groundwater quality results from these data summary reports were compared against the following public drinking water standards established by CDPH and/or the U.S. Environmental Protection Agency. These standards included primary MCLs, secondary maximum contaminant levels (SMCLs), notification levels (NLs), and lifetime health advisory levels (HALs). The summary of untreated-groundwater-quality results for these study units is shown on Table 9-17. In addition to these data summary reports, USGS has completed some assessment reports and fact sheets for the Tulare Lake region. These are reports are listed in Table 9-13.

Table 9-17 Groundwater Quality Results from GAMA Data Summary Reports and Tulare County Domestic Well Project

State Well Number Health Based Threshold		Number of Detections Greater Than Health Based Threshold						
		Southeast San Joaquin Valley (99 Wells)	Western San Joaquin Valley (13 Wells)	Kern County (50 Wells)	Sierra Nevada Study Unit (83 Wells)	Southern Sierra Study Unit (55 Wells)	South Coast Interior Study Unit (8 wells)	Tulare County Domestic Wells (181 wells)
Inorganic								
Arsenic	MCL	6	2	2	5	4	1	2
Beryllium	MCL	-	-	-	-	-	-	1
Boron	NL	2	5	-	2	1	1	1
Chromium (Total)	MCL	-	-	-	-	-	-	2
Fluoride	MCL	-	-	-	1	-	1	-
Nickel	MCL	-	-	-	-	-	-	3
Nitrate	MCL	6	-	2	-	-	-	72
Nitrite	MCL	-	-	-	-	-	-	4
Selenium	MCL	-	-	-	1	-	-	-
Thallium	MCL	-	-	-	-	-	-	6
Uranium	MCL	2	-	-	2	-	-	-
Vanadium	NL	1	-	1	-	-	-	14
Organic								
VOCs	MCL	1	3	-	-	-	-	-
Pesticides	MCL	-	-	-	-	-	-	-
Pesticides	MCL	8	-	1	-	-	-	8
Constituents of Special Interest								
Perchlorate	MCL	1	-	-	-	-	-	2
1,2,3 TCP	NL	-	-	-	-	-	-	-
NDMA	NL	-	-	-	-	1	-	1
Radioactive Constituents								
Gross Alpha	MCL	5	-	-	4	-	-	3

State Well Number Health Based Threshold		Number of Detections Greater Than Health Based Threshold						
		Southeast San Joaquin Valley (99 Wells)	Western San Joaquin Valley (13 Wells)	Kern County (50 Wells)	Sierra Nevada Study Unit (83 Wells)	Southern Sierra Study Unit (55 Wells)	South Coast Interior Study Unit (8 wells)	Tulare County Domestic Wells (181 wells)
Secondary								
Iron	SMCL	-	-	-	7	2	-	2
Manganese	SMCL	3	5	-	8	3	2	2
Sulfate	SMCL	2	9	2	-	-	1	-
Total Dissolved Solids	SMCL	7	7	3	4	2	6	4

Sources: U.S. Geological Survey reports on groundwater-quality data reports for Southeast San Joaquin Valley, 2006-06; Western San Joaquin Valley, 2010; Kern County Subbasin Study Unit, 2006: Sierra Nevada Study Unit, 2008; Southern Sierra Nevada Study Unit,2006; South Coast Interior Basins Study Unit,2006; and SRCB GAMA – Domestic Well Project, Groundwater Quality Data Report San Diego County Focus Area, 2010.

Notes:

GAMA = Groundwater Ambient Monitoring and Assessment Program ; HAL = lifetime health advisory level (U.S. Environmental Protection Agency); MCL = maximum contaminant level (State and/or federal); NL = notification level (State); SMCL = secondary maximum contaminant level (State); TDS = total dissolved solids; VOC = volatile organic compound

The Low-Use Basin area includes wells sampled in both Colorado River and South Lahontan hydrologic regions.

The Western San Joaquin Valley Study Unit includes wells in the Tulare Lake and San Joaquin River hydrologic regions. Only results from the Westside subbasin which is in the Tulare Lake region are shown.

The Sierra Nevada Study Unit includes wells sampled in the Sacramento River, San Joaquin River, Tulare Lake, and North Lahontan hydrologic regions.

The South Coast Interior Basins Study Unit includes 54 wells in the San Francisco Bay, Central Coast, and Tulare Lake hydrologic regions. Eight wells are in the Tulare Lake region in Cuyama Valley, Castaic Lake Valley, Cuddy Canyon Valley, Cuddy Ranch Area, Cuddy Valley, and Mil Potrero Study Areas (Shown on U.S. Geological Survey report Figure 5. Well ID Nos. CUY 09, 10, CUYU 01 thru 06).

Groundwater Quality at Domestic Wells

Private domestic wells are typically used by either single family homeowners or other groundwater-reliant systems which are not regulated by the State. Domestic wells generally tap shallower groundwater, making them more susceptible to contamination. Many domestic well owners are often unaware of the quality of the well water because the State does not require well owners to test the quality of their water. Although private domestic well water quality is not regulated by the State, it is a concern to local health and planning agencies, and to State agencies in charge of maintaining water quality.

In an effort to assess domestic well water quality, the SWRCB's GAMA Domestic Well Project samples domestic wells for commonly detected chemicals at no cost to well owners who voluntarily participate in the program. Results are shared with the well owners and used by the GAMA Program to evaluate the quality of groundwater used by private well owners. As of 2011, the GAMA Domestic Well Project had sampled 1,146 wells in six county focus areas: Monterey, San Diego, Tulare, Tehama, El Dorado, and Yuba.

The GAMA Domestic Well Project tests for chemicals that are most commonly a concern in domestic well water. These constituents include:

- Bacteria (total and fecal coliform).
- General minerals (sodium, bicarbonate, calcium, others).
- General chemistry parameters (pH, TDS, and others).
- Inorganics (lead, arsenic and other metals) and nutrients (nitrate, others).
- Organics (benzene, toluene, PCE, MTBE, and others).

In addition to these constituents, the GAMA Domestic Well Project may analyze for locally known chemicals of concern. Some of these chemicals include radionuclides, perchlorate, pesticides, and chromium-VI.

In 2006, the GAMA Domestic Well Project sampled 181 private domestic wells in Tulare County. All were located in the Tulare Lake region. Of the 181 sampled private domestic wells, approximately 81 percent were located within a defined DWR groundwater subbasin (Kings, Kaweah, and Tule). Approximately 19 percent of the wells were located in the foothills area outside of DWR-defined groundwater basins. These domestic wells generally tap fractured crystalline rock associated with uplift and emplacement of the Sierra Nevada Mountains. Tulare County was selected for sampling because of the large number of domestic wells located within the county and the availability of well-owner data. Based on a 1999 survey, it is estimated that Tulare County has more than 20,000 private domestic wells. Tulare County ranks eighth in California in terms of domestic well water use, accounting for approximately 3 percent of California's total domestic well water withdrawals (State Water Resources Control Board 2010).

For comparison purposes only, groundwater quality results were compared against public drinking water standards established by CDPH. These standards included primary MCLs, SMCLs, and NLs. The summary of untreated-groundwater-quality results for the 181 private domestic wells in the Tulare Lake region are shown in Table 9-16.

Groundwater Quality Protection

In the Central Valley, a number of efforts are underway to protect groundwater quality. The Central Valley RWQCB has approved a groundwater quality protection strategy and is working on a comprehensive salt and nitrate management plan through the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS), which is a collaborative basin planning effort to address problems with salinity and nitrates in surface water and groundwater. These efforts are further discussed in this section.

Groundwater Quality Protection Strategy

In 2008, the Central Valley RWQCB started a public process to solicit information from stakeholders on groundwater quality protection concerns in the Central Valley, including the Tulare Lake region. In 2010, the Central Valley RWQCB approved the following recommended actions:

- Develop a salt and nutrient management plan.
- Implement a groundwater-quality monitoring program.
- Implement groundwater protection programs through IRWM plan groups.
- Broaden public participation in all programs.
- Coordinate with local agencies to implement well design and destruction program.
- Groundwater database.
    - Alternative dairy waste disposal.
- Develop individual and general orders for poultry, cattle feedlots, and other types of combined animal feeding operations.
- Implementation of a long-term irrigated lands regulatory program.
    - Coordinate with the California Department of Food and Agriculture to identify methods to enhance fertilizer program.
- Reduce site cleanup backlog.
    - Draft waiver following recently adopted regulation based on AB 885.
- Update guidelines for waste disposal for land developments.
    - Develop methods to reduce backlog; increase facilities regulated.

Additional information on Central Valley RWQCB’s Groundwater Quality Protection Strategy is available at:
http://www.waterboards.ca.gov/centralvalley/water_issues/groundwater_quality/index.shtml

Salt and Nutrient Management Plans

The SWRCB’s Recycled Water Policy was adopted in 2009 (Resolution No. 2009-0011) with a goal of managing salt and nutrients from all sources on a basin-wide or watershed-wide basis. This policy requires the development of regional or sub-regional salt and nutrient management plans for every groundwater basin and sub-basin in California. Each plan must include monitoring, source identification, and implementation measures.

Throughout the San Joaquin Valley, and particularly in the Tulare Lake region which is a closed basin, participating in the development of the salt and nitrate management plan is of paramount importance to improve water quality in the region and provide for a sustainable economic and environmental future. The CV-SALTS is a strategic initiative to address problems with salinity and nitrates in surface water and groundwater in the San Joaquin Valley.

The long-term plan developed under CV-SALTS will identify and require implementation of management measures aimed at the reduction and/or control of major sources of salt and nitrate, as well as support activities that alleviate known impairments to drinking water supplies. Since this issue impacts all water users (stakeholders) in the San Joaquin Valley, it is important that all stakeholders participate in CV-SALTS to be part of the development and have input on the implementation of salt and nitrate management within the San Joaquin Valley. For the San Joaquin Valley, the only acceptable process to develop the salt and nutrient management plans required under state policy (State Water Resources Control Board 2009) is through CV-SALTS. Eventually, the management plans will provide guidance on addressing salinity and nitrate concerns to all the Central Valley RWQCB's regulatory and non-regulatory programs.

