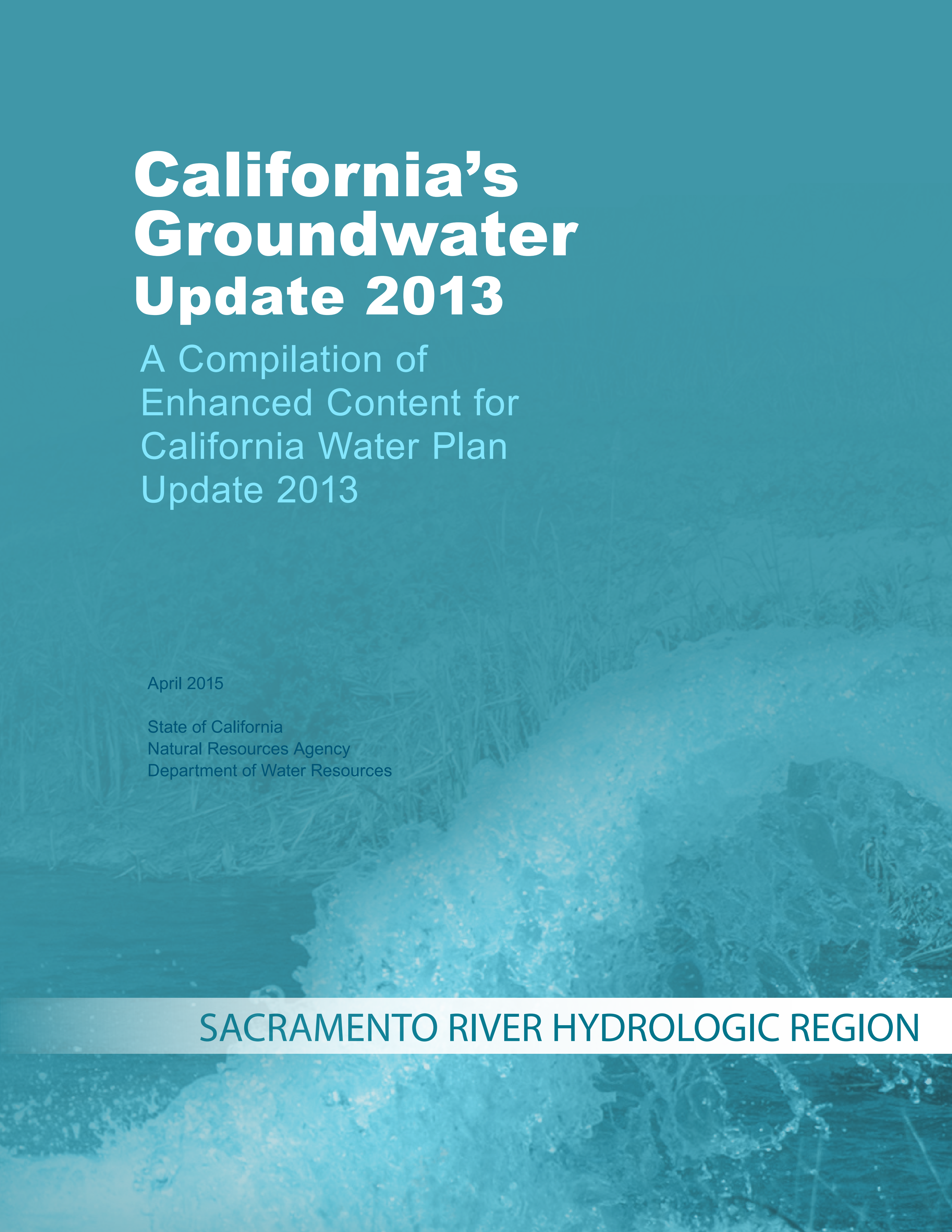

California's Groundwater Update 2013

A Compilation of Enhanced Content for California Water Plan Update 2013

April 2015

State of California
Natural Resources Agency
Department of Water Resources

SACRAMENTO RIVER HYDROLOGIC REGION

The Sacramento River Hydrologic Region Groundwater Update is dedicated to the memory of our friend and colleague Dean Crippen, whose efforts in the field of groundwater monitoring helped further implement sustainable groundwater management in California.

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Acronyms and Abbreviations Used in This Chapter

AB	Assembly Bill
ACWA	Association of California Water Agencies
af/yr	acre-feet per year
ASR	aquifer storage and recovery
bgs	below ground surface
BMO	basin management objective
CAFO	combined animal feeding operation
CASGEM	California Statewide Groundwater Elevation Monitoring
CDFA	California Department of Food and Agriculture
CDPH	California Department of Public Health
CORS	continuous operating reference station
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
DWR	California Department of Water Resources
EPA	U.S. Environmental Protection Agency
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	lifetime health advisory level
IRWM	integrated regional water management
ITRC	Irrigation Training and Research Center
maf	million acre-feet
MCL	maximum contaminant level

msl	mean sea level
MTBE	methyl tertiary butyl ether
NL	notification level
PCE	tetrachloroethylene
RWMG	regional water management group
Sacramento River region	Sacramento River Hydrologic Region
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 Number
SWP	State Water Project
SWRCB	State Water Resources Control Board
Sy	specific yield
TDS	total dissolved solids
USGS	U.S. Geological Survey
UWMP	urban water management plan

Chapter 7. Sacramento River Hydrologic Region Groundwater Update

Introduction

The primary goal of the Sacramento River Hydrologic Region (Sacramento River 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 that will serve as a guide to 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 a substitute for local studies and analysis. Nonetheless, where information is readily available, this update does report some aspects of regional groundwater conditions in greater detail.

The Sacramento River region, depicted in Figure 7-1, covers more than 27,200 square miles and includes all, or portions of, 22 predominantly rural Northern California counties. The counties in the Sacramento River region include all, or most, of Butte, Colusa, Glenn, Lake, Napa, Nevada, Placer, Plumas, Sacramento, Shasta, Sierra, Solano, Sutter, Tehama, Yolo, and Yuba counties and small areas of El Dorado, Alpine, Amador, Lassen, Modoc, and Siskiyou counties. The region extends from the Oregon border to the Sacramento-San Joaquin Delta and from the crest of the Sierra Nevada in the east to the summit of the Coast Ranges in the west, and includes six of the state’s 18 national forests. The Sacramento River is the longest river system in California and includes the Pit, Feather, Yuba, Bear, and American rivers as tributaries. Significant geographic features include the Sacramento Valley, Sierra Valley, Clearlake, and the Modoc Plateau. The topography, geology, hydrology, and land use practices are highly variable, as are the various associated approaches to water resource management.

The climate in the northern, high-desert plateau area of the region is characterized by cold, snowy winters with moderate precipitation and hot, dry summers. This area depends on adequate snowpack to provide runoff for summer supply. Annual precipitation ranges from 10 to 20 inches. Other mountainous areas in the northern and eastern portions of the region have cold, wet winters with large amounts of snow, which typically provide abundant runoff for summer supplies. Annual precipitation ranges from 40 to more than 80 inches. Summers are generally mild in these areas. The Coast Ranges and southern Klamath Mountains receive copious amounts of precipitation, but most of the runoff flows toward the Pacific coast in the North Coast drainage. Sacramento Valley comprises the remainder of the region. At a much lower elevation than the rest of the region, the valley has mild winters with moderate precipitation. Annual precipitation varies from about 35 inches in Redding to about 18 inches in Sacramento. Summers in the valley are hot and dry.

Information from the 2010 census indicates the population of the region is 2,983,156, with 52 percent of the population living in the area overlying the North and South American groundwater subbasins of the Sacramento Valley Groundwater Basin. An additional 10 percent of the population lives in the area overlying the Yolo, Vina, and West Butte groundwater subbasins.

The groundwater update for the Sacramento River region provides an overview and assessment of the region's groundwater supply and development, groundwater use, monitoring efforts, aquifer conditions, and various management activities. It also identifies challenges and opportunities associated with sustainable groundwater management. The regional update starts with a summary of findings, examines groundwater data gaps, and makes recommendations to further improve the overall sustainability of groundwater resources. This is followed by a comprehensive overview of the relevant groundwater topics.

Findings, Data Gaps, and Recommendations

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

Findings

The bulleted items presented 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 (GWMP) 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 of the California Department of Water Resources (DWR) Bulletin 118 and the 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 Sacramento River region.

Figure 7-1 **Sacramento River Hydrologic Region**

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

Groundwater Supply and Development

- The Sacramento River region contains 88 alluvial groundwater basins and subbasins recognized by DWR Bulletin 118-2003. Those groundwater basins and subbasins underlie approximately 7,800 square miles, or 29 percent, of the hydrologic region (Figure 7-2 and Table 7-1).
- Based on DWR well-log records, the total number of wells completed in the Sacramento River region between 1977 and 2010 is approximately 108,346 and ranges from a high of 13,993 wells for Nevada County to a low of 389 wells for Sierra County (Figure 7-3 and Table 7-3).
- Based on the California Statewide Groundwater Elevation Monitoring (CASGEM) Basin Prioritization completed in December 2013, five subbasins in the Sacramento River region are identified as high priority, 16 basins and subbasins are identified as medium priority, seven subbasins are listed as low priority, and the remaining 60 basins and subbasins are listed as very low priority.
- The 21 basins and subbasins designated as high or medium priority include 89 percent of the annual groundwater use and nearly 98 percent of the 2010 population living within the region’s groundwater basin boundaries (Figure 7-6 and Table 7-4).

Groundwater Use and Aquifer Conditions

- The 2005-2010 average annual total water supply for the Sacramento River region, based on planning area boundaries, is estimated at 9 million acre-feet (maf). Water demands in the region are met through a combination of local surface water supplies, State (State Water Project [SWP]) and federal (Central Valley Project [CVP]) surface water deliveries, groundwater, and reused/recycled water supplies (Figure 7-7).
- Groundwater contributes about 30 percent (2.7 maf) of the 2005-2010 average annual total water supply for the Sacramento River region (Figure 7-7).
- Groundwater supplies, based on average annual estimates for 2005-2010, contributes 30 percent of the supply to meet the total agricultural water uses, 47 percent of the supply to meet total urban uses, and 4 percent of the total managed wetlands supply in the Sacramento River region (Table 7-5).
- Between 2002 and 2010, annual groundwater use in the Sacramento River region ranged between 2,446 taf (in 2005) and 3,069 taf (in 2008), and contributed between 28 percent (2002 and 2006) and 32 percent (2008 and 2009) toward the annual water supply (Figure 7-8).
- Of the groundwater pumped on an annual basis between 2002 and 2010, a range of 13 percent to 19 percent was used for urban purposes (Figure 7-9).
- Depth-to-groundwater and groundwater-elevation contours using spring 2010 data were graphically displayed for the Sacramento Valley portion of the Sacramento River region. Some parts of the Sacramento Valley showed groundwater levels at depths exceeding 150 feet below ground surface (bgs). But, most of the Sacramento Valley has groundwater located within 50 feet of the ground surface (Figure 7-12 and 7-13).
- Change-in-groundwater elevations between spring 2005 and spring 2010 show that many areas of the Sacramento Valley have exhibited groundwater elevation declines of 20 feet or more. Yet, most areas throughout the valley have shown groundwater elevation changes within ±10 feet (Figure 7-15).

- A geographic information system (GIS) tool developed by DWR indicated that, between spring 2005 and spring 2010, the water table in the Sacramento Valley portion of the Sacramento River region declined by an average of 3.3 feet, which represented a loss of groundwater in storage between 703 taf and 1,706 taf (Figure 7-16 and Table 7-12).

Groundwater Monitoring Efforts

- A total of 1,306 wells are actively monitored for groundwater-level information in the Sacramento River region (Figure 7-10 and Table 7-8).
- There are an estimated 504 community water systems (CWSs) in the Sacramento River region, with an estimated 1,199 active CWS wells; 101 of the CWS wells (8 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 61 CWSs in the region, with 45 of the 61 affected CWSs serving small communities (Tables 7-14 and 7-15).
- The most prevalent groundwater contaminants affecting community drinking water wells in the region include arsenic, nitrate, tetrachloroethylene (PCE), and gross alpha particle activity. In addition, a total of two regional wells are affected by multiple contaminants (Table 7-16).
- In the Sacramento River region, land subsidence associated with groundwater withdrawal has been documented in the North American and Yolo subbasins. Although some land subsidence is occurring in the southern portion of the Sacramento Valley, the central and northern portions of the Sacramento Valley have not yet observed any significant inelastic land subsidence.