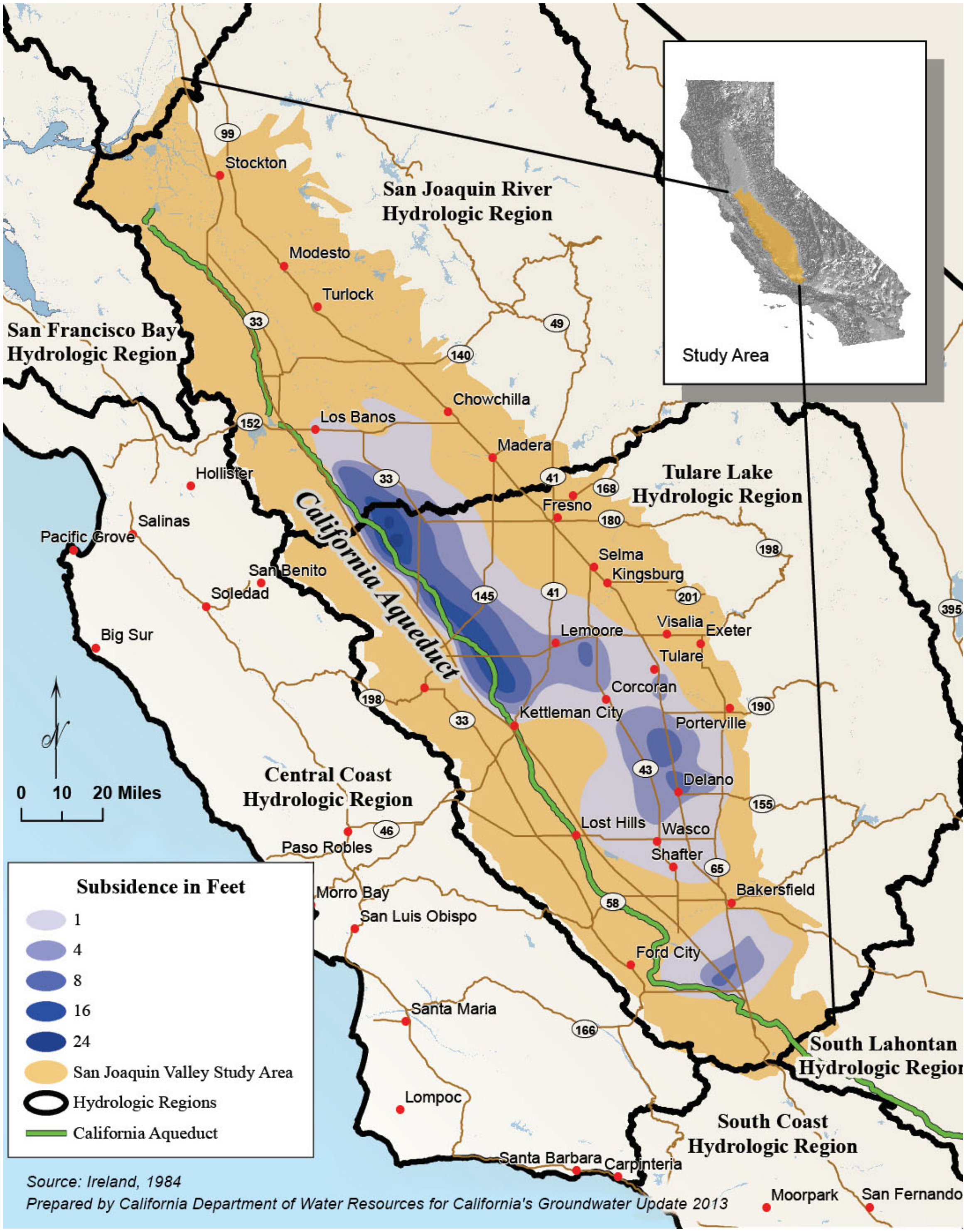
The salt and nitrate management plan will include basin plan amendments that establish regulatory structure and policies to support basin-wide salt and nitrate management. The regulatory structure will have five key elements: (1) refinement of the agricultural supply, municipal and domestic supply, and groundwater recharge beneficial uses; (2) revision of water quality objectives for these uses; (3) establishment of policies for assessing compliance with the beneficial uses and water quality objectives; (4) establishment of management areas where there are large scale differences in baseline water quality, land use, climate conditions, soil characteristics, existing infrastructure, and where short and long term salt and/or nitrate management is needed; and (5) an overarching framework to provide consistency for the development of management plans within the management areas to facilitate implementation efforts and ensure a sustainable future.

CV-SALTS also has a number of pilot projects that affect both surface water and groundwater. Pilot projects that affect groundwater are to demonstrate refinement of beneficial uses in the groundwater in the Tulare Lake Bed and development of a management plan to assist areas with inadequate economic capacity to address high levels of nitrate contamination in drinking water (CV-SALTS 2012a; CV-SALTS 2012b). Additional information on CV-SALTS is available online at: http://cvsalinity.org/ and
http://www.waterboards.ca.gov/centralvalley/water_issues/salinity/index.shtml.

Land Subsidence

Land subsidence was first noted in the San Joaquin Valley in 1935 in the Delano area (Galloway et al. 1999). By the mid-1950s, land subsidence was a widely recognized problem, with the rapid subsidence on the west side of the valley being correlated with the rapid decline of confined aquifer pressure (Riley 1998). In 1955, about one-fourth of the total groundwater extracted for agricultural uses in the United States was pumped from the San Joaquin Valley and regional aquifer compaction was occurring at a rate of about 1 foot per year (Swanson 1995). As of 1960, water levels in the deep aquifer system were declining at a rate of about 10 feet per year (Galloway et al. 1999). In west Fresno County, during the highest pumping years of the 1960s, maximum subsidence exceeded 30 feet and the regional ground surface was sinking at rates of 1 to 1.5 feet per year. By the late 1960s, more than 5,200 square miles of farm land, or half the San Joaquin Valley, had subsided by at least 1 foot (Ireland 1989). Figure 9-17 shows land subsidence within the San Joaquin Valley from 1926 to 1970, with the vast majority of the

Figure 9-17 Land Subsidence in the San Joaquin Valley (1926 to 1970)



Source: Ireland, 1984

Prepared by California Department of Water Resources for California's Groundwater Update 2013

subsidence occurring in the Tulare Lake region and in the southern central portion of the San Joaquin region.

Surface water deliveries from the SWP and other regional conveyance facilities in the 1970s and 1980s significantly reduced the agricultural demand for groundwater. Between 1967 and 1974, groundwater levels in the deep aquifer recovered as much as 200 feet (Galloway et al. 1999). Although reduced groundwater pumping and imported surface water largely diminished the subsidence problem, subsidence still continued in some areas, but at a slower rate, because of the time-lag related to the redistribution of pressures in the confined aquifers.

A combination of drought conditions, regulatory restrictions of imported surface water, increasing population, and agricultural trend toward the planting of more permanent crops has incrementally led to a renewed reliance on groundwater pumping in the Tulare Lake region over the last few decades. In 1995, Swanson conducted a land subsidence update for the San Joaquin Valley and concluded that (1) subsidence is continuing in all subsidence areas but at lower rates than before the completion of the California Aqueduct, (2) subsidence centers have probably shifted to areas where groundwater pumping is concentrated, (3) subsidence rates are expected to increase in the near future as groundwater pumping replaces surface water diverted for environmental uses, and (4) subsidence may contribute to lost channel capacity and flooding in areas where these problems have been previously attributed entirely to other causes.

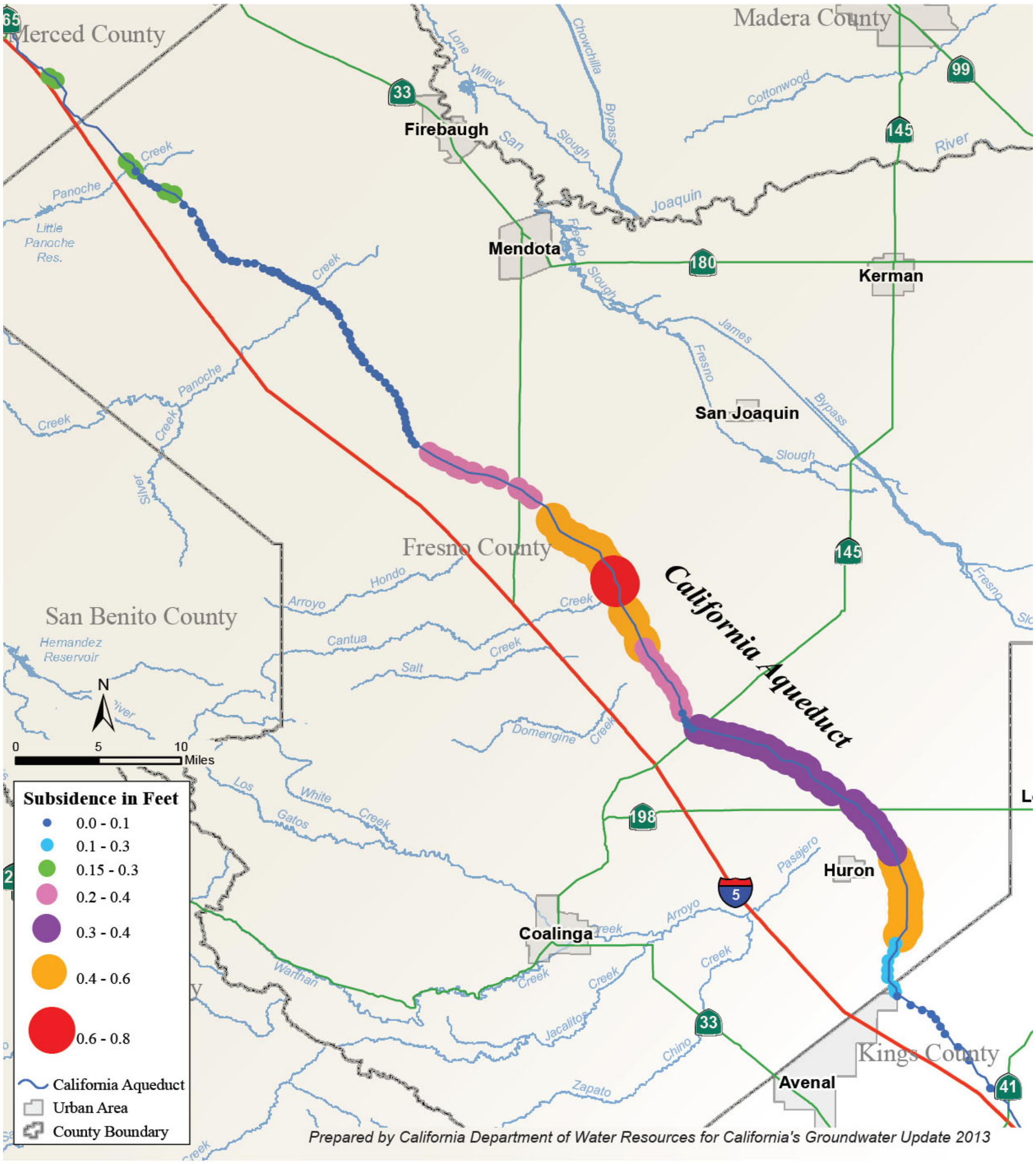
Drought conditions and regulatory restrictions on imported surface water in 2007 through 2009 resulted in a doubling of groundwater pumping to meet agricultural demand, as compared with the 2005-2006 groundwater estimates (Figure 9-8). In the Westlands Water District (WWD) area, the average annual groundwater extraction between 2007 and 2009 was more than nine times the 2005-2006 average (Westlands Water District 2013). To meet the rapidly increasing demand for groundwater supplies during the 2007-2009 period, annual installation of new agricultural wells nearly tripled. As new and existing agricultural wells extracted groundwater to meet increased permanent crop demand, deep aquifer pumping increased, confined aquifer pressures decreased, and groundwater levels in some regional areas reached historic lows. Evidence of land subsidence began to be observed in areas where little or no subsidence had previously been recorded. More recent studies indicate that land subsidence rates of 1 foot per year have returned to San Joaquin Valley basins that are highly reliant on groundwater supplies.

Land subsidence investigations in the southern San Joaquin Valley and Tulare Lake region include various regional and local monitoring efforts (see the “Land Subsidence Monitoring” section). A discussion of the results from some of these land subsidence monitoring activities is provided in this section. Additional efforts to monitor, evaluate, and mitigate land subsidence are being conducted by some groundwater management groups in the region. Reference to a recent statewide study of land subsidence resulting from groundwater pumping is presented in Appendix F.

California Aqueduct Subsidence

DWR performs periodic elevation surveys along the California Aqueduct to measure land subsidence effects along the canal and guide maintenance repairs as needed. DWR surveys compared elevations along portions of the aqueduct in Fresno and Kings counties in 2000, 2006,

Figure 9-18 **Land Subsidence along the California Aqueduct in the Tulare Lake Hydrologic Region**



Prepared by California Department of Water Resources for California's Groundwater Update 2013

and 2009. Figure 9-18 shows subsidence of as much as 0.8 feet from 2000 to 2009 with data showing an accelerated level of subsidence from 2006 to 2009.

Borehole Extensometer Data

There are currently seven active extensometers in the San Joaquin Valley being monitored for groundwater levels and land subsidence (Table 9-11). Extensometer 30S25E16L5 is the only extensometer in the Tulare Lake region being actively monitored by DWR. The extensometer is located in the Kern Water Bank (Figure 9-11) and was installed in 1966. The extensometer site also includes four groundwater-level monitoring wells constructed to monitor various depth intervals within the aquifer system. Groundwater levels in the Kern Water Bank extensometer well cluster show relatively large changes in water levels as the water bank's aquifers are recharged and groundwater is extracted. The aquifer compaction and subsidence monitored by the extensometer show a small elastic response to changes in the water levels. Elastic subsidence is reversible and will typically not develop into inelastic (irreversible) subsidence until groundwater levels drop below the lowest historic level. Additional discussions of the borehole extensometers in the San Joaquin Valley are found in Chapter 8, "San Joaquin River Hydrologic Region."

USGS InSAR Monitoring

InSAR is a remote sensing tool that uses satellite radar signals to measure deformation of the Earth's crust at a high degree of spatial detail and measurement resolution (U.S. Geological Survey 2000). In cooperation with DWR and the USBR, the USGS is currently evaluating 2007 to 2011 InSAR survey data for evidence of subsidence in the San Joaquin and Tulare Lake regions.

Preliminary InSAR survey results show two areas of subsidence. They include an area in western Madera County (just north of the Tulare Lake region), and a broad area in central Tulare Lake region located west of State Route 99 within Kings and Tulare counties. Additional information regarding subsidence in western Madera County is included in Chapter 8, "San Joaquin River Hydrologic Region." Data evaluation from the InSAR survey (January 2007 to March 2011) is being processed and only preliminary subsidence rates have been determined. Comparing the preliminary InSAR survey results with the Caltrans elevation surveys described in the next paragraph show significant and on-going subsidence in the region.

Caltrans State Route 198 Elevation Monitoring

Caltrans periodically resurveys its network of existing benchmarks along key sections of highway. In 2004, Caltrans surveyed a section of State Route 198 in the San Joaquin Valley from the junction of Interstate 5 to Exeter, just east of Visalia. The 2004 cross section shows the level of subsidence that has occurred in this area since the USGS subsidence studies in the 1960s. Figure 9-19 shows the location of the State Route 198 ground surface elevation survey and Figure 9-20 shows the cross section results of the survey.

Figure 9-19 shows that land subsidence at the eastern and western ends of the State Route 198 survey is negligible. However, moving toward the center of the valley between Lemoore and Hanford, a land subsidence trough of nearly 10 feet has developed between the 1960s and 2004. The extent and magnitude of land subsidence north and south of this cross section is unknown. Subsidence in the area is continuing beyond the 2004 date as confirmed by conversations with city officials in Corcoran who confirm that deep wells have been pushed out of the ground by about 2 feet in the last few years. The wells have since been repaired.

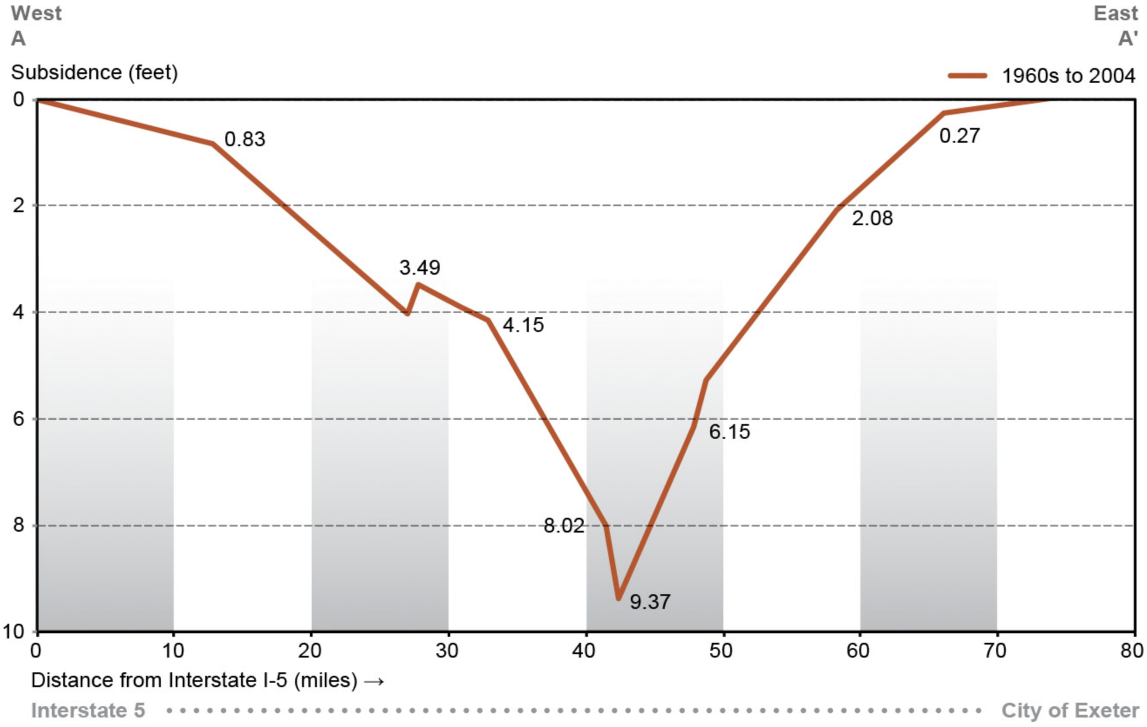
Figure 9-19 Caltrans State Route 198 Groundwater Elevation Survey

California Department of Transportation, 2004

GPS Array Monitoring

UNAVCO operates the Plate Boundary Observatory and uses precision GPS monitoring sites for western United States plate tectonics studies. The UNAVCO GPS stations provide continuous monitoring of the land surface elevation, providing a potential direct measurement of subsidence. Several of the stations are close to the edge of the valley and provide only partial insight into the regional magnitude of subsidence, while others lie outside of areas susceptible to subsidence. However, a number of UNAVCO stations provide important information regarding changes in the land surface for the San Joaquin Valley and the Tulare Lake region. The locations of 13 UNAVCO San Joaquin Valley stations, along with graphical summaries of changes in ground surface elevation, are shown in Figure 9-21. A graph showing nearby depth to water beneath the

Figure 9-20 **Land Subsidence Results of Caltrans State Route 198 Ground Surface Elevation Survey**



Source: California Department of Transportation 2004

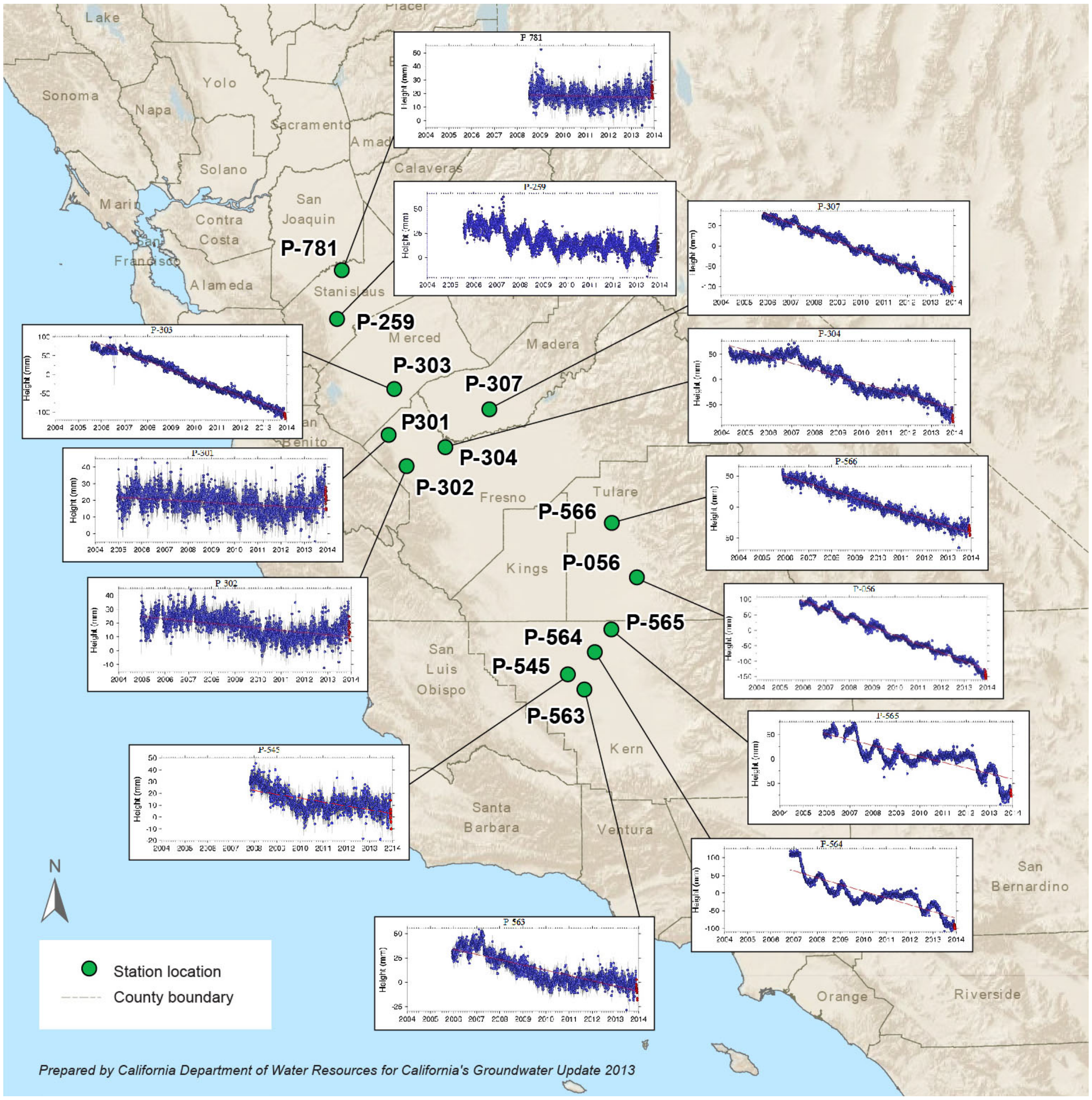
Corcoran clay and the results from UNAVCO GPS Site P304 (near Mendota) are shown in Figure 9-22. Additional information regarding UNAVCO GPS monitoring results is available online at the UNAVCO Web site: http://pbo.unavco.org.

Many of the land surface displacement summary graphs in Figure 9-21 show a significant trend of declining land surface within the San Joaquin Valley portion of the Tulare Lake region. The graph in Figure 9-22 shows the correlation between the post-2007 decline in groundwater levels beneath the Corcoran clay and the decline in land surface elevations near Mendota. Between 2007 and 2010, groundwater levels in the Mendota area have declined by approximately 30 feet, while the vertical displacement in the land surface has declined about 0.2 feet.

Groundwater-Level Monitoring and Subsidence

As shown in Figure 9-22, the rate, extent, and type (elastic versus inelastic) of land subsidence is directly related to the rate and extent of declining groundwater levels. In areas that have undergone historic subsidence, the threat for renewed subsidence is commonly considered to be minimized if current groundwater levels can me maintained above historic lows. The west side of the San Joaquin Valley has historically experienced some largest amounts of land subsidence in California. The WWD lies within this area and has maintained water level records since 1955.