Groundwater Management and Conjunctive Management

- There are 38 GWMPs in the Sacramento River region that collectively cover about 73 percent of the Bulletin 118-2003 alluvial basin area within the region and about 25 percent of the overall region (Figure 7-18).
- DWR's assessment of GWMPs in the Sacramento River region determined that 28 of the 38 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 (Figure 7-18).
- Thirteen GWMPs in the region address all of the required components identified in California Water Code Section 10753.7 (Figure 7-18).
- Of the 89 agencies or programs identified as operating a conjunctive management or groundwater recharge program in California, three programs are located in the Sacramento River region; two agencies operate in-lieu recharge programs, and one agency has developed an aquifer storage and recovery program. The effort to fully characterize the 89 conjunctive management programs as part of *California Water Plan Update 2013* was largely unsuccessful, because numerous agencies were reluctant to make details about their groundwater recharge operations publically available (Appendix D).

Data Gaps

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 Sacramento River region; however, many of the identified 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 Sacramento River 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 data are 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 Sacramento River region is limited. Much of the related information 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, or is publically available, about the fractured-bedrock aquifers located outside the Sacramento Valley and how they interact with the valley's groundwater system.

Some local water agencies in the Sacramento River region are collecting appropriate groundwater data, conducting necessary analyses, and sustainably managing their basins by using their existing authorities. But, locally collected and analyzed data, which could be used by RWMGs and State agencies to better characterize the groundwater basins in the Sacramento River 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 located outside of the Sacramento Valley portion of the Sacramento River region.

Groundwater quality in the Sacramento River region is generally good. But there are areas with local groundwater problems, and there are areas that have not yet been investigated as extensively for groundwater contamination.

Land subsidence investigations in the Sacramento River region include various monitoring efforts, but because of the increase in depth to groundwater and the reduction of groundwater in storage throughout the Sacramento Valley, land subsidence will continue to occur in areas that have already experienced subsidence and could occur in areas that have experienced increased groundwater pumping.

Although three conjunctive management programs were identified in the Sacramento River region, the survey conducted as part of *California Water Plan Update 2013* was unable to collect comprehensive information about those programs. For that reason, a general understanding of the effectiveness of the region's groundwater recharge and conjunctive management programs could not be determined. In addition, it is unknown 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 28 active GWMPs in the Sacramento River region that meet some or all of the SB 1938 groundwater management requirements cover 59 percent of the alluvial groundwater basin area. Although 75 percent of the region's GWMPs address groundwater overdraft policies in their plans, the Sacramento River region, from 2005-2010, has depleted between 703 taf and 1,706 taf of its groundwater in storage from the portion of the region that reports 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-stressed areas.

Recommendations

While much information is known about some of the groundwater basins in the Sacramento River 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 Sacramento River 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 mountain counties have with the Sacramento Valley aquifers.
- Increase land subsidence monitoring to quantify the permanent loss and potential loss of storage for groundwater throughout the region, which 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.
- Update all existing GWMPs to meet the standards set forth in California Water Code Section 10750 et seq. and ensure that GWMPs are prepared for all high- and medium-priority groundwater basins as identified by the CASGEM Groundwater Basin Prioritization process.
- Determine the extent and effectiveness of the groundwater recharge and conjunctive management programs in the Sacramento River region. DWR should work with local water managers to complete the conjunctive management survey information and 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 minimum 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-stressed areas as needed, to establish a better path toward sustainable groundwater management.
- Develop annual groundwater management reports that summarize groundwater management goals, objectives, and performance measures; current and projected trends for groundwater extraction; groundwater levels; groundwater quality; land subsidence; and surface-water–groundwater interaction. Annual reports should evaluate how existing groundwater management practices contribute toward sustainable groundwater management. They should also identify proposed actions for improvements.

Groundwater Supply and Development

This section provides an overview of the key 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 Sacramento River region are supplied by both alluvial and fractured-rock aquifers. Alluvial aquifers are comprised 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 in cracks, fractures, or other void spaces. The distribution and extent of alluvial and fractured-rock aquifers and water wells vary within the Sacramento River 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 at http://www.water.ca.gov/groundwater/bulletin118/update_2003.cfm.

Alluvial Aquifers

DWR Bulletin 118-2003 identifies 88 alluvial groundwater basins and subbasins in the Sacramento River region. The 88 basins and subbasins underlie approximately 7,800 square miles, or approximately 29 percent of the hydrologic region. The majority of the groundwater in the Sacramento River region is stored in alluvial aquifers. A detailed description of aquifers within this hydrologic region is beyond the scope of this chapter. This section includes a brief summary of the major groundwater basins and aquifers in this hydrologic region. Additional information regarding groundwater basins in this hydrologic region may be obtained online from DWR Bulletin 118-2003 (http://www.water.ca.gov/groundwater/bulletin118/update_2003.cfm) or DWR Bulletin 118 Groundwater Basin Maps and Descriptions (http://www.water.ca.gov/groundwater/bulletin118/gwbasins.cfm). Figure 7-2 shows the location of each alluvial groundwater basin and subbasin in the region, and Table 7-1 lists the name and number associated with each alluvial groundwater basin and subbasin.

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.

Figure 7-2 Alluvial Groundwater Basins and Subbasins within the Sacramento River Hydrologic Region

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

Table 7-1 Alluvial Groundwater Basins and Subbasins in the Sacramento River Hydrologic Region

Basin/Subbasin	Basin Name	Basin/Subbasin	Basin Name
5-1	Goose Lake Valley	5-21.65	South American
5-1.01	Lower Goose Lake Valley	5-21.66	Solano
5-1.02	Fandango Valley	5-21.67	Yolo
5-2	Alturas Area	5-21.68	Capay Valley
5-2.01	South Fork Pitt River	5-30	Lower Lake Valley
5-2.02	Warm Springs Valley	5-31	Long Valley
5-3	Jess Valley	5-35	Mccloud Area
5-4	Big Valley	5-36	Round Valley
5-5	Fall River Valley	5-37	Toad Well Area
5-6	Redding Area	5-38	Pondosa Town Area
5-6.01	Bowman	5-40	Hot Springs Valley
5-6.02	Rosewood	5-41	Egg Lake Valley
5-6.03	Anderson	5-43	Rock Prairie Valley
5-6.04	Enterprise	5-44	Long Valley
5-6.05	Millville	5-45	Cayton Valley
5-6.06	South Battle Creek	5-46	Lake Britton Area
5-7	Lake Almanor Valley	5-47	Goose Valley
5-8	Mountain Meadows Valley	5-48	Burney Creek Valley
5-9	Indian Valley	5-49	Dry Burney Creek Valley
5-10	American Valley	5-50	North Fork Battle Creek
5-11	Mohawk Valley	5-51	Butte Creek Valley
5-12	Sierra Valley	5-52	Gray Valley
5-12.01	Sierra Valley	5-53	Dixie Valley
5-12.02	Chilcoot	5-54	Ash Valley
5-13	Upper Lake Valley	5-56	Yellow Creek Valley
5-14	Scotts Valley	5-57	Last Chance Creek Valley

Basin/Subbasin	Basin Name	Basin/Subbasin	Basin Name
5-15	Big Valley	5-58	Clover Valley
5-16	High Valley	5-59	Grizzly Valley
5-17	Burns Valley	5-60	Humbug Valley
5-18	Coyote Valley	5-61	Chrome Town Area
5-19	Collayomi Valley	5-62	Elk Creek Area
5-20	Berryessa Valley	5-63	Stonyford Town Area
5-21	Sacramento Valley	5-64	Bear Valley
5-21.50	Red Bluff	5-65	Little Indian Valley
5-21.51	Corning	5-66	Clear Lake Cache Formation
5-21.52	Colusa	5-68	Pope Valley
5-21.53	Bend	5-86	Joseph Creek
5-21.54	Antelope	5-87	Middle Fork Feather River
5-21.55	Dye Creek	5-88	Stony Gorge Reservoir
5-21.56	Los Molinos	5-89	Squaw Flat
5-21.57	Vina	5-90	Funks Creek
5-21.58	West Butte	5-91	Antelope Creek
5-21.59	East Butte	5-92	Blanchard Valley
5-21.60	North Yuba	5-93	North Fork Cache Creek
5-21.61	South Yuba	5-94	Middle Creek
5-21.62	Sutter	5-95	Meadow Valley
5-21.64	North American		

The description of the alluvial aquifers in the Sacramento River region is organized according to the major unconfined and confined aquifer systems within and outside the Sacramento Valley Groundwater Basin, followed by a short overview of irrigation pump performance and aquifer susceptibility to land subsidence.

Sacramento Valley Groundwater Basin

The boundaries of the Sacramento Valley Basin (5-21) are formed by the foothills of the Sierra Nevada and Cascade Range to the east, the Coast Ranges to the west, and the Klamath Mountains to the northwest. The Sacramento Valley Basin is underlain by an extensive alluvial aquifer system covering approximately 3,780,180 acres. In areas outside of the Sacramento Valley Basin, groundwater occurs in alluvium deposited in smaller valleys and along stream and river channels. Well-yield data (from well completion reports) indicate that the average groundwater production varies greatly between the subbasins within the Sacramento Valley Basin, ranging between 275 and 2,000 gallons per minute (gpm).

The primary fresh groundwater-bearing formations in the Sacramento Valley Basin are the Tehama, Tuscan, Laguna, and Mehrten formations. The Tehama Formation consists of a series of stacked and overlapping alluvial fan deposits. The alluvial fans were derived from material eroded from the Coast Ranges and Klamath Mountains, and consist of interbedded gravel, sand, silt, and clay layers. The rolling hills formed by the Tehama Formation run nearly uninterrupted on the west side of the valley, from Cottonwood in the north to Davis in the south. The Tehama Formation is present in both surface exposures and in the subsurface of the valley, where it is overlain by more recent alluvial material. In the subsurface, the Tehama Formation extends east toward the Sacramento River in most locations. Gravel and sand layers within the Tehama Formation can yield moderate to high amounts of groundwater in many locations.

The Tuscan Formation is derived primarily from mud flow and reworked volcanic deposits originating near Lassen Peak. In the valley, the Tuscan Formation composition consists of interbedded layers of gravel, sand, silt, and clay. On the eastern edge of the valley, the mud flows of the Tuscan can be seen in outcrops from north of Oroville to Redding. In some locations, the volcanic flow deposits continued into the valley as far west as Interstate 5, but were eventually buried under reworked volcanic sands and fine gravels. Gravel and sand layers within the Tuscan Formation can yield moderate to high amounts of groundwater in many locations.

The Laguna Formation is composed of material eroded from the Sierra Nevada. Similar to the Tehama Formation, the Laguna Formation is exposed at the surface along the rolling hills near the eastern edges of the valley. Exposures of the Laguna Formation can be seen at the base of the Sierra Nevada on the east side of the valley between Oroville and Sacramento. In the subsurface, the Laguna Formation extends west to approximately the Sacramento River. The Laguna Formation consists of layers of gravel, sand, and silt. Gravel and sand layers within the Laguna Formation are more limited than in the Tehama and Tuscan formations, and can yield moderate amounts of water in many locations.

The Mehrten Formation is composed of volcanic material eroded from an ancient version of the Sierra Nevada. The Mehrten Formation is located in the southeastern portion of the Sacramento Valley and is present in the subsurface from the base of the foothills, westward beyond the axis of the valley. It consists of two distinct units, a dark-gray andesitic sand and gravel, and an andesitic tuff-breccia. Thickness of the Mehrten Formation can be more than 1,000 feet thick in many locations within the valley. The andesitic sand and gravel unit is highly permeable and can yield large amounts of groundwater in many locations.

Throughout much of the valley, recent alluvial formations (including the Red Bluff, Riverbank, Modesto) and basin deposits cover the Tehama, Tuscan, and Laguna formations with as much as 200 feet of gravel, silt, and clay. In localized areas, the recent alluvium can be a significant source of groundwater for domestic, agricultural, and public use, but generally these units provide a modest amount of water to primarily domestic users.

Redding Area Groundwater Basin

The Redding Area Groundwater Basin (5-6) is bounded by the Cascade Mountains to the east, the Klamath Mountains to the north, and the Coast Ranges to the west, and covers approximately 390,160 acres. To the south, the Red Bluff Arch separates the groundwater resources of the Redding Area Groundwater Basin from those of the Sacramento Valley Groundwater Basin to the south. This geologic structure trends in a generally east-west direction between the cities of Red Bluff and Cottonwood. The Redding Area Groundwater Basin is divided into six subbasins: Bowman, Rosewood, Anderson, Enterprise, Millville, and South Battle Creek. These subbasins overlay portions of both Shasta and Tehama counties.

The center of the Redding Area Groundwater Basin is underlain by a fairly thick alluvial aquifer system, which thins toward the edges of the basin and along smaller valleys adjacent to local stream and river channels. Similar to the Sacramento Valley Groundwater Basin, the primary fresh groundwater-bearing formations in the Redding Area Groundwater Basin include the Tuscan and Tehama formations. Description of these units is provided under the Sacramento Valley Basin discussion. Well-yield data (from well completion reports) indicate that groundwater production in the Redding Area Groundwater Basin varies between 8 and 2,000 gpm, with an average yield of 288 gpm.