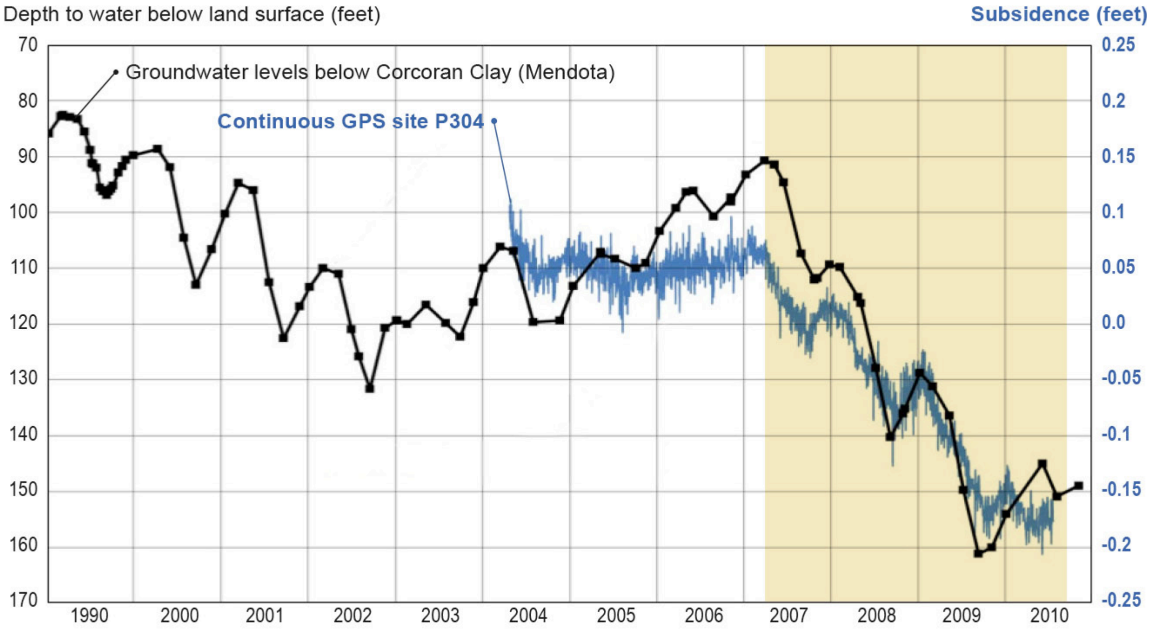
Figure 9-21 **UNAVCO GPS Land Surface Displacement Monitoring Stations and Station Data Summary Graphs**



Prepared by California Department of Water Resources for California's Groundwater Update 2013

Figure 9-23 is a composite hydrograph showing groundwater levels for three wells (16S15E34N001M, 16S15E34N004M, and 16S15E32Q001M) located adjacent to WWD and along an alluvial fan emanating from the Coast Ranges. The hydrograph also shows the historic levels of land subsidence between 1960 and 1995, as recorded from borehole extensometer 16S15E34N001. Figure 9-23 illustrates how imported surface water supplies during the late 1960s and 1970s contributed to the recovery of nearby groundwater levels from their historic low of 600 feet below land surface and the corresponding near elimination of land subsidence by 1975. Figure 9-23 also provides evidence that renewed subsidence can occur even when existing groundwater levels have not reached or exceeded the historic low. The hydrograph shows that during the 1976-1977 drought, a rapid return to groundwater pumping and the associated rapid lowering of groundwater levels by about 150 feet resulted in a fairly rapid response of renewed

Figure 9-22 **Depth to Water and Vertical Land Surface Displacement at UNAVCO GPS Site 304, Near Mendota**



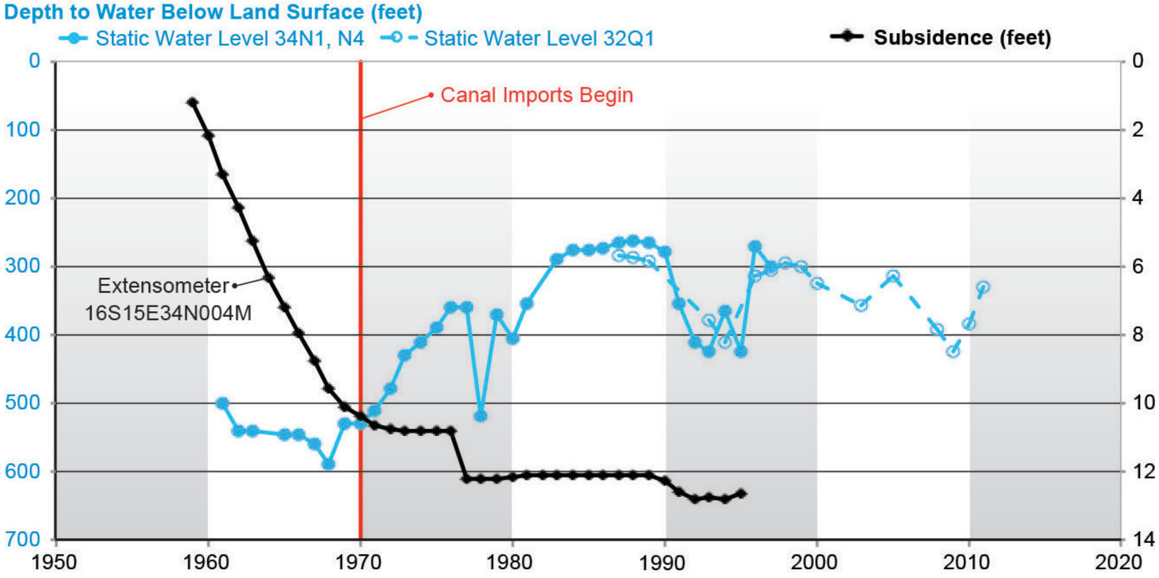
Source: U.S. Geological Survey 2011 presentation on Central Valley subsidence. Land surface elevation data from UNAVCO Station 304; depth to water data provided by Luhdorff and Scalmanini, Consulting Engineers.

subsidence — even though groundwater levels were 80 feet above historic lows. The wet decade of the 1980s showed recovery of groundwater levels and a small inelastic rebound of the land surface elevation. During the drought of the early 1990s, a drop in groundwater levels showed a corresponding renewal of several feet of land subsidence even though groundwater levels were about 180 feet above the historic low. The collection of land subsidence data from the extensometer in this area was discontinued in the mid-1990s.

The hydrograph in Figure 9-23 illustrates that maintaining groundwater levels above historic lows can help reduce the near-term risk for nearby land subsidence. However, maintaining groundwater levels above historic lows does not completely safeguard against subsidence. Rapidly declining groundwater levels and confined aquifer pressures can lead to renewed subsidence even when groundwater levels remain well above historic lows.

Groundwater pumping at rates and volumes that far exceed natural aquifer recharge, or the ability to actively recharge using conjunctive management practices, has resulted in a long-term economic boom for California's agriculture economy and allowed the San Joaquin Valley to become one of the world's most productive agricultural regions. These economic benefits have not gone without a broader cost to the infrastructure affected by land subsidence, to the quantity and quality of groundwater resources, to the increased energy required to pump groundwater, and to the decline in ecosystem services provided by the interaction of groundwater-surface water resources. In water-short regions, implementing effective groundwater management can be extremely challenging. Local water resource managers in the region currently utilize conjunctive management and water conservation measures to help reduce unsustainable demands on the

Figure 9-23 Relationship between Changing Groundwater Levels and Land Subsidence Along the West Side of the San Joaquin Valley Portion of the Tulare Lake Hydrologic Region



16S15E32Q001M
Ground Surface Elevation: 356ft
Well Depth: 2,301ft
Monitoring Period: 40 years (1969 - 2008)
Well Use: Irrigation well

16S15E34N001M, 16S15E34N004M
Ground Surface Elevation: 334ft
Well Depth: 503ft (N1), 2,000ft (N4)
Monitoring Period: 21 years (1962 - 1982)
Well Use: Observation well (N1, N4)
Well Use: Extensometer (N4)

Notes:
Prepared by California Department of Water Resources for California's Groundwater Update 2013.
Composite groundwater-level hydrograph created from data Collected from wells 16S15E34N001M, 16S15E34N004M, and 16S15E32Q001M.

aquifer systems, but in many cases groundwater levels continue to decline and evidence of renewed land subsidence remains. Existing agricultural and urban development should critically evaluate the broader and longer-term costs associated with unsustainable groundwater pumping and take more aggressive actions to adjust water resource management and land use practices to help mitigate the escalation of future impacts. Additional information regarding land subsidence in California is provided in Appendix F.

Groundwater Management

In 1992, the California Legislature provided an opportunity for formal groundwater management with the passage of AB 3030, the Groundwater Management Act (California Water Code Section 10750 et seq.). Groundwater management, as defined in DWR's Bulletin 118-2003, is "the planned and coordinated monitoring, operation, and administration of a groundwater basin, or portion of a basin, with the goal of long-term groundwater resource sustainability." Groundwater management needs are generally identified and addressed at the local level in the form of GWMPs. If disputes over how groundwater should be managed cannot be resolved at the local level, additional actions, such as enactment of ordinances by local entities with jurisdiction over groundwater, passage of laws by the Legislature, or decisions made by the courts (basin adjudications) may be necessary to resolve the conflict. Under current practice, DWR's role in groundwater management is to provide technical and financial assistance to support local agencies in their groundwater management efforts.

Groundwater management in California also occurs through other resource planning efforts. Urban water management plans (UWMPs) incorporate long-term resource planning to meet existing and future water demands. Agriculture water management plans (AWMPs) advance irrigation efficiency that benefits both farms and the environment. IRWM planning is a collaborative effort to regionally identify and align all aspects of water resource management and planning. Given California's reliance on groundwater to meet municipal, agricultural, and environmental needs, developing a thorough understanding of the planning, implementation, and effectiveness of existing groundwater management in California is an important step toward the accurate evaluation and sustainable management of this valuable resource.

DWR's Groundwater Web site (http://www.water.ca.gov/groundwater/) has the most recent information on California's groundwater management planning efforts and includes a summary of the Sustainable Groundwater Management Act that was enacted in September 2014. The Sustainable Groundwater Management Act, a three-bill legislative package, includes the provisions of SB 1168 (Pavley), AB 1739 (Dickinson), and SB 1319 (Pavley), which requires the formation of locally controlled groundwater sustainability agencies in high- and medium-priority groundwater basins with the goal of sustainably managing local groundwater resources. Many of the newly established components in the Sustainable Groundwater Management Act are based on the required, voluntary, and recommended groundwater management components assessed in the following sections.

The following sections provide an inventory and assessment of GWMPs, groundwater basin adjudications, county ordinances, and other groundwater planning activities within the Tulare Lake region.

Groundwater Management Plan Inventory

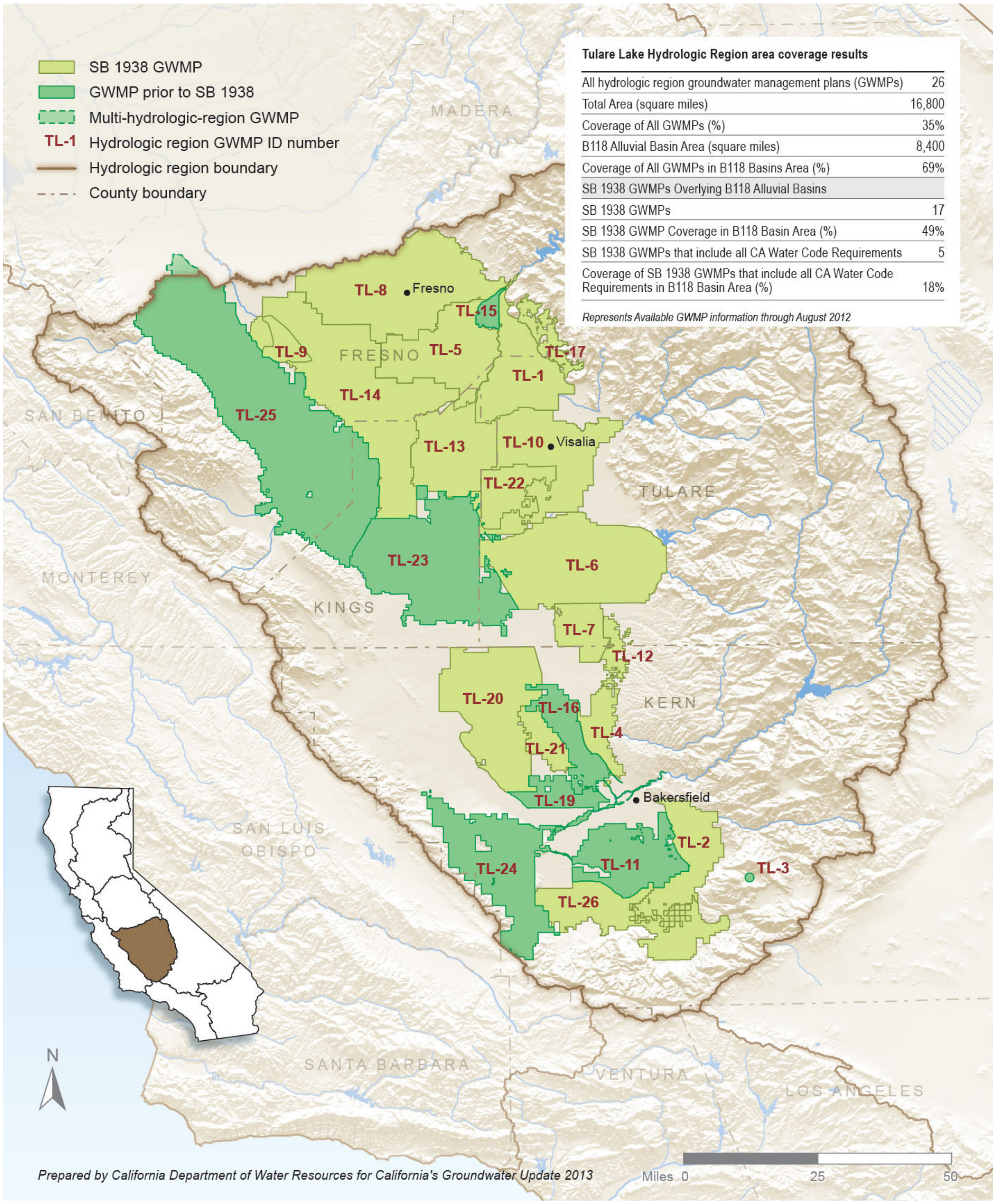
Groundwater management information included in this study is based on GWMP documents that were readily available or submitted to DWR as of August 2012. The inventory of GWMPs identifies adopting and signatory agencies, the date of plan adoption, the location of plans by county, and the groundwater basins the plans cover. The inventory also identifies how many of the GWMPs were developed based on 1992 AB 3030 legislation and how many were developed or updated to meet the additional requirements established by the 2002 SB 1938 legislation.

The Tulare Lake region includes about 8,400 square miles of Bulletin 118-2003 alluvial groundwater basins. Figure 9-24 shows the location and distribution of the GWMPs within the Tulare Lake region and indicates pre- and post-SB 1938 GWMPs. Table 9-18 lists the results of the GWMP inventory for the region with adopting agency, signatories, plan date, and groundwater basin(s). There are 26 GWMPs within the Tulare Lake region. Collectively, the 26 GWMPs cover about 69 percent of the Bulletin 118-2003 alluvial basin area within the region and about 35 percent of the overall regional area.

The inventory and assessment of GWMPs in the Tulare Lake region determined that 17 of the 26 plans have been developed or updated to include the SB 1938 requirements and are considered "active" for the purposes of the GWMP assessment. The 17 active GWMPs cover about 50 percent of the Bulletin 118-2003 alluvial basin area. Detailed review of the GWMPs indicates that five of the 17 active GWMPs address all of the California Water Code requirements for groundwater management. These five GWMPs cover 18 percent of the alluvial basin area in Tulare Lake region.

Eight of the groundwater basins in the Tulare Lake region are identified as high or medium priority based on the CASGEM Basin Prioritization efforts. The eight basins designated as high or medium priority include 98 percent of the annual groundwater use and nearly 98 percent of the 2010 population living within the region's groundwater basin boundaries.

Figure 9-24 Groundwater Management Plans in the Tulare Lake Hydrologic Region



Tulare Lake Hydrologic Region area coverage results

All hydrologic region groundwater management plans (GWMPs)	26
Total Area (square miles)	16,800
Coverage of All GWMPs (%)	35%
B118 Alluvial Basin Area (square miles)	8,400
Coverage of All GWMPs in B118 Basins Area (%)	69%
SB 1938 GWMPs Overlying B118 Alluvial Basins	
SB 1938 GWMPs	17
SB 1938 GWMP Coverage in B118 Basin Area (%)	49%
SB 1938 GWMPs that include all CA Water Code Requirements	5
Coverage of SB 1938 GWMPs that include all CA Water Code Requirements in B118 Basin Area (%)	18%

Represents Available GWMP information through August 2012

Prepared by California Department of Water Resources for California's Groundwater Update 2013

Table 9-18 Groundwater Management Plans in the Tulare Lake Hydrologic Region

Map Label	Agency Name	Date	County	Basin Number	Basin/Subbasin Name
TL-1	**Alta Irrigation District**	2010	Tulare	5-22.08	Kings
	No Signatories on File				
TL-2	**Arvin Edison Water Storage District**	2003	Kern	5-22-08	Kern County
	No Signatories on File				
TL-3	**Bear Valley Community Services District**	1998	Kern	5-69	Cummings Valley
	No Signatories on File				
TL-4	**Cawelo Water District**	2007	Kern	5-22.14	Kern County
	No Signatories on File				
TL-5	**Consolidated Irrigation District**	2009	Fresno	5-22.08	Kings
	No Signatories on File				
TL-6	**Deer Creek and Tule River Authority**	2006	Tulare	5-22.13	Kings
	Lower Tule River Irrigation District				
	Pixley Irrigation District				
	Porterville Irrigation District				
	Saucelito Irrigation District				
	Stone Corral Irrigation District				
	Tea Pot Dome Water District				
	Terra Bella Irrigation District				
TL-7	**Delano Earlimart Irrigation District**	2007	Tulare	5-22.13	Tule
	No Signatories on File		Kern	5-22.14	Kern
TL-8	**Fresno Area Regional**	2006	Fresno	5-22-08	Kings
	County of Fresno				
	City of Fresno				
	City of Clovis				
	City of Kerman				
	Malaga County Water District				
	Pinedale County Water District				
	Fresno Metropolitan Flood Control District				
	Bakman Water Company				
	Garfield Water District				
	Fresno Irrigation District				

Map Label	Agency Name	Date	County	Basin Number	Basin/Subbasin Name
TL-9	**James Irrigation District**	2010	Fresno	5-22.08	Kings
	City of San Joaquin				
TL-10	**Kaweah Delta Water Conservation District**	2006	Tulare	5-22.11	Kaweah
	No Signatories on File				
TL-11	**Kern Delta Water District**	1996	Tulare	5-22.14	Kern County
	No Signatories on File				
TL-12	**Kern-Tulare Water District and Rag Gulch Water District**	2006	Kern	5-22.14	Kern County
	No Signatories on File				
TL-13	**Kings County Water District**	2011	Kings	5-22.11	Kaweah
	No Signatories on File			5-22.12	Tulare Lake
TL-14	**Kings River Conservation District – Lower Kings**	2005	Fresno	5-22.08	Kings
	Burrel Ditch Company			5-22.12	Tulare Lake
	Clark Forks Reclamation District #2069				
	Corcorn Irrigation District				
	Crescent Canal Company				
	Empire West Side Irrigation District				
	John Heinlen Mutual Water Company				
	Laguna Irrigation District				
	Last Chance Water Ditch Company				
	Lemoore Canal and Irrigation Company				
	Liberty Canal Company				
	Liberty Mill Race Company				
	Peoples Ditch Company				
	Rasin City Water District				
	Reed Ditch Company				
	Riverdale Irrigation District				
	Stratford Irrigation District				
TL-15	**Kings River Water District**	1995	Fresno	5-22.08	Kings
	No Signatories on File				
TL-16	**North Kern Water Storage District and Rosedale Ranch Improvement District**	1993	Kern	5-22.14	Kern County
	No Signatories on File				

Map Label	Agency Name	Date	County	Basin Number	Basin/Subbasin Name
TL-17	**Orange Cove Irrigation District**	2006	Tulare	5-22.08	Kings
	Hills Valley Irrigation District				
	Tri-Valley Water District				
TL-18	**Not Used**				
TL-19	**Rosedale-Rio Bravo Water Storage District**	1997	Kern	5-22.14	Kern County
	No Signatories on File				
TL-20	**Semitropic Water Storage District**	2003	Kern	5-22.14	Kern County
	Kern County Water Agency				
	Southern San Joaquin Municipal Utility District				
	North Kern Water Storage District				
	Shafter-Wasco Irrigation District				
	Rosedale-Rio Bravo Water Storage District				
	Buena Vista Water Storage District				
TL-21	**Shafter-Wasco Irrigation District**	2007	Kern	5-22.14	Kern County
	No Signatories on File				
TL-22	**Tulare Irrigation District**	2010	Tulare	5-22.11	Kaweah
	No Signatories on File				
TL-23	**Tulare Lake Bed**	1998[a]	Kings	5-22.12	Tulare Lake
	Alpaugh Irrigation District				
	Angiola Water District				
	Atwell Island Water District				
	City of Corcoran				
	Corcoran Irrigation District				
	Melga Water District				
	Tulare Lake Basin Water Storage District				
	Private Landowners				
TL-24	**West Kern Water District**	1997	Kern	5-22.14	Kern County
	No Signatories on File				
TL-25	**Westlands Water District**	1996	Fresno	5-22.09	Westside
	No Signatories on File				
TL-26	**Wheeler Ridge-Maricopa Water Storage District**	2007	Kern	5-22.14	Kern County
	No Signatories on File				

Map Label	Agency Name	Date	County	Basin Number	Basin/Subbasin Name
TL-27	**Buena Vista Water Storage District**	2002	Kern	5-22.14	Kern County
	No Signatories on File				

Note:

[a] Received an updated plan after cutoff date of August 2012. The updated plan was not included in Senate Bill 1938 assessment results.

Groundwater Management Plan Assessment

In 2011 and 2012, DWR partnered with the Association of California Water Agencies (ACWA) to survey local water agencies about their groundwater management, conjunctive management, and water banking practices, to build a better understanding of existing groundwater management efforts in California. In addition to the information gleaned from the DWR/ACWA groundwater management survey, DWR independently reviewed the GWMPs to assess the following:

- How many of the post-SB 1938 (2002) GWMPs meet the six required components included in SB 1938 and incorporated into California Water Code Section 10753.7.
- How many of the post-SB 1938 GWMPs include the 12 voluntary components included in California Water Code Section 10753.8.
- How many of the implementing or signatory GWMP agencies are actively implementing the seven recommended components listed in DWR Bulletin 118-2003.

Groundwater management planning information collected through the DWR/ACWA survey and through DWR's assessment is not intended to be punitive in nature. It is widely understood that the application of effective groundwater management in California is ripe with jurisdictional, institutional, technological, and fiscal challenges. DWR is committed to assisting local agencies in developing and implementing effective, locally planned, and locally controlled groundwater management programs. DWR is also committed to helping promote State and federal partnerships, and coordinating with local agencies to expand groundwater data collection, management, and planning activities that promote sustainable local groundwater management. The overall intent of the GWMP assessment is to help identify groundwater management challenges and successes, and provide recommendations for local and statewide improvement.

As previously mentioned, information associated with the GWMP assessment is based on data that was readily available or submitted to DWR through August 2012. Requirements associated with the 2011 AB 359 (Huffman) legislation, related to groundwater recharge mapping and reporting, did not take effect until January 2013 and are not included in the 2012 GWMP assessment effort. The following information will only address the active plans that were determined by DWR to meet some or all of the requirements of SB 1938.

Required GWMP Components

California Water Code Section 10753.7 requires that six components be included in a GWMP for an agency to be eligible for State funding administered by DWR for groundwater projects, including projects that are part of an IRWM program or plan. The required components of a GWMP include:

1. **Basin Management Objectives**: Includes components relating to the monitoring and management of groundwater levels within the groundwater basin, groundwater quality degradation, inelastic land surface subsidence, changes in surface flow and surface water quality that directly affect groundwater levels, or quality, or are caused by groundwater pumping in the basin, and a description of how recharge areas identified in the plan substantially contribute to the replenishment of the groundwater basin.
2. **Agency Cooperation**: The plan will involve other agencies that enable the local agency to work cooperatively with other public entities whose service area or boundary overlies the groundwater basin.
3. **Mapping**: The plan will include a map that details the area of the groundwater basin, as defined in DWR's Bulletin 118, and the area of the local agency that is subject to the plan, as well as the boundaries of other local agencies that overlie the basin in which the agency is developing a groundwater management plan.
4. **Recharge Areas**: Commencing January 1, 2013, the GWMP shall include a map identifying the recharge areas for the groundwater basin, and provide the map to the appropriate local planning agencies and all interested persons, after adoption of the GWMP.
5. **Monitoring Protocols**: The local agency shall adopt monitoring protocols designed to detect changes in groundwater levels, groundwater quality, inelastic surface subsidence (in basins for which subsidence has been identified as a potential problem), and flow and quality of surface water that directly affect groundwater levels or quality or are caused by groundwater pumping in the basin.
6. **GWMPs Located Outside Bulletin 118 Groundwater Basins**: Plans located outside the DWR Bulletin 118 alluvial groundwater basins will incorporate the above components and shall use geologic and hydrologic principles appropriate to those areas.

Three of the above components contain required subcomponents that were also evaluated. The requirement to develop a map of recharge areas was not required until January 1, 2013, and was consequently not evaluated. In addition, the requirement for local agencies outside a Bulletin 118-2003 recognized groundwater basin was not applicable for any of the GWMPs in the Tulare Lake region. As a result, the GWMP assessment focused on four of the six components listed in the California Water Code.