Alturas Area, Big Valley, and Fall River Valley Groundwater Basins

Northeast of the Sacramento Valley Groundwater Basin, 27 basins and subbasins are located in Modoc, Siskiyou, Lassen, and Shasta counties. The major groundwater basins within this area are the Alturas Area, Big Valley, and Fall River Valley basins.

The Alturas Area Groundwater Basin (5-2) includes the South Fork Pit River and the Warm Springs Valley groundwater subbasins. The two subbasins cover approximately 182,000 acres in Modoc County and a small portion in Lassen County, and are surrounded by various volcanic rocks and deposits, including basalt flows, pyroclastic rocks, and volcanic ash deposits. Well-yield data indicates that production is significantly higher in the South Fork Pit River Subbasin with estimated well yields (from well completion reports) between 55 and 5,000 gpm with an average of 1,075 gpm. Well-yield data for the Warm Springs Valley Subbasin indicates a range of estimated yields between 100 and 400 gpm, with an average yield of 314 gpm.

The principal water-bearing formation in the South Fork Pit River and the Warm Springs Valley subbasins is the Alturas Formation. The Alturas Formation consists of beds of volcanic ash (tuff), ashy sandstone, and diatomite. The formation can be as thick as 800 feet in some locations. With a moderate to high permeability and significant thickness, this formation can yield large amounts of groundwater to wells in many locations. Other water-bearing formations within the South Fork Pit River and Warm Springs Valley subbasins include Holocene sedimentary deposits, Pleistocene near-shore deposits, and Pleistocene and Late Pliocene volcanic rocks. These formations vary in location, thickness, and permeability. Yields from wells completed in these formations vary from low to high, depending on the well construction and character of the deposits at the location.

The Big Valley Groundwater Basin (5-4) covers 92,000 acres in Lassen and Modoc counties. The basin is bounded by various volcanic rock formations and deposits, including basalt flows and pyroclastic rocks. Estimated well yields (from well driller reports) range between 100 and 4,000 gpm with an average of 880 gpm.

The principal water-bearing formation in the Big Valley Basin is the Bieber Formation. The Bieber Formation consists of clay, silt, sand, and gravel interbedded by its deposition in a lake environment. This formation is as much as 2,000 feet thick in some locations. With a moderate permeability and significant thickness this formation can yield large amounts of groundwater to wells in many locations. Other water-bearing formations within the Big Valley Groundwater Basin include Pliocene to Pleistocene volcanic rocks and Holocene sedimentary deposits. These deposits vary in location, thickness, and permeability. Yields from wells constructed in these formations vary from low to high, depending on well construction and character of the deposits at the location.

The Fall River Valley Groundwater Basin (5-5) covers 54,800 acres in Shasta and Lassen counties. The basin is bounded by volcanic basalt and andesitic rock. Several geologic formations and deposits in the basin yield groundwater in varying amounts, depending on the character of the formation at the location. Estimated well yields (from well completion reports) range between 0 and 1,500 gpm with an average of 266 gpm.

The principal alluvial water-bearing formations in the Fall River Valley Groundwater Basin are the lake and near-shore deposits and Holocene sedimentary deposits. The Pleistocene near-shore deposits consist of clay, silt, and sand, and have a maximum depth of 300 feet. With moderate permeability, this formation can yield moderate amounts of groundwater in some locations. Holocene sedimentary deposits consist of silt, sand, and gravel. These sediments can yield moderate amounts of groundwater in areas where it is both sufficiently permeable and thick; but, those areas are limited. In most areas, the formation is significantly less than 100 feet thick.

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 hydrogeological properties of the aquifer. Pump testing of irrigation wells is periodically conducted 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 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, Salinas, and San Joaquin Valley groundwater basins (Burt 2011). In the Sacramento Valley Groundwater Basin, approximately 500 irrigation pump test records were compiled and evaluated by ITRC. In addition to evaluating the pump test data for well efficiency 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 7-2. Average values shown in Table 7-2 are weighted by input horsepower of the pump motor and are grouped according to a given range of values. Information in Table 7-2 is presented in order of increasing pumping rates.

Table 7-2 shows that the average groundwater pumping rates are lowest for the Dye Creek and Red Bluff subbasins, and highest for the Antelope, Corning, East Sutter, South American, and West Butte subbasins. With nearly 500 pump test records, the average pumping rates for the Dye Creek and Red Bluff subbasins range between 677 and 867 gpm. Average groundwater pumping rates for the highest pumping rate subbasins range between 1,630 and 2,540 gpm. Pumping rates for the reminder of the subbasins tested range between 1,249 and 1,629 gpm. The average pumping rate for all of the wells in the Sacramento Valley Groundwater Basin is approximately 1,553 gpm.

Static groundwater levels, which are typically taken just prior to a pump test, do not show any particular regional correlations with the depth to groundwater. The ranges for the pre-test measurements of static groundwater levels are 18 to 81 feet. The least amount of drawdown was measured in the Antelope, Corning, and Vina subbasins, and range from 8 to 24 feet bgs. The subbasins with the greatest amount of drawdown are Dye Creek, North American, and Yolo, with drawdowns ranging from 39 to 43 feet. Pumping drawdown results for the subbasins of the Sacramento Valley Groundwater Basin tend not to be region specific, and the average drawdown is approximately 35 feet.

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 7-2 shows specific capacity estimates for the Sacramento River region range from a low of 16 gallons per minute per foot (gpm/ft) of drawdown in the Dye Creek Subbasin, to a high of 318 gpm/ft in the Antelope and Corning subbasins.

The overall results for the Sacramento Valley pump tests performed by IRTC found that the Sacramento Valley Basin's pump test had a higher average pumping rate and lower average kilowatt-hour per acre-foot, total dynamic head, motor horsepower, and depth to static-water level than the well pump tests in the other regions.

Table 7-2 Irrigation Pump Test Data for the Sacramento Valley Portion of the Sacramento River 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					
Red Bluff	5-21.50	29-32	677-867	49-81	25-29	23-35
Corning	5-21.51	2	1,630-2,540	18-49	8-24	68-318
Colusa	5-21.52	24-27	1,439-1,629	49-81	35-38	38-47
Antelope	5-21.54	75-97	1,630-2,540	18-49	8-24	68-318
Dye Creek	5-21.55	18-34	677-867	18-49	39-43	16-22
Vina	5-21.57	14-22	1,439-1,629	49-81	8-24	60-204
West Butte	5-21.58	15-25	1,630-2,540	49-81	25-29	56-102
East Butte	5-21.59	8-10	1,439-1,629	18-49	35-38	38-47
North Yuba	5-21.60	7	1,439-1,629	18-49	30-34	42-54
South Yuba	5-21.61	76-82	1,439-1,629	49-81	30-34	42-54
East Sutter	5-21.62	3-5	1,630-2,540	18-49	25-29	56-102
North American	5-21.64	1	1,439-1,629	49-81	39-43	33-42
South American	5-21.65	22-36	1,630-2,540	49-81	35-38	43-73
Solano	5-21.66	12-15	1,249-1,438	4981	30-34	37-48
Yolo	5-21.67	76-101	1,439-1,629	49-81	39-43	33-42

Source: 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 Irrigation Training and Research Center 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 serious long-term 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. Then again, the overall magnitude and extent of land subsidence is usually caused by a combination of factors, such as the amount and rate of artesian head decline and the size and thickness of aquifer sediments.

Land subsidence is a global phenomenon defined as the lowering of the ground surface relative to a reference datum, such as sea level. Land subsidence is usually gradual, but can also be sudden. The primary causes of land subsidence are aquifer-system compaction, drainage of organic soils, underground mining, hydrocompaction, natural compaction, sinkholes, and thawing permafrost (National Research Council 1991). Just aquifer-system compaction will be discussed in this report.

In the United States, more than 17,000 square miles in 45 states have been directly affected by land subsidence, and more than 80 percent of the identified subsidence has been a consequence of human influence on groundwater (National Research Council 1991). The compaction of unconsolidated aquifers associated with excessive groundwater pumping is the single largest cause of subsidence (U.S. Geological Survey 2000).

When groundwater is extracted from some aquifers in sufficient quantity, the groundwater level is lowered, and the water pressure which supports the skeletal structure of the sediment grains decreases. A decrease in water pressure causes more of the overlying weight of the sediments to be supported by the sediment grains within the aquifer. In unconsolidated deposits, the overlying weight of the deposits may compact the fine-grained materials and result in a permanent decrease in porosity, the overall volume of the fine-grained sediments, and the ability to store water. This reduction in volume results in land subsidence and possible ground failures (California Department of Water Resources 2003). In the Sacramento River region, land subsidence associated with groundwater withdrawal has been documented in the North American and Yolo Groundwater subbasins. Additional land subsidence information for the Sacramento River region is provided in the “Land Subsidence Monitoring” and “Aquifer Conditions” sections of this report. An overview of land subsidence is provided in Appendix F.

Fractured-Rock Aquifers

Fractured-rock aquifers are generally found in the mountain and foothill areas adjacent to the alluvial groundwater basins. Because of the highly variable nature of void spaces in 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 10 gpm or less. Although fractured-rock aquifers are less productive compared with the alluvial aquifers in the region, fractured-rock aquifers tend to be a critically important water supply source for many individual domestic wells and small public water systems within the Sacramento River region.

The principal composition of the fractured-rock aquifer in the Fall River Valley Basin is Pliocene to Holocene volcanic rock. The Pliocene to Holocene volcanic rock consists of highly fractured basalt flows interbedded with layers of cinders. The basalt flows are the one component of the formation with a broad enough size to be a significant source of groundwater in the basin. In portions of the basin where the basalt is fractured and open, well yields can be high, but there are also areas where the basalt is impermeable and little to no groundwater can be produced.

Well Infrastructure

A key aspect to understanding the region’s groundwater supply and development is identifying the age, distribution, and type of wells that have been drilled in the region. A valuable source of well information are well completion reports, or well logs, submitted by licensed well drillers to the landowner, the local county department of environmental health, and DWR. Among other things, well logs commonly identify well location, construction details, borehole geology data, installation date, 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 who construct, alter, abandon, or destroy a well, to submit a well completion report (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 conducting studies, to the owner of the well, and to persons performing environmental cleanup studies.

Well logs submitted to DWR for wells completed from 1977 to 2010 were used to evaluate the distribution and the uses of groundwater wells in the region. DWR does not have well logs for all of the wells completed in the region; for some well logs, information regarding well location or use is inaccurate, incomplete, ambiguous, or missing. For these reasons, some well logs could not be used in the evaluation. Even so, for a regional-scale evaluation of well installation 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 in Appendix A.

The number and distribution of wells in the Sacramento River region are grouped according to their location by county and according to the six most common well-use types: domestic, irrigation, public supply, industrial, monitoring, and other. Public supply wells include all wells identified on the well log as municipal or public. Wells identified as “other” include a combination of the less-common well types, 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. Of the 22 counties located fully or partially within the Sacramento River region, details for 17 of these counties are included in this chapter. Nine of these detailed counties are fully contained with the Sacramento River region, and eight counties are partially contained within one or more adjacent hydrologic regions.

Well-log data listed in Table 7-3 and illustrated in Figure 7-3 show that the distribution and number of wells varies widely by county and by use. Table 7-3 also indicates which counties in the Sacramento River region are included in the well infrastructure analysis. The total number of wells installed in the Sacramento River region between 1977 and 2010 is approximately 108,346, and ranges from a high of 13,993 wells for Nevada County to a low of 389 wells for Sierra County.

The top counties with the most domestic wells are Nevada, Placer, El Dorado, Butte, Tehama, and Shasta, with a range of 13,282 to 7,453 wells. For Sacramento, Yolo, and Solano counties, the percentage of domestic wells compared with the overall total number of wells for each county is lower than the average for the region. These same three counties, though, have the highest percentage of monitoring wells, with monitoring wells accounting for 52, 39, and 28 percent of the total number of wells in Sacramento, Solano, and Yolo counties, respectively. Regions having a high percentage of monitoring wells, compared with other well types, tend to also have a higher number of local groundwater quality problem areas. Counties with the most irrigation wells on file include Butte, Yolo, Glenn, Sutter, and Tehama, with a range of about 1,170 to 614 wells.