Overall, DWR determined that 17 of the 26 GWMPs incorporated some or all of the four required components evaluated, and five GWMPs were determined to adequately address all four components. Table 9-19 identifies the percentage of the 17 active plans that meet the required components and subcomponents listed in California Water Code Section 10753.7. A detailed description of the individual component assessment is provided in the following sections.

Basin Management Objectives

The basin management objectives (BMOs) assessment consists of four required subcomponents that were individually assessed. The subcomponents include the monitoring and management of (1) groundwater levels, (2) groundwater quality, (3) inelastic land subsidence, and (4) surface water and groundwater interaction.

Table 9-19 Assessment for GWMP Required Components in the Tulare Lake Hydrologic Region

Senate Bill 1938 Required Components	Percentage of Plans that Meet Requirement
Basin Management Objectives	29%
BMO: Monitoring/Management Groundwater Levels	88%
BMO: Monitoring Groundwater Quality	88%
BMO: Inelastic Subsidence	71%
BMO: SW/GW Interaction and Affects to Groundwater Levels and Quality	29%
Agency Cooperation	100%
Map	76%
Map: Groundwater Basin Area	76%
Map: Area of Local Agency	82%
Map: Boundaries of other Local agencies	76%
Recharge Areas (January 1, 2013)	Not Assessed
Monitoring Protocols	35%
MP: Changes in Groundwater Levels	88%
MP: Changes in Groundwater Quality	88%
MP: Subsidence	76%
MP: SW/GW Interaction and Affects to Groundwater Levels and Quality	41%
GWMPs Outside Groundwater Basin	0%
Met all Required Components, and Subcomponents	29%

Notes:
GW = groundwater; GWMP = groundwater management plan; SW = surface water
Table reflects assessment results of Senate Bill 1938 plans that were received by August 2012.

The assessment indicated that five of the 17 GWMPs met the overall BMO requirement by providing the necessary measurable objectives, along with actions which will occur when specific conditions are met, for each of the BMO subcomponents. Ten active GWMPs did not meet the overall BMO component but did have the required information for one or more of the required BMO subcomponents. As a result, the GWMP was found to be in partial compliance. The remaining two GWMPs did not meet any of the BMO subcomponents.

The most common BMO subcomponent that was missing, or not adequately addressed, within the 17 active GWMPs is the planning requirements for the monitoring and management of surface water and groundwater interaction. The majority of the GWMPs in the Tulare Lake region mentioned this requirement, but did not describe how an appropriate program would be initiated, measured, and managed.

Agency Cooperation

All 17 GWMPs provided sufficient details on how the agency was going to coordinate and share groundwater management activities with neighboring agencies and local governments.

Mapping

The mapping requirement of SB 1938 has three subcomponents. The GWMPs are required to provide (1) one or more maps that depict the GWMP area, (2) the associated Bulletin 118 groundwater basin(s), and (3) all neighboring agencies located within the basin(s). The GWMP review determined that 13 of 17 of the plans met all three of the requirements for mapping, while four GWMPs did not provide one or more of the required components. No common issue was identified by the four agencies as to why they did not comply with the mapping requirement(s).

Monitoring Protocols

The monitoring protocol component consists of four subcomponents. Under the requirements of SB 1938, GWMPs are required to establish monitoring protocols for assessing (1) groundwater levels, (2) groundwater quality, (3) inelastic land subsidence, and (4) surface water and groundwater interaction. In general, these monitoring protocols should directly relate to the BMOs that address these same topics.

The overall results of the assessment for the monitoring protocols component were similar to those for the BMO components. The assessment determined that six GWMPs met all four required monitoring-protocol subcomponents, while nine plans were missing details for one or more of the subcomponents. Of the active GWMPs, 15 of the 17 plans met the monitoring protocol requirements for measuring groundwater levels and groundwater quality, while 13 of the GWMPs included monitoring protocols for inelastic subsidence.

The review of the GWMPs determined that 10 plans did not identify activities to evaluate surface water and groundwater interaction. These same 10 GWMPs also did not develop sufficient monitoring protocols that would help ensure correctness and consistency when measuring, recording, and presenting field data. Two plans provided monitoring protocols for surface water and groundwater interaction but did not sufficiently establish BMOs or identify the necessary management actions that would be implemented in the event that BMOs were not met.

Voluntary GWMP Components

As part of the GWMP review, 12 voluntary components included in California Water Code Section 10753.8 were assessed. During the GWMP review, some voluntary components were expanded to include subcomponents, which provided more opportunities to meet the various voluntary criteria. However, the reporting and analysis was not done on a subcomponent level. In many cases during the review, if the GWMP included one or more of the subcomponents, full compliance credit was given for the GWMP assessment. Partial compliance was given when the plan left out key planning components, examples of which include missing timelines, vagueness on the specifics of a plan, or vagueness on how a project met the GWMP’s goals or objectives.

The voluntary components presented in California Water Code Section 10753.8 include:

1. The control of saline water intrusion.
2. Identification and management of wellhead protection areas and recharge areas.
3. Regulation of the migration of contaminated groundwater.
4. The administration of a well abandonment and well destruction program.
5. Mitigation of conditions of overdraft.
6. Replenishment of groundwater extracted by water producers.
7. Monitoring of groundwater levels and storage.
8. Facilitating conjunctive use operations.
9. Identification of well construction policies.
10. The construction and operation by the local agency of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects.
11. The development of relationships with State and federal regulatory agencies.
12. The review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination.

It is important to note that not all agencies addressed every voluntary component. Based on conversations with a majority of the agencies statewide, it was apparent that if the lead agency determined that the component was not an issue, then there was a good chance it was not addressed or even mentioned in the GWMP. For example, if saline intrusion and overdraft were a non-issue within the plan's boundary, or in some cases, in the groundwater basin, no discussion or actions were taken as part of the planning and implementation. Also, decisions on which components could be achieved by the agency were primarily driven by the availability of funding. The percentage of GWMPs that discussed the voluntary components in the Tulare Lake region is shown in Table 9-20.

Table 9-20 shows that well abandonment and destruction, groundwater extraction and replenishment, groundwater monitoring, conjunctive use, and well construction policies were included in more than 90 percent of the active GWMPs in the Tulare Lake region. This is followed by saline intrusion and overdraft policies in more than 80 percent of the plans. The least incorporated of the voluntary components was the development of relationships with State and federal regulatory agencies.

The components of wellhead protection and recharge, along with construction and operation of facilities, ranked poorly in the GWMP review with a compliance rating of 65 and 59 percent, respectively. For the wellhead protection and recharge component, three GWMPs were given a partial rating for insufficient details and three GWMPs did not address the component at all. The construction and operation of facilities were mentioned in each of the GWMPs reviewed; however, details relating to facilities construction and operations of several of the GWMPs were extremely limited and insufficient to determine how this component was being implemented.

Subsequent communication with agencies concerning well abandonment, destruction, and well construction components revealed that they were not discussed because the agency felt that existing county, State, and federal rules met the requirement. Unfortunately, GWMPs often do not mention reliance on external polices and ordinances to meet local groundwater management

Table 9-20 Assessment for GWMP Voluntary Components in the Tulare Lake Hydrologic Region

Voluntary Components	Percentage of Plans that Include Component
Saline Intrusion	82%
Wellhead Protection and Recharge	65%
Groundwater Contamination	76%
Well Abandonment and Destruction	94%
Overdraft	88%
Groundwater Extraction and Replenishment	100%
Monitoring Groundwater Levels and Storage	100%
Conjunctive Use Operations	94%
Well Construction Policies	94%
Construction and Operation	59%
Regulatory Agencies	53%
Land Use	76%

Note:
Table reflects assessment results of Senate Bill 1938 plans that were received by August 2012.

objectives. Effectively communicating how components of local groundwater management are being implemented was a challenge for many GWMPs throughout the state.

Bulletin 118-2003 Recommended GWMP Components

Bulletin 118-2003 contains suggestions on how GWMPs should be developed and provides details that should be included during development of a plan. Bulletin 118-2003, Appendix C provides a list of seven recommended components related to the management, development, implementation, and evaluation of a GWMP that should be considered to help ensure effective and sustainable groundwater management.

1. **Guidance**: Establish an advisory committee to assist in GWMP development and implementation.
2. **Management Area**: Describe the physical setting, aquifer characteristics, and background data.
3. **BMO, Goals, and Actions***:* Describe how the current or planned actions help to meet the overall management objectives and goals.
4. **Monitoring Plan Description**: Describe groundwater monitoring type, location, frequency, and aquifer interval.
5. **IRWM Planning**: Describe efforts to coordinate with other land use or water management planning.
6. **Implementation**: Develop status reports with management actions, monitoring activities, basin conditions, and achievements.
7. **Evaluation**: Periodic assessment of conditions versus management objectives.

Table 9-21 identifies the percentage of the Tulare Lake region's 17 active GWMPs that include each of the seven recommended components in Bulletin 118-2003. Groundwater management plan implementation, definition of the management area, and establishment of the BMO's goals and actions were detailed in 16 of the 17 active plans. Thirteen of the region's GWMPs incorporated six or more of the seven recommended GWMP components listed Bulletin 118-2003. Only 10 active plans provided a description of the groundwater monitoring plan. Recommendations provided in Bulletin 118-2003 identify how monitoring plan descriptions should include maps showing sites used for monitoring and descriptions of the type of monitoring and measurements, along with the site-specific information. The GWMPs that did not provide an adequate groundwater monitoring plan description indicated that various aspects of monitoring are shared or provided by other organizations, or identified concerns about maintaining the privacy of participating landowners. Continued implementation of the CASGEM groundwater-level monitoring program may serve to resolve this common GWMP challenge.

DWR/ACWA Survey — Key Factors for Successful GWMP Implementation

As noted in the previous section, DWR partnered with ACWA to survey its member agencies on various topics covering groundwater management. The survey respondents were asked to provide feedback on which components helped make their GWMP implementation successful. The participants were not asked to rank their responses in terms of importance, but were asked to provide additional insights and list additional components. Eleven agencies from the Tulare Lake region participated in the ACWA survey, but only 10 responded to the question regarding key factors contributing to successful implementation. Table 9-22 summarizes the individual responses from these 10 agencies.

Table 9-21 **Assessment of DWR Bulletin 118-2003 Recommended Components in the Tulare Lake Hydrologic Region**

Suggested Components	Percentage of Plans that Include Component
GWMP Guidance	82%
Management Area	94%
BMOs, Goals, & Actions	94%
Monitoring Plan Description	59%
IRWM Planning	88%
GWMP Implementation	94%
GWMP Evaluation	88%

Notes:
BMO = basin management objectives; IRWM = integrated regional water management;
GWMP = groundwater management plan
Table reflects assessment results of Senate Bill 1938 plans that were received by August 2012.

Table 9-22 Survey Results for Key Components Contributing to Successful GWMP Implementation in the Tulare Lake Hydrologic Region

Key Components	Respondents
Data collection and sharing	10
Outreach and education	9
Developing an understanding of common interest	9
Sharing of ideas and information with other water resource managers	8
Broad stakeholder participation	8
Adequate surface water supplies	6
Adequate regional and local surface storage and conveyance systems	5
Water budget	4
Funding	8
Time	6
Respondent Supplied Components	
Land conservation program for overdraft mitigation	1
Unregulated pumping	1

Notes:
GWMP = groundwater management plan
Results from an on-line survey sponsored by the California Department of Water Resources and conducted by the Association of California Water Agencies, 2011 and 2012.

Data collection and sharing of information was included on all 10 of the respondents' lists. Developing an understanding of common interest, along with outreach and education, were selected as key components by nine survey responders in the Tulare Lake region. The sharing of ideas and information with other water resource managers, broad stakeholder participation, and funding were included by eight of the responders as a key component to successful GWMP implementation.

Only four to six of the survey participants thought that water budgets, adequate water supplies, storage and conveyance systems, and having adequate time were also key components to successful groundwater management. One agency indicated that a land conservation program for overdraft mitigation was a key component that should be considered, while a different agency indicated that unregulated groundwater pumping was an important component that led to its success.

DWR/ACWA Survey — Key Factors Limiting GWMP Success

Survey respondents were also asked to identify challenges that they felt impeded implementation of their GWMP. Six survey participants from the Tulare Lake region responded to this question; Table 9-23 includes the results of those respondents. Overall, respondents pointed to a lack of adequate funding as the greatest impediment to GWMP implementation. Adequate funding is a challenge for many agencies because of the significant costs associated with development and implementation of groundwater management programs and projects. Lack of surface storage and conveyance capacity was also considered as a key limiting component by five of the six respondents. Four of the respondents stated that groundwater supply was an impediment and three pointed to funding for groundwater management planning. Two respondents cited lack of funding to assist stakeholder participation as an impediment, and two cited the lack of understanding local issues as a potentially key impediment. Finally, unregulated pumping, access to planning tools, and outreach and education were all identified by one respondent as key impediments to successful implementation of groundwater management.

DWR/ACWA Survey — Opinions of Groundwater Sustainability

Local agencies were asked if they were confident in the long-term sustainability of their current groundwater supply. Six out of the 10 Tulare Lake region respondents felt long-term sustainability of their groundwater supply was not feasible.

Groundwater Ordinances

Groundwater ordinances are laws adopted by local authorities, such as cities or counties, to manage groundwater. In 1995, the California Supreme Court declined to review a lower court decision (*Baldwin v. Tehama County)* concluding that state law, while regulating some aspects of groundwater, does not preclude counties from adopting ordinances to manage and regulate groundwater. Since 1995, the decision has remained untested. As a result, the precise nature and extent of the police power of cities and counties to regulate groundwater is still uncertain.

There are a number of groundwater ordinances that have been adopted by counties in the Tulare Lake region. The Tulare Lake region includes Fresno, Kern, Kings, and Tulare counties. Of the four counties, Fresno County has the most groundwater related ordinances. The three Fresno County ordinances require permits pertaining to water exports or transfers, well abandonment and destruction, and well construction. Kern, Kings, and Tulare counties each have two groundwater ordinances pertaining to water exports or transfers, well abandonment, or well construction. Tulare County also adopted an ordinance that addresses water conservation within the county that is based on four stages. It includes voluntary and mandatory compliances and prohibitions. The Tulare County ordinance also has penalties for failure to comply. Table 9-24 lists the ordinances being implemented by the counties in the Tulare Lake region.

Table 9-23 Survey Results for Factors that Limited the Successful GWMP Implementation in the Tulare Lake Hydrologic Region

Limiting Factors	Respondents
Limited Participation Across a Broad Distribution of Interests	-
Limited Data Collection and Sharing	-
Limited Funding for Groundwater Management Planning	3
Limited Funding for Groundwater Management Projects	6
Limited Funding to Assist in Stakeholder Participation	2
Limited Understanding of the Local Issues	2
Limited Outreach and Education	1
Limited Groundwater Supply	4
Limited Surface Storage and Conveyance Capacity	5
Limited Access to Planning Tools	1
Unregulated Pumping	1
Lack of Governance	-

Notes:
GWMP = groundwater management plan
Results from an on-line survey sponsored by the California Department of Water Resources and conducted by the Association of California Water Agencies, 2011 and 2012.

Table 9-24 County Groundwater Ordinances for the Tulare Lake Hydrologic Region

County	Groundwater Management	Guidance Committees	Export Permits	Recharge	Well Abandonment and Destruction	Well Construction Policies
Fresno	-	-	Yes	-	Yes	Yes
Kern	-	-	Yes	-	-	Yes
Kings	-	-	-	-	Yes	Yes
Tulare[a]	-	-	-	-	Yes	Yes

Notes:
[a] Adopted water conservation ordinance.
Table represents information as of August 2012.

Special Act Districts

Greater authority to manage groundwater has been granted to a few local agencies or districts created through a special act of the Legislature. The specific authority of each agency varies, but the agencies can be grouped into two general categories: (1) agencies having authority to limit export and extraction (upon evidence of overdraft or threat of overdraft); or (2) agencies lacking authority to limit extraction, but having authority to require reporting of extraction and to levy replenishment fees.

There are many special act districts established by the California State Legislature consisting of different authorities that may or may not have groundwater management authority. It was not part of the scope for *California Water Plan Update 2013* to identify individual types of special act districts or provide a listing of the established agencies. This report includes the GWMPs that were prepared by these agencies and submitted to DWR, as discussed in the preceding section.

Court Adjudication of Groundwater Rights

Another form of groundwater management in California is conducted through the courts. When the groundwater resources do not meet water demands in an area, landowners may turn to the courts to determine how much groundwater can be rightfully extracted by each overlying landowner or appropriator. The court typically appoints a watermaster to administer the judgment and to periodically report to the court.

There are 24 groundwater adjudications in California. Of the 24, three adjudications relate to groundwater basins in the Tulare Lake region. Table 9-25 and Figure 9-25 provide information and shows the location of groundwater adjudications in the Tulare Lake region. The Brite, Tehachapi West, and Cummings basins are collectively managed by The Tehachapi-Cummings County Water District. The Tehachapi East Basin is located in the South Lahontan Hydrologic Region.

Table 9-25 Groundwater Adjudications in the Tulare Lake Hydrologic Region

Map Label	Court Judgment	Basin Number	Basin Name	County	Judgment Date
A-18	Tehachapi Basin	5-28 6-45	Tehachapi Valley – West Basin Tehachapi Valley – East Basin	Kern	1971
A-19	Cummings Basin	5-27	Cummings Valley Basin	Kern	1972
A-20	Brite Basin	5-80	Brite Valley Basin	Kern	1970

Note:
Table represents information as of April 2013.

Figure 9-25 Groundwater Adjudications in the Tulare Lake Hydrologic Region

Prepared by California Department of Water Resources for California's Groundwater Update 2013

Other Groundwater Management Planning Efforts

Groundwater management is also occurring through other avenues. IRWM incorporates the physical, environmental, societal, economic, legal, and jurisdictional aspects of water management into regional solutions through an open and collaborative stakeholder process to promote sustainable water use. UWMPs incorporate long-term resource planning to meet existing and future water demands. AWMPs advance irrigation efficiency that benefits both farms and the environment.

Integrated Regional Water Management Plans

IRWM improves water management and supports economic stability, environmental stewardship, and public safety. IRWM plans involve multiple agencies, stakeholders, individuals, and groups. They can cross jurisdictional, watershed, and political boundaries. The methods used in IRWM planning include developing water management strategies that relate to water supply and water quality, water use efficiency, operational flexibility, stewardship of land and natural resources, and groundwater resources. Statewide, the majority of IRWM plans address groundwater management in the form of goals, objectives, and strategies. They defer implementation of groundwater management and planning to local agencies through local GWMPs. Few IRWM plans actively manage groundwater. Efforts by IRWM RWMGs may include creating groundwater contour maps for basin operations criteria, monitoring groundwater elevations, and monitoring groundwater quality.

Statewide, there are 48 IRWM plans that have been accepted or conditionally accepted. The Tulare Lake region includes seven of the 48 IRWM planning groups. As of August 2012, four of the seven region plans are actively implemented, while three are in various stages of implementation. Two of the established plans extend northward into the San Joaquin River Hydrologic Region. Table 9-26 lists the IRWM plans for the region and Figure 9-26 shows the location and planning areas for the IRWM plans. Additional information regarding IRWM planning can be found on the DWR Web site: http://www.water.ca.gov/irwm/grants/index.cfm.

The Poso Creek and Kern County IRWM plans rely on member entities to implement GWMPs consistent with existing California Water Code requirements. Common groundwater management themes identified in the Poso Creek and Kern County IRWM plans are to preserve and maximize groundwater quantity and quality, and protect against inelastic land surface subsidence. Common management practices are to monitor groundwater quantity and quality, and participate in groundwater recharge activities.

The Westside IRWM planning group relies on local groundwater management entities to implement groundwater-related projects which help improve local groundwater management. One of the main goals of the Westside IRWM is to minimize regional conflict by addressing problems such as water supply reliability, overdraft, drainage, and water quality.

While similarly relying on local management entities to implement local GWMPs, the Upper Kings Basin IRWM Authority planning group also seeks to integrate existing local GWMPs into a single, comprehensive management plan at the regional level. Effective groundwater management is practiced through conjunctive management programs implemented by individual

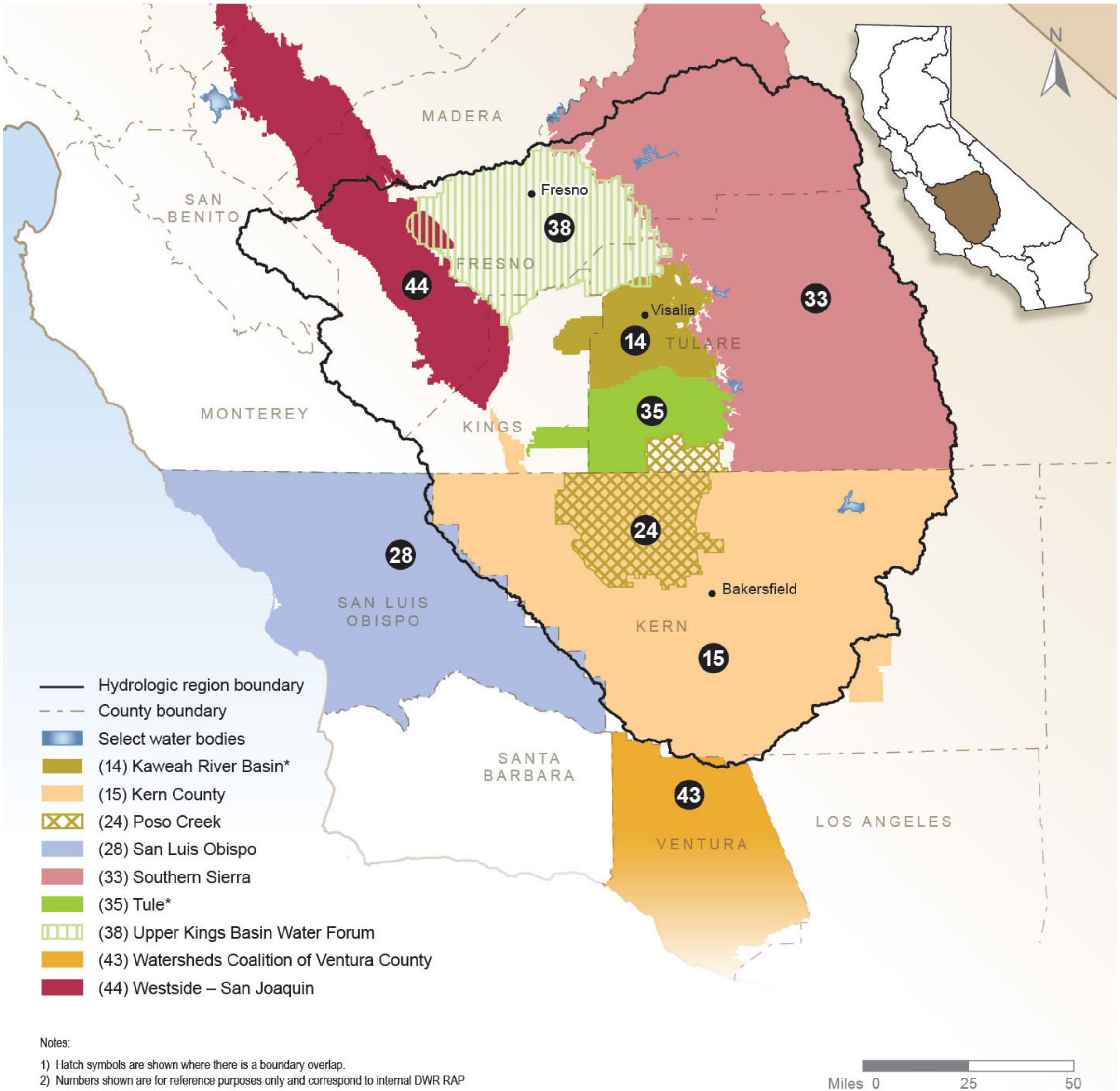
Table 9-26 Status of Integrated Regional Water Management Plans in the Tulare Lake Hydrologic Region