Table 7-3 Number of Well Logs, According to Well Use and County, for the Sacramento River Hydrologic Region (1977-2010)

County	Total Number of Well Logs by Well Use						Total Well Records
	Domestic	Irrigation	Public Supply	Industrial	Monitoring	Other	
Modoc	1,320	381	17	6	103	188	2,015
Shasta	7,453	145	160	32	1,210	252	9,252
Tehama	7,889	614	79	19	540	331	9,472
Glenn	1,784	845	18	20	322	165	3,154
Butte	8,678	1,170	108	48	1,076	447	11,527
Plumas	2,876	76	116	22	212	148	3,450
Lake	2,757	500	105	13	283	239	3,897
Colusa	815	425	36	25	192	108	1,601
Sutter	1,375	663	66	25	422	107	2,658
Yuba	3,931	282	69	17	625	46	4,970
Sierra	253	23	21	1	56	35	389
Nevada	13,284	27	151	10	468	53	13,993
Placer	9,461	67	152	8	941	228	10,857
Sacrament	3,991	302	209	41	6,858	1,754	13,155
El Dorado	9,165	176	180	3	563	114	10,201
Yolo	1,355	828	89	42	1,027	300	3,641
Solano	1,873	257	52	36	1,616	280	4,114
Total Well Records	**78,260**	**6,781**	**1,628**	**368**	**16,514**	**4,795**	**108,346**

Figure 7-3 Number of Well Logs, According to County and Use, for the Sacramento River Hydrologic Region (1977-2010)

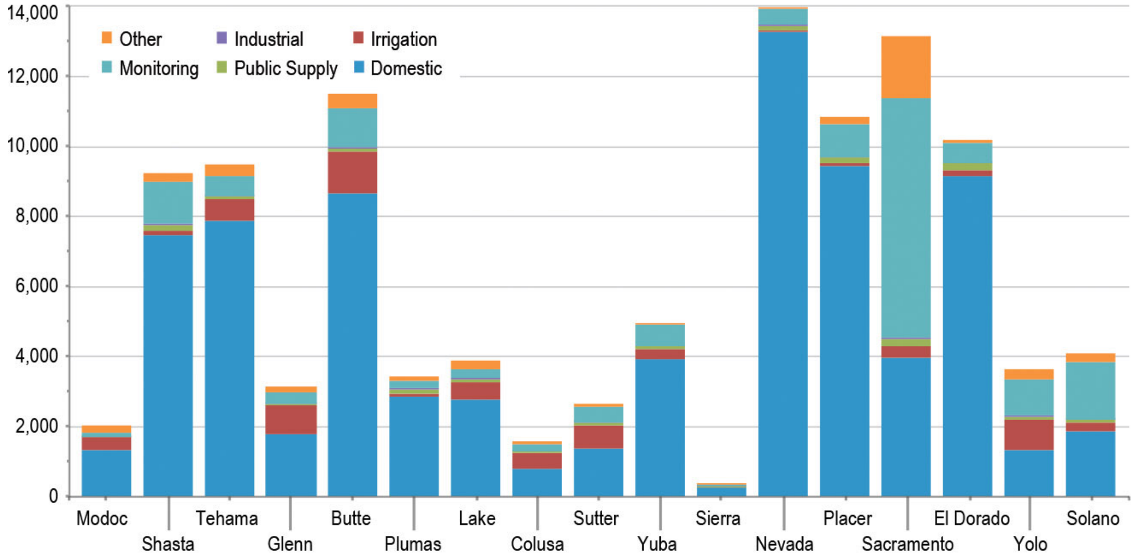

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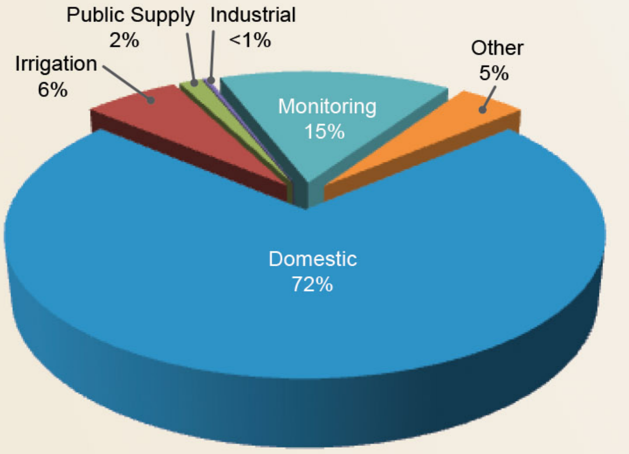
Figure 7-4 displays the percentage of wells, by well use, for the Sacramento River region between 1977 and 2010. Figure 7-4 shows that domestic, monitoring, and irrigation wells account for nearly 94 percent of all wells installed in the region, with domestic wells comprising 72 percent, irrigation wells totaling about 6 percent, and monitoring wells accounting for about 15 percent of well logs. Statewide, domestic wells account for about 54 percent of the total number of wells, irrigation wells account for about 10 percent of the total number of wells, and monitoring wells account for 24 percent of the total number of wells.

In addition to analyzing the number of wells by location and use, well logs were analyzed by well installation date (Figure 7-5). Evaluating the number and types of wells drilled over time can help offer a perspective on the average age of the existing infrastructure and the general pattern of wells installed during various water years and economic cycles. Well-log records for 2007 through 2010 are known to be less than complete because of lag time with drillers submitting logs to DWR and administrative constraints associated with processing and incorporating the data.

Figure 7-5 shows that the number of wells drilled in the Sacramento River region ranges from about 1,537 wells in 2010 (this number may be low) to 5,329 wells in 1990, with an average of 3,187 wells per year. Installation of irrigation wells tends to follow climatic conditions. Figure 7-5 shows that installation of irrigation wells peaked at 768 wells per year following the 1976-1977 drought, and continued at an average installation rate of 380 wells per year through 1981. Irrigation well installation dropped to under 100 wells per year during the wet years of the mid-1980s, before increasing to 371 wells per year during the drier years of 1989-1994, then dropping to 255 wells per year during the 2008-2009 drought. Much of the irrigation well infrastructure installed during the late 1970s and early 1980s is still being used today.

Similar to irrigation well installation, domestic well construction is often in response to changes in weather conditions. The average number of domestic wells installed between 1977 and 2010 was 2,302 wells per year; however, between 1988 and 1994, the average rate of domestic well installation was 3,083 wells per year, with a peak in 1990 of 4,215 domestic wells drilled. Variations in domestic well drilling activity can also be attributed to economic trends and the associated fluctuation in residential housing construction. The years between 2002 and 2006 were generally seen as a housing boom in the Sacramento River region, and domestic well installations peaked during this time at 2,909 wells in 2003. Similarly, the 2007 to 2010 decline in domestic well drilling is likely the result of declining economic conditions and a 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 logs.

Figure 7-4 Percentage of Well Logs, According to Type of Use, for the Sacramento River Hydrologic Region (1977-2010)

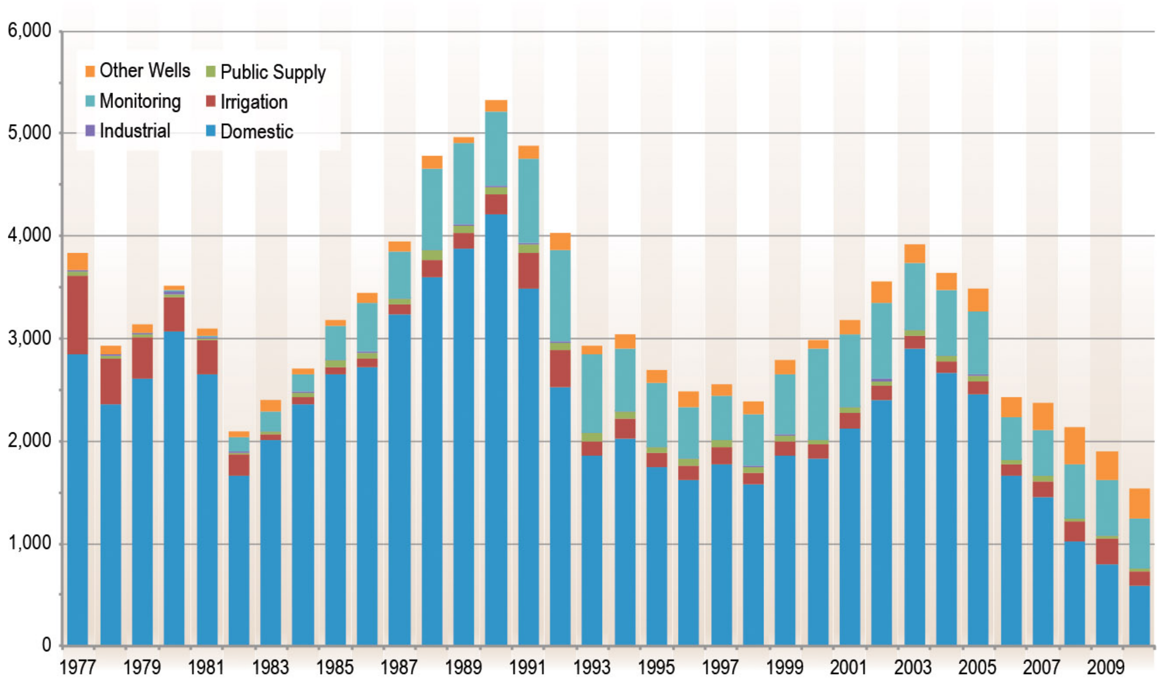


Sacramento River Well Logs Summary by Well Type

Well Type	Number of Well Logs
Domestic	78,260
Irrigation	6,781
Public Supply	1,628
Industrial	368
Monitoring	16,514
Other	4,795
Total	**108,346**

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

Figure 7-5 Number of Well Logs Filed per Year, According to Well Use, for the Sacramento River Hydrologic Region (1977-2010)



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Monitoring wells in the Sacramento River region were first recorded in significant numbers in 1982, with 141 wells installed that year. Starting in 1984, the State of California Underground Storage Tank program took effect and the installation of wells to monitor groundwater quality quickly increased to 893 monitoring wells installed in 1992. Between 1984 and 2010, an average of 598 monitoring wells was installed each year. The DWR well-log database does not distinguish between monitoring wells installed as part of a groundwater cleanup project, versus those installed primarily to collect changes in groundwater levels. But, because of the high number of local groundwater quality assessment and remediation projects, it is estimated that the majority of monitoring well installation is in response to groundwater quality monitoring.

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 current extent of groundwater elevation monitoring in 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 (California Water Code Section 10933[b]) directs DWR to consider, to the extent data are available, the following eight 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 and categorized them into four prioritization groups: high, medium, low, and very low.

Table 7-4 lists the draft CASGEM high-, medium-, and low-priority groundwater basins for the Sacramento River region. The final CASGEM groundwater basin prioritization is provided in Appendix B. Figure 7-6 shows the groundwater basin prioritization for the region. Of the 88 groundwater basins and subbasins in the Sacramento River region, five subbasins (West Butte, South American, North American, Vina, and Yolo) in the Sacramento Valley Basin are identified as high priority. Sixteen basins and subbasins are listed as medium priority, seven basins are low priority, and the remaining 60 basins and subbasins in the region are very low priority. The 21 basins and subbasins designated as high or medium priority include 89 percent of the annual groundwater use in the region, and encompass 98 percent of the 2010 population that overlies the alluvial groundwater basin area.

Table 7-4 CASGEM Prioritization for Groundwater Basins in the Sacramento River Hydrologic Region

Basin Priority	Count	Basin/Subbasin Number	Basin Name	Subbasin Name	2010 Census Population
High	1	5-21.58	Sacramento Valley	West Butte	36,152
High	2	5-21.65	Sacramento Valley	South American	718,113
High	3	5-21.64	Sacramento Valley	North American	832,746
High	4	5-21.57	Sacramento Valley	Vina	71,397
High	5	5-21.67	Sacramento Valley	Yolo	194,158
Medium	1	5-21.52	Sacramento Valley	Colusa	48,369
Medium	2	5-21.54	Sacramento Valley	Antelope	6,124
Medium	3	5-12.01	Sierra Valley	Sierra Valley	2,196
Medium	4	5-21.59	Sacramento Valley	East Butte	38,465
Medium	5	5-21.51	Sacramento Valley	Corning	18,852
Medium	6	5-14	Scotts Valley		6,553
Medium	7	5-21.62	Sacramento Valley	Sutter	82,125
Medium	8	5-6.04	Redding Area	Enterprise	68,627
Medium	9	5-15	Big Valley		6,344
Medium	10	5-21.66	Sacramento Valley	Solano	119,263
Medium	11	5-6.03	Redding Area	Anderson	52,937
Medium	12	5-6.01	Redding Area	Bowman	7,165
Medium	13	5-21.50	Sacramento Valley	Red Bluff	28,053
Medium	14	5-21.61	Sacramento Valley	South Yuba	45,014
Medium	15	5-21.56	Sacramento Valley	Los Molinos	2,220
Medium	16	5-21.55	Sacramento Valley	Dye Creek	1,626
Low	7	See Appendix B			
Very Low	60	See Appendix B			
Total	**88**	**Population of Groundwater Basin Area:**			**2,450,515**[a]

Notes:

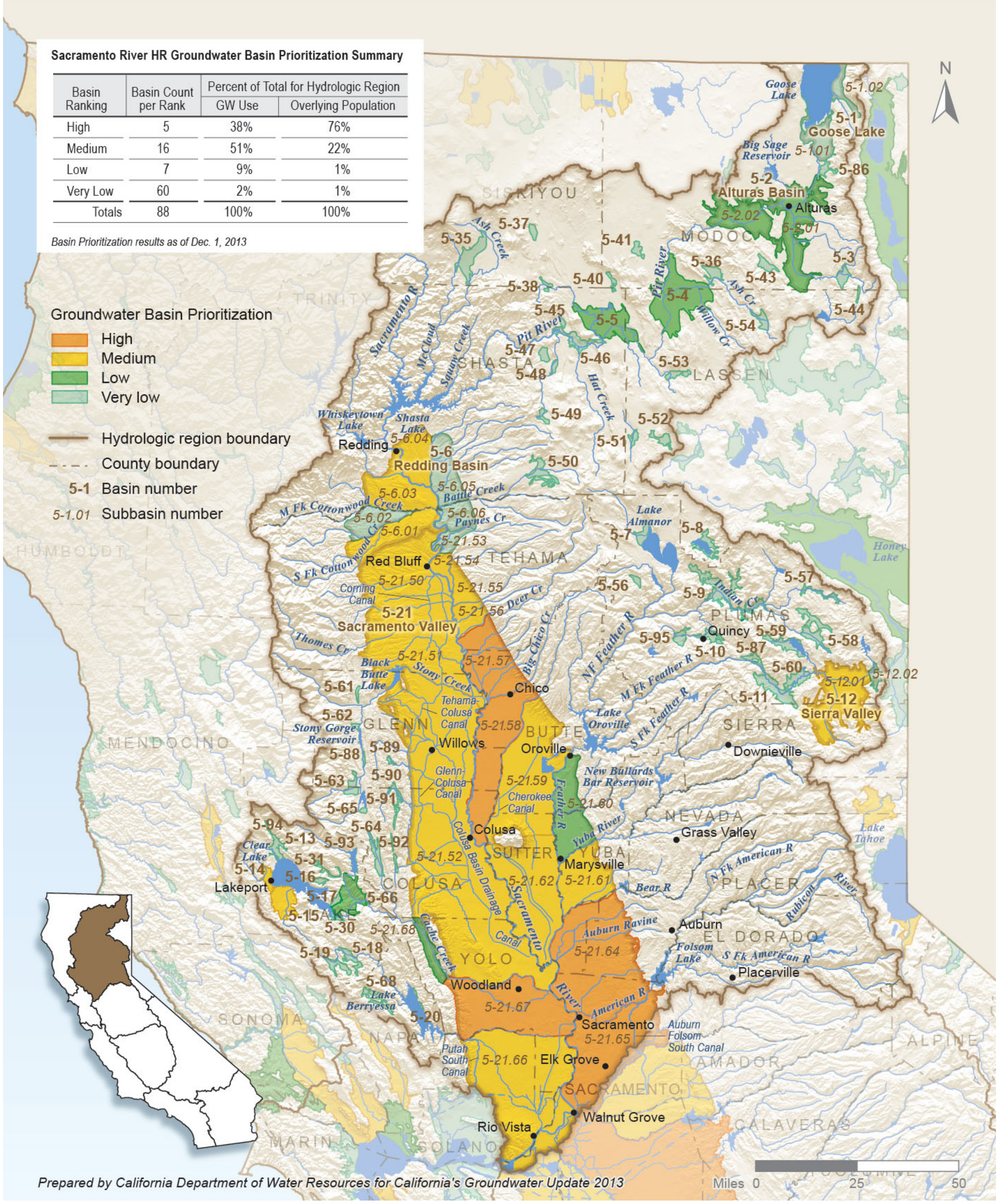
[a] Population of groundwater basin area includes the population of all basins within Sacramento River Hydrologic Region.

Ranking as of December 2013 (Draft).

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, DWR 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 effects 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 DWR.

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

Figure 7-6 CASGEM Groundwater Basin Prioritization for the Sacramento River Hydrologic Region



Sacramento River HR Groundwater Basin Prioritization Summary

Basin Ranking	Basin Count per Rank	Percent of Total for Hydrologic Region	
		GW Use	Overlying Population
High	5	38%	76%
Medium	16	51%	22%
Low	7	9%	1%
Very Low	60	2%	1%
Totals	88	100%	100%

Basin Prioritization results as of Dec. 1, 2013

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

Although the primary intent of basin prioritization is to assist DWR in implementing the CASGEM Program, which is based on the comprehensive set of data included in the analysis, basin prioritization is also a valuable statewide tool to help evaluate, focus, and align limited resources. Basin prioritization is also an important tool to implement effective groundwater management practices by improving the statewide reliability and sustainability of groundwater resources.

In the Sacramento River region, implementation of sustainable groundwater resource management should focus initially on the 21 basins listed in Table 7-4 as medium or high priority.

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 publically record their annual groundwater extraction amount. 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 the first to be 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 frequent exchanges between surface water and groundwater supplies, making accurate estimates of annual groundwater extraction by 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 are first compiled and analyzed by detailed analysis units (DAUs). Water and supply data for DAUs are then compiled into larger planning areas, into hydrologic regions after that, 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 local groundwater basins, DWR does not currently generate groundwater use 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 wetland uses. Reference to *total water supply* for a region represents the sum of surface water supplies, groundwater supplies, and reused/recycled water supplies. Groundwater use information is presented by planning area, county, and by type of use. Additional information regarding water use analysis is provided in Appendix A and in Appendix C."

2005-2010 Average Annual Groundwater Supply

Water demands in the Sacramento River region are met through a combination of local surface water supplies, State (SWP) and federal (CVP) surface water deliveries, groundwater, and recycled water supplies. The 2005-2010 average annual total water supply for the region is estimated at 9,008 taf. Local groundwater resources play a significant role in meeting annual water demands by contributing about 30 percent (2,743 taf) to the total overall supply. Groundwater extraction in the Sacramento River region accounts for approximately 17 percent of California’s 2005-2010 average annual groundwater use.

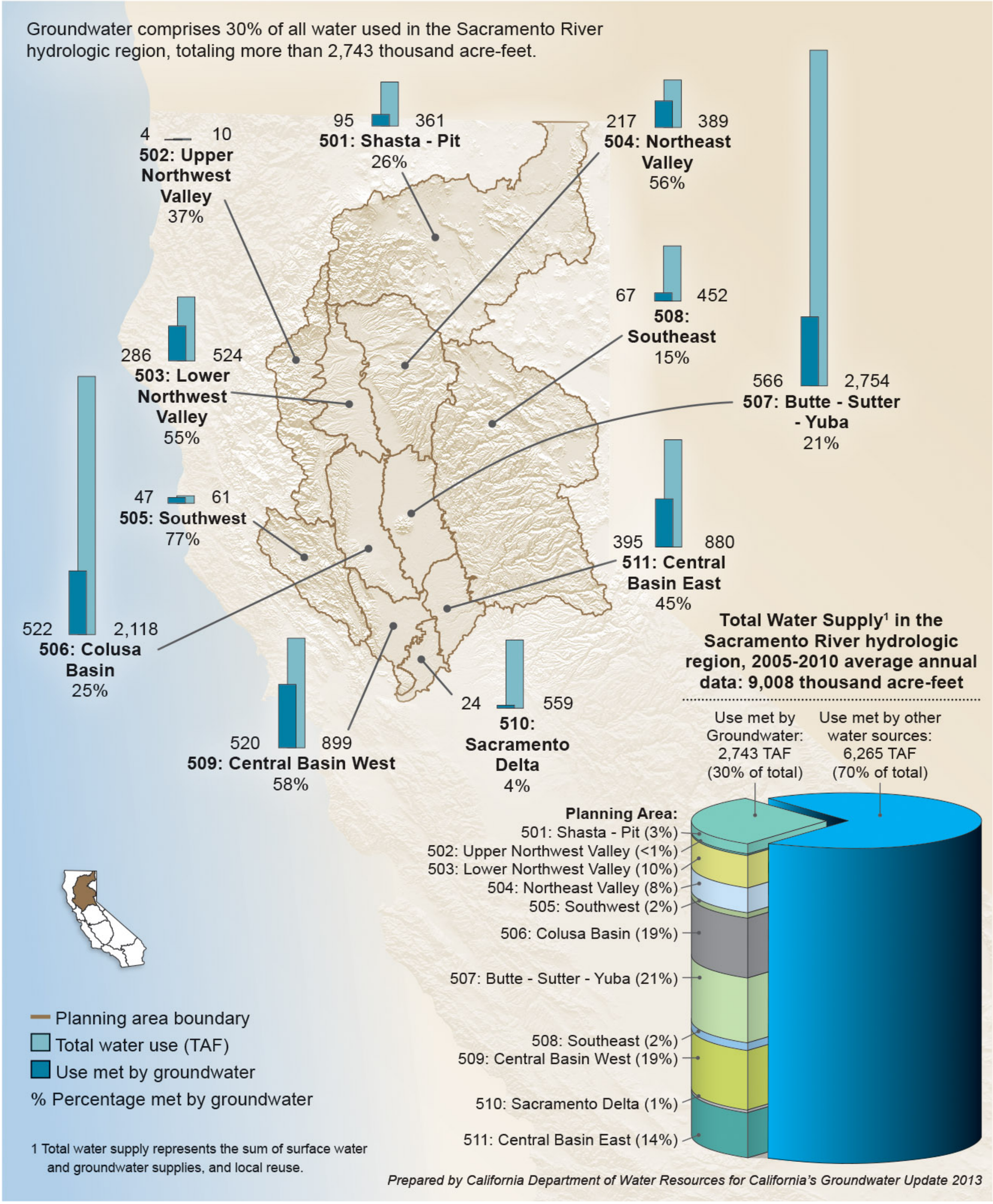
The Sacramento River region includes 11 planning areas. Table 7-5 lists the 2005-2010 average annual total water supply met by groundwater, by planning area and by type of use, and shows the quantity and the percentage of groundwater contribution to the total water supply for the region. Table 7-6 identifies the percentage of the Sacramento River region’s annual groundwater supply used within each planning area, by type of use. Figure 7-7 shows the planning areas for the region and illustrates the groundwater use information presented in Table 7-5 and Table 7-6.

Table 7-5 shows that, on average, groundwater supplies contribute to 30 percent (2,743 taf) of the total water supply within the Sacramento River region. Evaluating groundwater supply by type of use indicates that groundwater contributes to 30 percent (2,294 taf) of the total annual agricultural water supply, 47 percent (429 taf) to the total urban water supply, and 4 percent (20 taf) to the total managed wetlands supply.

Groundwater use by planning area shows that two of the largest groundwater users in the region, the Butte-Sutter-Yuba Planning Area (PA) and Colusa Basin PA, rely on about 1,007 taf of combined groundwater pumping to meet 21 and 25 percent, respectively, of their total water supply. In terms of volume, the Butte-Sutter-Yuba PA applies 90 percent (508 taf) of the groundwater extracted toward agricultural purposes, while the Colusa Basin PA uses 96 percent (499 taf) of the groundwater extracted for agricultural purposes.

The annual pumping volume and reliance on groundwater supplies is also high for the Central Basin West PA, as groundwater pumping is required to meet 58 percent (520 taf) of their total water supply. For the Central Basin West PA, 91 percent of the groundwater extracted (473 taf) meets 57 percent of the total agricultural water needs in the planning area. The Southwest PA is the planning area most reliant upon groundwater because 77 percent (47 taf) of its combined urban and agricultural water supply comes from groundwater. The one Sacramento River planning area 100-percent reliant on groundwater to meet total urban water supply is the Colusa Basin PA, using 14 taf for urban use annually.

Figure 7-7 **Groundwater Use and Total Water Supply Met by Groundwater, According to Planning Area, in the Sacramento River Hydrologic Region (2005-2010)**



Groundwater comprises 30% of all water used in the Sacramento River hydrologic region, totaling more than 2,743 thousand acre-feet.