Hydrologic Region	IRWM Plan Name	Date	IRWM Plan Status	IRWM Map Number
Tulare Lake	Kaweah River Basin	NA	In Progress	14
Tulare Lake/ South Lahontan	Kern County	2011	Active	15
Tulare Lake	Poso Creek	2007	Active	24
Tulare Lake	Tule	NA	In Progress	35
Tulare Lake/ San Joaquin River	Southern Sierra	NA	In Progress	33
Tulare Lake	Upper Kings Basin	2007	Active	38
Tulare Lake/ San Joaquin River	Westside	2013	Active	44
			IRWM Planning Regions:	7
			Active IRWM Plans:	4
			IRWM Plans In Development:	3
			IRWM Plans that Cross Hydrologic Boundaries:	3

Notes:
IRWM = integrated regional water management, NA = not available
Two additional IRWM areas, San Luis Obispo (28) and Ventura (43), extend into the Tulare Lake Hydrologic Region, but because of the small area involved they are not included in this table. They can be observed in Figure 9-26. Detailed information on San Luis Obispo (28) can be found in the Central Coast Hydrologic Region report. Ventura (43) can be found in the South Coast Hydrologic Region report.

districts or local basin groups. The Upper Kings Basin IRWM Authority plan also includes all of the local groundwater management projects and programs as foundational actions for the broader IRWM plan. The Upper Kings Basin IRWM Authority has established conjunctive use and effective groundwater management as a prevailing theme. It identifies groundwater overdraft in the basin as the highest priority problem. The Upper Kings Basin IRWM Authority RWMG has identified groundwater overdraft as being the greatest potential source of conflicts between water users, the potential source of economic losses to both urban and agricultural economies, and the greatest potential source of impacts to the environment. The Upper Kings Basin IRWM Authority integrated resource planning also recognizes that each of the overlying water districts need to continue working with stakeholders in their respective jurisdictions to update and implement their individual GWMPs. Overall, the Upper Kings Basin IRWM Authority outlines a comprehensive approach for integrating local groundwater management objectives into the broader IRWM planning for the region.

Figure 9-26 Integrated Regional Water Management Plans in the Tulare Lake Hydrologic Region



Notes:
1) Hatch symbols are shown where there is a boundary overlap.
2) Numbers shown are for reference purposes only and correspond to internal DWR RAP submittal indentifications.
3) Region boundaries shown are those submitted by each applicant as part of the RAP submittal.
   – RAP 2009 = ID No's 1 – 46
   – RAP 2011 = ID No's 47 – 49
4) * Denotes Region is conditionally approved

Prepared by California Department of Water Resources for California's Groundwater Update 2013

Urban Water Management Plans

UWMPs are prepared by California's urban water suppliers to support their long-term resource planning and to ensure adequate water supplies are available to meet existing and future water demands. UWMPs include system descriptions, demands, and supplies, as well as water shortage reliability and water shortage contingency planning. In addition, the Water Conservation Bill of 2009 (SB X7-7) requires that urban water suppliers:

- Develop a single standardized water use reporting form for urban water suppliers.
- Develop method(s) by July 1, 2011 to identify per capita targets, and update those methods in four years to meet the 20 percent reduction goal by 2020.
- Develop technical methodologies and criteria for calculating all urban water use.
- Convene a task force to develop alternative best management practices for commercial, industrial, and institutional water use.

Urban use of groundwater is one of the few uses that meter and report annual groundwater extraction volumes. The groundwater extraction data is currently submitted with the UWMP and then manually translated by DWR staff into a database. Online methods for urban water managers to directly enter their water use along with their UWMP are being evaluated. Additional information regarding urban water management and UWMPs can be found at http://www.water.ca.gov/urbanwatermanagement/.

Agricultural Water Management Plans

AWMPs are developed by water and irrigation districts to advance the efficiency of farm water management while benefitting the environment. The AWMPs provide another avenue for local groundwater management. Some of the efficient water management practices being implemented include controlling drainage problems through alternative use of lands, using recycled water that otherwise would not be used beneficially, improvement of on-farm irrigation systems, and lining or piping ditches and canals. SB X7-7 requires that agricultural water suppliers perform the following:

- Report the status of AWMPs and efficient water management practices and evaluate their effectiveness.
- Adopt regulations to measure the volume of water delivered and for adopting a pricing structure based on quantity delivered.
- Develop a method for quantifying efficiency of agriculture water use and a plan for implementation.
- Propose new statewide targets for regional water management practices for recycled water, brackish groundwater, and stormwater runoff.
- Promote implementation of regional water management practices through increased incentives and removal of barriers.

New and updated AWMPs addressing the SB X7-7 requirements were required to be submitted to DWR by December 31, 2012, for review and approval. More information about AWMPs can be found at http://www.water.ca.gov/wateruseefficiency/agricultural/agmgmt.cfm.

Conjunctive Management Inventory

Conjunctive management, or conjunctive use, refers to the coordinated and planned use and management of both surface water and groundwater resources to maximize the availability and reliability of water supplies in a region to meet various management objectives. Managing both resources together, rather than in isolation, allows water managers to use the advantages of both resources for maximum benefit.

Conjunctive management of surface water and groundwater has been utilized in the Tulare Lake region for decades to meet local water demands during surface water cutbacks, to mitigate declining groundwater levels, and help limit land subsidence. To meet water demands throughout the region, the groundwater supply is supplemented by imported surface water from State, federal, and local water projects. Many local agencies in the Tulare Lake region have developed groundwater recharge facilities to capture peak stormwater runoff and to fully utilize imported surface water supplies.

As part of *California Water Plan Update 2013*, an inventory and assessment of conjunctive management programs in California was conducted. The overall intent of this effort was to (1) provide a statewide summary of conjunctive water management program locations, operational methods, and capacities; and (2) identify their challenges, successes, and opportunities for growth, and then share the information with policy-makers and other stakeholders to enable an informed decision-making process regarding groundwater and its management. Additional information regarding conjunctive management in California, as well as a discussion on associated benefits, costs, and issues, can be found in *California Water Plan Update 2013,* Volume 3, Chapter 9, "Conjunctive Management and Groundwater Storage."

The statewide conjunctive management inventory and assessment consisted of literature research, an online survey, personal communication with local agencies, and a documented summary of the conjunctive management programs in California. Information from these efforts was compiled into a comprehensive spreadsheet of projects and historic operational information, which was updated and enhanced with data from a coordinated DWR/ACWA survey.

The online survey administered by ACWA requested the following conjunctive management program information from its member agencies.

- Location of conjunctive use project.
- Year project was developed.
- Capital cost to develop the project.
- Annual operating cost of the project.
- Administrator/operator of the project.
- Capacity of the project in units of acre-feet.

Although initial response to the survey was encouraging, the number of survey participants and the completeness of those responses were limited. In an attempt to build on the ACWA survey and develop a greater understanding of the size and diversity of conjunctive management projects in California, DWR's four region offices contacted, either by telephone or through email, each of the entities identified as having a conjunctive water management program. DWR's follow-up information requested additional details regarding:

- Source of water received.
- Put and take capacity of the groundwater bank or conjunctive use project.
- Type of groundwater bank or conjunctive use project.
- Program goals and objectives.
- Constraints on development of conjunctive management or groundwater banking (recharge) program.

Statewide, a total of 89 conjunctive management and groundwater recharge programs were identified. Because of confidentiality concerns expressed by some local agencies, information for some existing conjunctive management programs was not reported. Conjunctive management and groundwater recharge programs that were in the planning and feasibility stage were not included in the inventory. A statewide map and series of tables listing all of the conjunctive management projects identified by DWR, grouped by hydrologic region, and information specific to the 11 questions noted in this section, is provided in Appendix D.

Conjunctive Management Inventory Results

Of the 89 agencies or programs identified as operating a conjunctive management or groundwater recharge program in California, 37 projects are located in the Tulare Lake region. Although many of California's groundwater recharge programs are operated in the Tulare Lake region, the conjunctive management inventory conducted for *California Water Plan Update 2013* was unable to collect full details on most of the region's programs. The information provided in this section summarizes the details of the conjunctive management survey. The full survey results are provided in Appendix D.

Two of the 37 conjunctive management agencies identified in the Tulare Lake region reported information on the project start-up date. The earliest reported conjunctive management project in the Tulare Lake region was in 1992 by the Tehachapi-Cummings County Water District. The most recent project was developed in 2002 by the Kings County Water District. Although the majority of the agencies did not indicate the year their conjunctive management program was developed, based on the data that was received statewide, the majority of groundwater recharge programs were developed in the 1990s and 2000s. This time frame coincides with the enactment of the Groundwater Management Act (AB 3030) in 1992 and the approval of Proposition 13 in 1999, which funded DWR's groundwater storage and conjunctive use grants and loans program.

Capital costs and annual operating costs required to develop and operate a conjunctive management program were provided by two agencies in the Tulare Lake region. According to the survey responses, the largest capital expenditure to develop a local conjunctive management project was reported to be $5 million by the Kings County Water District. The Tehachapi-Cummings County Water District indicated capital costs of about $700,000 for its conjunctive management project. Survey responses for the Tulare Lake region indicated the annual operation cost for conjunctive management projects ranged from $30,000 for the Tehachapi-Cummings County project to about $250,000 by the Kings County Water District.

Quantitative information regarding the capacity of local conjunctive management programs were provided by six agencies within the Tulare Lake region. While some agencies reported actual capacity volumes, other agencies reported capacity estimates. According to the survey results, the largest conjunctive use program in the Tulare Lake region is operated by the Semitropic Water Storage District, with a reported capacity of 2.1 million acre-feet. The capacity of the Kern Water Bank Authority was reported to be 1 million acre-feet, while the city of Bakersfield's program reported a capacity of 800,000 acre-feet. The Arvin-Edison Water Storage District, the Kings County Water District, and the Tehachapi-Cummings County Water District have groundwater recharge programs of 500,000, 20,000, and 10,000 acre-feet, respectively. No other storage capacity details were provided.

Nine agencies in the Tulare Lake region provided details describing the sources of water received for use in their groundwater recharge programs. Of the nine agencies responding to the conjunctive management survey, seven agencies use water from the SWP, six agencies use water from the CVP, and seven agencies use local surface water for groundwater recharge. Recycled water was not indicated to be a source of recharge water from any of the nine agencies that reported data for the region.

Information regarding the put (recharge) and take (extraction) capacity of conjunctive management programs was provided by 18 agencies within the Tulare Lake region. DWR requested that agencies report:

- How much water is annually recharged.
- How much water has cumulatively been recharged.
- How much groundwater is annually withdrawn from the recharged aquifer.
- How much groundwater has cumulatively been withdrawn from the recharged aquifer.
- What is a normal or average dry-year take.

A summary table showing the individual recharge and extraction volumes that were reported in the survey is included in Appendix D.

The methods used for implementing groundwater recharge programs were provided by 18 agencies within the Tulare Lake region. Groundwater recharge using spreading or percolation basins was reported by each of the 18 agencies, and in-lieu recharge methods were reported by eight agencies. Aquifer storage and recovery methods were not identified as a recharge method by any of the programs in the Tulare Lake region.

The goals and objectives of conjunctive management programs were reported by 11 agencies within the Tulare Lake region. Most of the survey respondents included multiple goals and objectives. The survey results indicated that overdraft correction was identified by 82 percent of the survey participants as being the primary goal and objective for their conjunctive management program. A rather obvious goal, being part of a conjunctive management program, was also provided by 73 percent of respondents. An additional objective of water quality protection was identified by 27 percent of the survey respondents. Some additional goals included minimizing the water costs to farmers and drought protection.

Details about the development constraints of conjunctive management programs were provided by eight agencies within the Tulare Lake region. Respondents were asked to rank the following operational constraint categories: political, legal, institutional, limited aquifer storage, water quality issues, cost, and other. The ranking system used a “1” for minimal constraint, a “3” for moderate constraint, and a “5” for significant constraint. On average, cost (rank 2.9) was indicated to be the single greatest constraint toward development of a conjunctive management or groundwater banking project. Legal issues (rank 2.6) were identified as the next highest-ranking constraint, with the remainder of the issues generally considered less-than-moderate constraints (rank 2.0-2.1).

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