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

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Table 7-5 Percentage of Average Annual Total Water Supply Met by Groundwater, According to Planning Area and Type of Use, for the Sacramento River Hydrologic Region (2005-2010)

Sacramento River 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]**
501	Shasta - Pit	83.2	25%	11.3	67%	0.0	0%	94.5	26%
502	Upper Northwest	3.3	35%	0.4	62%	0.0	0%	3.7	37%
503	Lower Northwest	238.4	51%	47.9	79%	0.0	0%	286.3	55%
504	Northeast Valley	175.3	57%	41.5	51%	0.0	0%	216.8	56%
505	Southwest	42.1	81%	5.1	54%	0.0	0%	47.1	77%
506	Colusa Basin	498.7	26%	14.0	100%	9.2	6%	521.9	25%
507	Butte - Sutter - Yuba	508.3	21%	47.2	69%	10.9	4%	566.4	21%
508	Southeast	44.0	13%	23.3	20%	0.0	0%	67.3	15%
509	Central Basin West	473.0	57%	47.0	65%	0.0	0%	520.0	58%
510	Sacramento Delta	19.5	4%	4.6	15%	0.0	0%	24.2	4%
511	Central Basin East	208.5	47%	186.4	43%	0.0	0%	394.9	45%
2005-2010 Annual Average HR Total		**2,294.2**	**30%**	**428.6**	**47%**	**20.1**	**4%**	**2,742.9**	**30%**

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 met by groundwater, by type of use.

2005-2010 precipitation equals 96 percent of the 30-year average for the Sacramento River Hydrologic Region.

The Central Basin East PA is the largest urban groundwater user for the region. Urban water use for the Central Basin East PA is about 186 taf annually, which is more than triple the urban use amount of the next highest planning area in the Sacramento River region. The Central Basin East PA includes several urban centers, including the city of Sacramento, and uses groundwater to meet 43 percent of their total urban water supply and 47 percent of their total agricultural water supply.

Groundwater contributes 4 percent of region's total managed wetland supply, with all of the groundwater supply for managed wetland use (20 taf) occurring in the Butte-Sutter-Yuba and Colusa Basin PAs.

Table 7-6 provides a percentage breakdown of the Sacramento River region's average annual groundwater extraction, by planning area and by the type of use. On a region-wide scale, 84 percent of the average groundwater extraction went toward agricultural needs, 16 percent were used to meet urban demands, and less than 1 percent of the total groundwater extraction went toward managed wetlands use.

Table 7-6 Average Annual Groundwater Supply, According to Planning Area and Type of Use, in the Sacramento River Hydrologic Region (2005-2010)

Sacramento River Hydrologic Region		Agriculture Use of Groundwater	Urban Use of Groundwater	Managed Wetlands Use of Groundwater	Groundwater Use by PA
PA Number	**PA Name**	**%[a]**	**%[a]**	**%[a]**	**%[b]**
501	Shasta - Pit	88%	12%	0%	3%
502	Upper Northwest Valley	89%	11%	0%	0%
503	Lower Northwest Valley	83%	17%	0%	10%
504	Northeast Valley	81%	19%	0%	8%
505	Southwest	89%	11%	0%	2%
506	Colusa Basin	96%	3%	2%	19%
507	Butte - Sutter - Yuba	90%	8%	2%	21%
508	Southeast	65%	35%	0%	2%
509	Central Basin West	91%	9%	0%	19%
510	Sacramento Delta	81%	19%	0%	1%
511	Central Basin East	53%	47%	0%	14%
2005-2010 Annual Average HR Total		**84%**	**16%**	**< 1%**	**100%**

Notes:

HR = hydrologic region, PA = planning area

[a] *Percent use* is the average annual groundwater use by planning area and type of use, compared with the total groundwater use for the hydrologic region.

[b] Percentage of hydrologic region total groundwater use.

Groundwater Use by County Boundaries

Groundwater supply and use was also calculated by county for the Sacramento River Region. County boundaries do not align with planning area or hydrologic region boundaries, so regional totals for groundwater, based on county area, vary from the estimates shown in Table 7-5. The Sacramento River region includes all or most of Butte, Colusa, Glenn, Lake, Napa, Nevada, Placer, Plumas, Sacramento, Shasta, Sierra, Solano, Sutter, Tehama, Yolo, and Yuba counties, and small areas of El Dorado, Alpine, Amador, Lassen, Modoc, and Siskiyou counties. Tables showing groundwater use for all 58 California counties are provided in Appendix C.

Table 7-7 lists the 2005-2010 average annual groundwater use by county, by type of use, and by the percentage that groundwater contributes to the total water supply. Table 7-7 also lists the 17 counties included in the water analysis for the Sacramento River region. When calculating total groundwater use by county, the total groundwater use is estimated at 2,920 taf, which is higher than the 2,743 taf estimate created by using planning area boundaries.

Table 7-7 shows that groundwater contributes 13 to 75 percent of the total water supply for the counties included in the Sacramento River region. Although the vast majority of groundwater extraction in the Sacramento River region occurs for agricultural purposes (83 percent), groundwater supplies contribute 31 percent of the total agricultural water supply for the 17-county area. In contrast, groundwater supplies for urban use in the region amount to 16 percent of the overall groundwater use, but contribute to 45 percent of the total water supply for urban use.

Table 7-7 Average Annual Total Water Supply Met by Groundwater, According to County and Type of Use, for the Sacramento River Hydrologic Region (2005-2010)

Sacramento River Hydrologic Region	**Agriculture Use Met by Groundwater**		**Urban Use Met by Groundwater**		**Managed Wetlands Use Met by Groundwater**		**Total Water Use Met by Groundwater**	
County	**taf**	**%**[a]	**taf**	**%**[a]	**taf**	**%**[a]	**taf**	**%**
Butte	367.7	32%	51.0	73%	9.1	9%	427.7	32%
Colusa	231.6	19%	7.9	98%	7.7	5%	247.2	18%
El Dorado	0.6	4%	9.0	15%	0.0	0%	9.6	13%
Glenn	277.5	28%	11.0	100%	3.3	4%	291.8	27%
Lake	36.5	80%	4.6	52%	0.0	0%	41.0	75%
Modoc	90.9	25%	3.0	92%	0.0	0%	93.9	20%
Nevada	1.0	3%	8.3	29%	0.0	0%	9.3	14%
Placer	17.7	9%	20.8	19%	0.0	0%	38.5	13%
Plumas	14.4	18%	9.0	65%	0.0	0%	23.4	25%
Sacramento	179.1	44%	191.2	46%	0.1	0%	370.5	44%
Shasta	24.1	11%	40.2	47%	0.0	0%	64.3	21%
Sierra	23.9	30%	1.0	87%	0.0	0%	24.9	30%
Solano	254.6	46%	20.1	21%	0.0	0%	274.8	43%
Sutter	252.8	26%	9.6	37%	0.0	0%	262.4	24%
Tehama	227.6	66%	20.6	92%	0.0	0%	248.2	67%
Yolo	360.4	43%	38.8	68%	0.0	0%	399.2	44%
Yuba	74.4	21%	19.1	98%	0.0	0%	93.5	24%
2005-2010 Annual Average Total	**2,434.7**	**31%**	**465.2**	**45%**	**20.2**	**4%**	**2,920.0**	**31%**

Notes:

taf = thousand acre-feet

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

2005-2010 precipitation equals 96 percent of the 30-year average for the Sacramento River Hydrologic Region.

As previously stated and listed on Table 7-4, the 21 basins and subbasins designated as high or medium priority through CASGEM basin prioritization include 89 percent of the annual groundwater use in the region, and encompass 98 percent of the region's 2010 population overlying the alluvial groundwater basin area in the Sacramento River 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. Recent agricultural cropping trends for the Sacramento River region show a significant shift away from annual crops using surface water, toward permanent high-value crops reliant on groundwater. The trend toward an increased percentage of permanent crops versus annual crops tends to harden the demand for groundwater, regardless of the water year type.

Figure 7-8 illustrates the 2002-2010 total water supply trend for the Sacramento River region. The right side of Figure 7-8 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 met by those water sources. The center column identifies the water year along with the corresponding amount of precipitation, as a percentage of the 30-year average for the hydrologic region.

As shown in Figure 7-8, the total annual water supply for the Sacramento River region remained relatively stable, ranging from a low of 8,269 taf in 2003 to a high of 9,851 taf in 2004, with a nine-year average of approximately 9,049 taf. The amount of groundwater contributed to the total supply during this same nine-year period was also fairly stable, ranging between 28 and 32 percent of the total water supply for the region. Groundwater extraction during the 2002-2010 period averaged about 2,714 taf, with a low of 2,446 taf extracted in 2005 and a high of 3,069 taf in 2008. Figure 7-8 also shows that the amount of reuse water used in the Sacramento River region between 2002 and 2010 ranged from a low of 257 taf in 2004 to a high of 1,260 taf in 2006. As shown, reuse water contributed between 3 and 14 percent of the total water used annually during that 9-year period.

The wet water years of 2005 and 2006 saw the least amount of groundwater pumped; during this time, groundwater extraction was reduced to 2,446 taf and 2,478 taf, contributing 29 percent and 28 percent, respectively, of the total water supply. Conversely, during the dry years of 2007, 2008, and 2009, groundwater extraction, in response to cutbacks in surface water deliveries in the Sacramento River region, increased to 2,961 taf, 3,069 taf, and 2,919 taf, respectively, contributing about 32 percent of the total water supply.

Figure 7-9 shows the 2002-2010 groundwater supply trend by urban, agricultural, and managed wetland uses in the Sacramento River region. The right side of Figure 7-9 illustrates the annual volume of groundwater extraction by type of use, while the left side shows the percentage of groundwater extraction by type of use. The percentage of total groundwater extraction used to meet the agricultural water needs for the region ranged from a low of 81 percent in 2002, 2003, and 2010, to a high of 87 percent in 2004. During the dry and critically dry years of 2007, 2008, and 2009, groundwater pumping for agricultural use increased by approximately 500 taf when compared with the wet years that preceded and followed the dry years. The increase in groundwater extraction is attributed to a combination of increased irrigation demand and reduced surface water deliveries during these consecutive dry and critically dry years.

Groundwater pumping to meet urban water needs ranged from about 367 taf in 2004 to about 479 taf in 2010, and contributed between 13 and 19 percent toward the overall urban water supply. Compared with agricultural and urban uses in the Sacramento River region, groundwater supplies for managed wetlands use was fairly minor. Use of groundwater for managed wetlands ranged from 17 taf to 23 taf and contributed approximately 1 percent of the total managed wetland water supply.

Figure 7-8 **Annual Surface Water and Groundwater Supply Trend for the Sacramento River Hydrologic Region (2002-2010)**

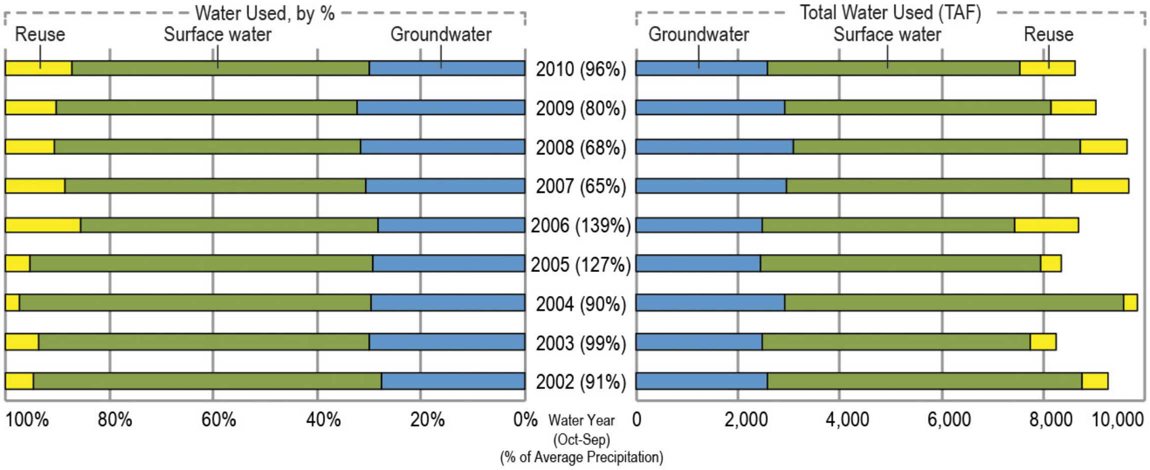

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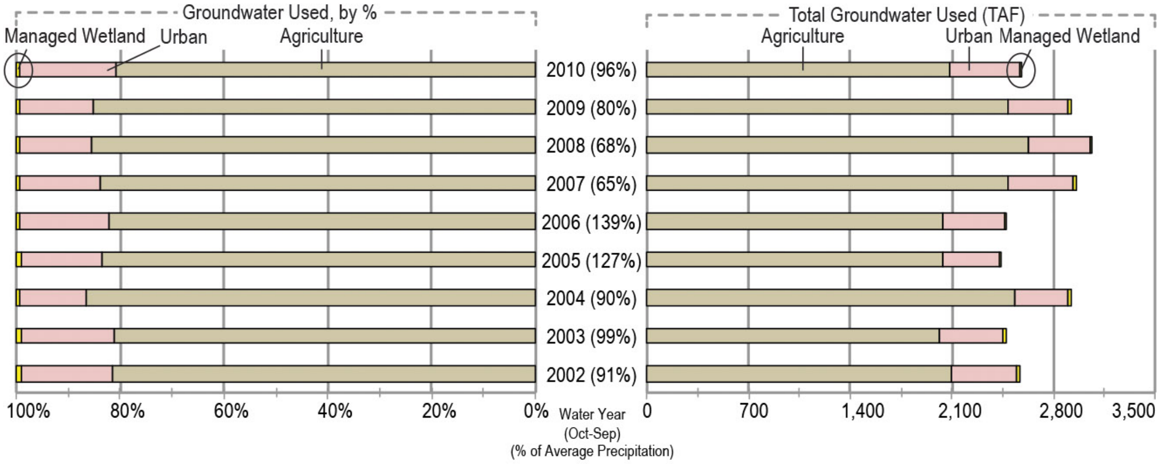
Figure 7-9 **Annual Groundwater Supply Trend, According to Type of Use, for the Sacramento River Hydrologic Region (2002-2010)**



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Groundwater Monitoring Efforts

Groundwater resource monitoring and evaluation is essential to understanding groundwater conditions, identifying effective resource management strategies, 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 in the Sacramento River region. The summary includes publically available groundwater data compiled by DWR, State Water Resources Control Board (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 in Appendix A.

Groundwater-level Monitoring

State and federal agencies with groundwater-level monitoring programs in the region include DWR, USGS, and USBR. Groundwater-level monitoring is also performed by CASGEM-designated monitoring entities, as well as local cooperators who measure or contract with others to measure groundwater levels. Groundwater-level information presented in this section represents data that are publically available through DWR or USGS online information systems. Privately collected and locally maintained groundwater-level information is not discussed in this section. 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 Sacramento River 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 the USGS National Water Information System (http://waterdata.usgs.gov/nwis).

A list of the number of monitoring wells in the Sacramento River region by monitoring agencies, cooperators, and CASGEM-designated monitoring entities is in Table 7-8. The locations of these monitoring wells, by monitoring entity and monitoring well type, are shown in Figure 7-10.

Table 7-8 shows that 1,306 wells in the Sacramento River region are actively monitored for groundwater-level information. The DWR monitoring network consists of 635 wells located in 36 of the region’s 88 alluvial basins and subbasins. The USBR monitoring network consists of 150 wells in six basins and subbasins, and the USGS actively monitors four wells in two subbasins. In addition to the State and federal agency monitoring efforts, six cooperators and 14 CASGEM monitoring entities monitor a combined total of 517 wells in 19 basins and subbasins in the Sacramento River region.

As part of the CASGEM basin-prioritization process, five subbasins in the Sacramento Valley Basin are identified as high priority, 16 basins and subbasins are listed as medium priority, seven basins rank a low priority, and the remaining 60 basins and subbasins in the region are very low priority. The 21 subbasins designated as high or medium priority include 89 percent of the annual groundwater use in the region and encompass 98 percent of the region's 2010 population. A list of the priority basins for the Sacramento River region, along with a breakdown of the number of groundwater-level monitoring wells, is provided in Table 7-9. The monitoring data in Table 7-9 includes just those wells entered into the CASGEM system as of July 2012.

Most of the groundwater-level monitoring networks include a variety of well-use types. The groundwater-level monitoring wells are categorized by the type of well use and include irrigation, domestic, observation, public supply, and 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 (wells with no information listed in 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 irrigation wells used for groundwater-level monitoring include actively operated wells, and some consist of older inactive or unused wells.

Typically, domestic wells are relatively shallow and screened in the upper portion of the aquifer system, while irrigation wells tend to be constructed deeper in the aquifer system. Consequently, 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, and are designed to characterize groundwater conditions at very specific and discrete production intervals throughout the aquifer system.

Figure 7-10 indicates what agency collects the groundwater elevation data and graphically displays groundwater-level monitoring wells by use. A percentage breakdown of the groundwater-level monitoring wells by use is illustrated by the pie chart. Based on the data available, irrigation wells and observation wells combine for over two-thirds of the groundwater-level monitoring wells in the region, with irrigation wells comprising 36 percent of the monitoring wells, and observation wells accounting for 32 percent of the region's groundwater-level wells. Domestic wells provide 21 percent of the region's groundwater-level information, and "other" wells account for 11 percent of the groundwater-level data.

Table 7-8 Groundwater-Level Monitoring Wells by Monitoring Entity for the Sacramento River Hydrologic Region

State and Federal Agencies	**Number of Wells**
California Department of Water Resources	635
U.S. Geological Survey	4
U.S. Bureau of Reclamation	150
Total State and Federal Wells	**789**
Monitoring Cooperators	**Number of Wells**
Colusa Rancheria	8
Sacramento County	18
Sutter County	6
Sutter South Water District	1
Yolo County Flood Control and Water Conservation District	118
Yuba County	30
Total Cooperator Wells	**181**
CASGEM Monitoring Entities	**Number of Wells**
Butte County Department of Water and Resource Conservation	70
City of Roseville	11
Colusa County	28
Feather Water District	4
Glenn County Department of Agriculture	82
Reclamation District No. 1500	7
Sacramento Central Groundwater Authority	24
Sacramento Groundwater Authority	35
Shasta County	3
South Sutter Water District	20
Sutter Extension Water District	9
Tehama County Flood Control and Water Conservation District	27
Water Resources Association of Yolo County	6
Yuba County Water Agency	10
Total CASGEM Monitoring Entity Wells	**336**
Total Sacramento River Hydrologic Region Monitoring Wells	**1,306**

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.

Table 7-9 Groundwater-Level Monitoring Wells within the CASGEM High- and Medium-Priority Basins for the Sacramento River Hydrologic Region

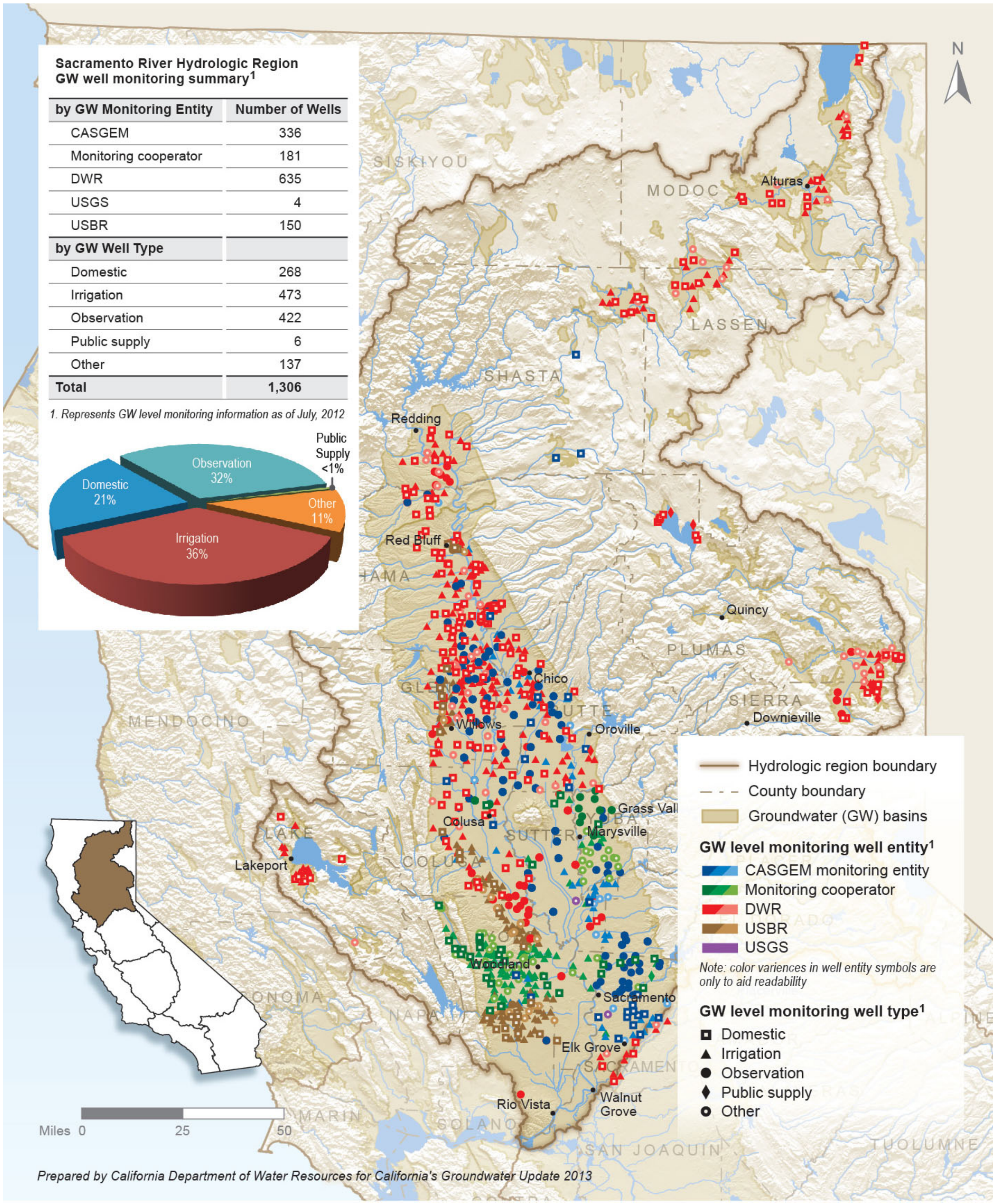
Basin/Subbasin Number	Basin Name	Subbasin Name	Basin Priority	Groundwater-Level Monitoring Wells[a,b]
5-21.58	Sacramento Valley	West Butte	High	54
5-21.65	Sacramento Valley	South American	High	40
5-21.64	Sacramento Valley	North American	High	94
5-21.57	Sacramento Valley	Vina	High	81
5-21.67	Sacramento Valley	Yolo	High	101
5-21.52	Sacramento Valley	Colusa	Medium	337
5-21.54	Sacramento Valley	Antelope	Medium	15
5-12.01	Sierra Valley	Sierra Valley	Medium	49
5-21.59	Sacramento Valley	East Butte	Medium	70
5-21.51	Sacramento Valley	Corning	Medium	85
5-14	Scotts Valley		Medium	3
5-21.62	Sacramento Valley	Sutter	Medium	34
5-6.04	Redding Area	Enterprise	Medium	14
5-15	Big Valley		Medium	16
5-21.66	Sacramento Valley	Solano	Medium	47
5-6.03	Redding Area	Anderson	Medium	21
5-6.01	Redding Area	Bowman	Medium	12
5-21.50	Sacramento Valley	Red Bluff	Medium	30
5-21.61	Sacramento Valley	South Yuba	Medium	26
5-21.56	Sacramento Valley	Los Molinos	Medium	29
5-21.55	Sacramento Valley	Dye Creek	Medium	8

Notes:

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

[b] Total of 1,166 wells monitored as of July 2012.

Figure 7-10 Monitoring Well Location by Agency, Monitoring Cooperator, and CASGEM Monitoring Entity for the Sacramento River Hydrologic Region



Sacramento River Hydrologic Region GW well monitoring summary[1]

by GW Monitoring Entity	Number of Wells
CASGEM	336
Monitoring cooperator	181
DWR	635
USGS	4
USBR	150
by GW Well Type	
Domestic	268
Irrigation	473
Observation	422
Public supply	6
Other	137
Total	**1,306**

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

Hydrologic region boundary
County boundary
Groundwater (GW) basins

GW level monitoring well entity[1]
CASGEM monitoring entity
Monitoring cooperator
DWR
USBR
USGS

Note: color variences in well entity symbols are only to aid readability

GW level monitoring well type[1]
■ Domestic
▲ Irrigation
● Observation
♦ Public supply
○ Other

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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 is used to evaluate current conditions, and can be used to establish groundwater quality thresholds and 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 future 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 current 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 Sacramento River region groundwater-quality monitoring results is beyond the scope of this report. A summary of the statewide and regional groundwater-quality monitoring results and information is provided below.

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) Web site (http://www.waterboards.ca.gov/gama/geotracker_gama.shtml), and the 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 over 200,000 wells and contains more than 125 million data records. These data records were obtained from different sources, such as the SWRCB, regional water quality control boards, CDPH, California Department of Pesticide Regulation (DPR), USGS, and Lawrence Livermore National Laboratory (LLNL). 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 7-10 lists agency-specific groundwater quality information. Additional information regarding assessment and reporting of groundwater quality information is listed under the "Aquifer Conditions" section of this chapter.

Table 7-10 Sources of Groundwater Quality Information for the Sacramento River Hydrologic Region

Agency	Links to Information
State Water Resources Control Board http://www.waterboards.ca.gov/	**Groundwater** http://www.waterboards.ca.gov/water_issues/programs/#groundwater) • Communities that Rely on a Contaminated Groundwater Source for Drinking Water http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/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) Program** 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/
California Department of Public Health http://www.cdph.ca.gov/Pages/DEFAULT.aspx	**Division of Drinking Water and Environmental Management** http://www.cdph.ca.gov/programs/Pages/DDWEM.aspx • 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-6 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
California 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

Agency	Links to Information
	• Well Completion Reports http://www.water.ca.gov/groundwater/wells/well_completion_reports.cfm
California Department of Toxic Substance Control http://www.dtsc.ca.gov/	EnviroStor http://www.envirostor.dtsc.ca.gov/public/
California 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/	U.S. Environmental Protection Agency STORET Environmental Data System http://www.epa.gov/storet/
U.S. Geological Survey http://ca.water.usgs.gov/	U.S. Geological Survey 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 that supports the skeletal structure of the sediment grains decreases. A decrease in water pressure causes more weight from the overlying sediments to be supported by the sediment grains in the aquifer. In unconsolidated deposits, the increased weight from overlying sediments may compact 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 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 in the Sacramento River region occurs from compaction of clay beds within the aquifer systems. A more in-depth discussion of the mechanics of land subsidence can be found in Appendix F of this report. DWR also maintains an extensive display of information dedicated to the subject of land subsidence in the Sacramento River Basin, including mechanics, potential, monitoring, and data collected. This information can be reviewed at the following Web sites:

- http://www.water.ca.gov/groundwater/.
- http://www.water.ca.gov/floodsafe/fessro/subsidence.cfm.

DWR monitors land subsidence using extensometers and a surveyed global positioning system (GPS) network. While extensometers are site-specific monitoring devices that generally monitor subsidence on a local level, GPS networks use many sites to monitor regional trends over greater distances.

Figure 7-11 shows the locations of the 11 extensometers and GPS locations currently in use throughout the Sacramento River region. Table 7-11 lists the data for the extensometers, along with the location and type of extensometer. The following sections contain information about the types of subsidence monitoring DWR performs, as well as a brief overview of additional types of subsidence monitoring by varying agencies.

Borehole Extensometer Monitoring

A borehole extensometer is designed to act as a 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 the 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.

The first extensometer DWR installed in the Sacramento River region was in 1992, the next was installed in 1994, and eight more were installed in 2005. In 1992, DWR began maintaining and monitoring an extensometer that USGS installed in Yolo County in 1988. The locations of the extensometers were based on geographic distribution in the center portion of the valley and where access to a site could be obtained. The extensometers in the Sacramento Valley range in depth from 716 feet deep to over 1,000 feet deep.

GPS Subsidence Monitoring

In 2008, DWR, together with 20 State, federal, and local agencies, developed and surveyed a land elevation measurement network in the Sacramento Valley. The Sacramento Valley Height-Modernization Project provides accurate measurements of land surface elevations with GPS technology using a consistent vertical datum known as “NAVD88.” Land elevations were measured using the GPS survey equipment and survey monuments located on an approximate 3- to 5-mile grid.

The GPS station network consists of 339 survey monuments that covers all or part of 10 counties (Figure 7-11). The network extends from northern Sacramento County eastward to the USBR’s Folsom Lake network, southwest to DWR’s Delta/Suisun Marsh network, and north to USBR’s Lake Shasta network. DWR and USBR shared the cost of a contract, which coordinated field measurements involving 47 staff from various agencies. The network is scheduled to be re-surveyed on a 3-year frequency to measure elevation changes over time.

Table 7-11 Borehole Extensometer Information for the Sacramento Valley Portion of the Sacramento River Hydrologic Region

State Well Number	Groundwater Basin Number	County	Latitude	Longitude	Well Depth	Initial Start of Data Record
18N01E35L001M	5-21.59	Butte	39.36744	121.82787	1006	July 8, 2005
19N01E35B002M	5-21.59	Butte	39.46344	121.8277	1026	July 7, 2005
20N01E18L001M	5-21.58	Butte	39.57706	121.9082	1060	March 3, 2005
16N02W05B001M	5-21.52	Colusa	39.27527	122.1056	986	February 3, 2005
17N02W09H002M	5-21.52	Colusa	39.34169	122.0837	940	August 10, 2005
19N02W08Q001M	5-21.52	Glenn	39.5157	122.11224	1000	December 1, 2005
21N02W33M001M	5-21.52	Glenn	39.62991	122.1006	1020	March 2, 2005
22N02W15C002M	5-21.51	Glenn	39.76341	122.07714	880	March 1, 2005
11N04E04N005M	5-21.64	Sutter	38.823863	121.543073	800	April 13, 1994
09N03E08C004M	5-21.67	Yolo	38.64643	121.667379	716	January 24,1992
11N01E24Q008M	5-21.52	Yolo	38.779855	121.812422	1003	June 15, 1988

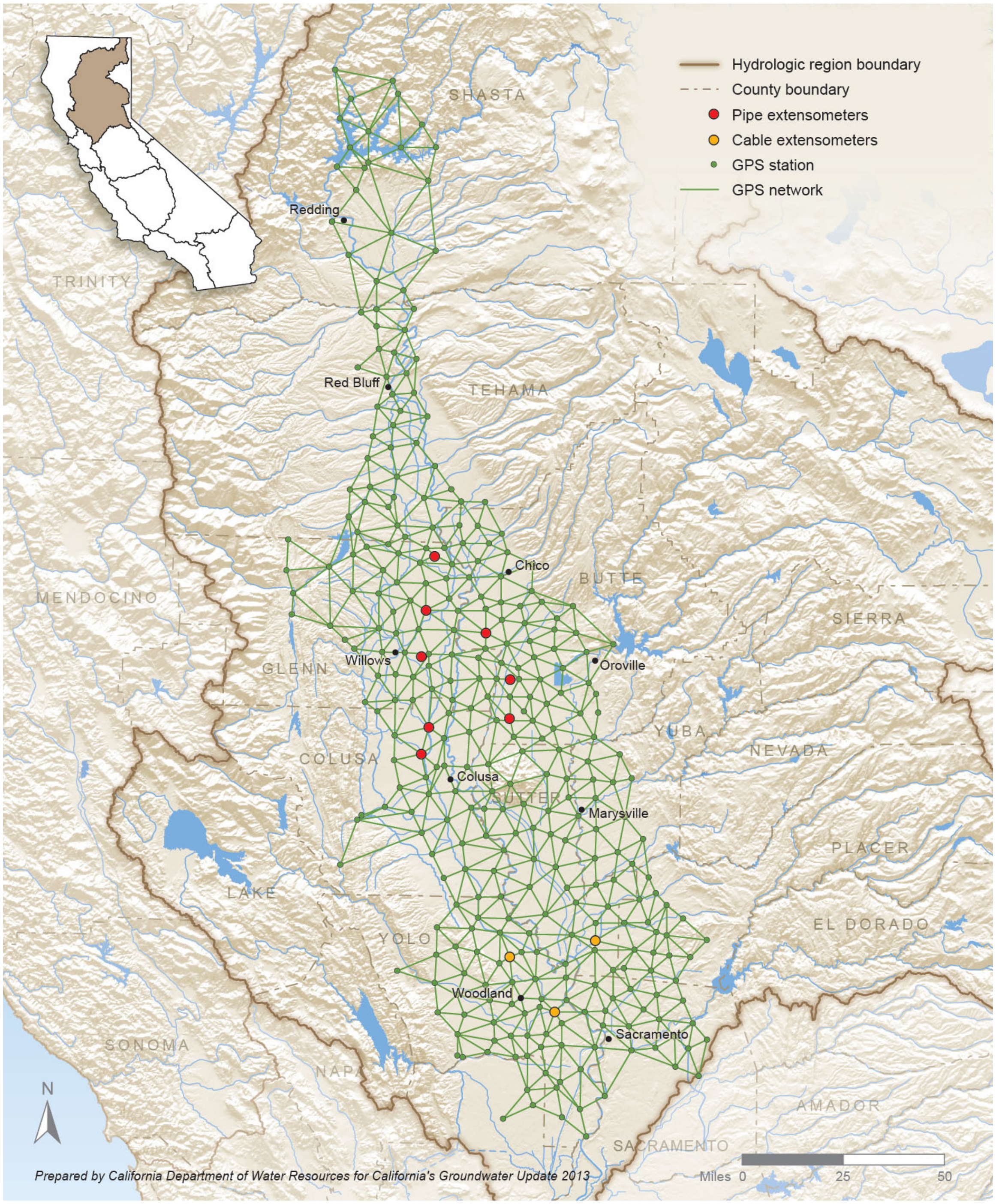
Subsidence Monitoring Gaps

The DWR Sacramento Valley subsidence monitoring network includes 11 extensometers and a GPS network. The 11 extensometers straddle the center of the valley from Sutter and Yolo counties in the south to Butte County in the north (Figure 7-11). The network is sparse and does not provide adequate coverage of the Sacramento Valley. There are at least two areas that show data gaps from the lack of extensometers. These areas include the area south of the Sutter Buttes (including the entire Yuba County portion of the Sacramento Valley Groundwater Basin) and the southern Tehama County area. In addition, the Redding Area Basin does not have any continuous subsidence monitoring.

DWR also measures groundwater levels in monitoring wells near each extensometer. Together, these data show a correlation between land subsidence and groundwater declines during the growing season, and land recovery as groundwater rises in winter.

Although current evidence of Sacramento Valley subsidence is limited, expanding agriculture and the shift toward more permanent crops that rely on groundwater increases the potential of future subsidence. Furthermore, future demands to provide additional in-stream flows through conjunctive management and more frequent groundwater substitution transfers will also increase the potential for future subsidence. On average, spring groundwater levels are down 9 to 10 feet from where they were in 2004 (considered a normal year). If these trends continue, the Sacramento Valley may begin to see the beginning of land subsidence issues similar to the San Joaquin Valley. The addition of several strategically placed, continuously operating reference stations (CORS) to constantly record the surface elevation, along with several extensometers in areas of high groundwater use would help quantify existing subsidence and help provide a more robust early-warning system for detecting land subsidence.

Figure 7-11 Borehole Extensometer and GPS Network Locations for the Sacramento Valley Portion of the Sacramento River Hydrologic Region



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The GPS subsidence monitoring grid was constructed in 2008 by a coordinated effort between several agencies. The intent was to resurvey the GPS grid every three years; however, the grid has not been resurveyed because of a lack of resources and questions regarding the existing accuracy associated with reoccupying the network and calculating benchmark elevations. Although the GPS subsidence monitoring network does provide a more complete coverage of the Sacramento Valley, accuracy estimates of ±5 centimeters makes detecting slight elevation changes difficult.

Further efforts need to be taken to explore the potential cost and accuracy associated with resurveying the GPS subsidence network, as opposed to installing additional extensometers that can record land subsidence on a continuous basis. Additionally, a complementary effort to evaluate subsidence in the Sacramento Valley by using InSAR methods should be considered.

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. As a result, if groundwater levels rise sufficiently, water table aquifers can reconnect to surface water systems and contribute to the overall base flow, or discharge directly to the surface via wetlands, seeps, and springs.

During dry years or periods of increased groundwater use, seasonal groundwater levels tend to fluctuate more extensively and, depending on annual recharge conditions, may respond with a long-term decline in local and regional groundwater levels. Depending on the amount, timing, and duration of groundwater-level decline, affected well owners may need to deepen wells or lower pumps to regain access to groundwater.

Lowering of groundwater levels can also affect the surface-water–groundwater interaction by inducing additional infiltration and recharge from nearby surface water systems, and reducing groundwater discharge to wetlands. 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.

The Sacramento Valley Groundwater Basin has historically been considered a groundwater-rich region. Major surface water systems, such as the Sacramento, Feather, Yuba, Bear, and American rivers provide significant recharge to regional aquifers and serve as an important source of surface water supply for agricultural, urban, and managed wetland uses. In addition, numerous smaller creeks along the eastern edge of the valley provide sources of local aquifer recharge. Reduced precipitation along the west side of the valley results in mostly ephemeral creeks; however, these surface water systems also provide an important source of groundwater recharge.

Surface water deliveries from federal, State, and numerous local projects help reduce reliance on groundwater, but population increases in groundwater-dependent urban areas and increases in agricultural land use along the margins of the valley (where previous groundwater use was limited), has resulted in an ongoing increase in groundwater demand for the Sacramento Valley portion of the region. In addition, the trend toward more permanent crops irrigated by groundwater has hardened agricultural groundwater demands and reduced the opportunities for conjunctive management. In areas with limited surface water supplies or poor surface-water supply reliability, the overall reliance on groundwater is high, and annual volume of groundwater extraction can exceed the natural rate of aquifer recharge.

The following overview of Sacramento River region aquifer conditions focuses on the highest groundwater use basins in the California Central Valley portion of the region. The overview of aquifer conditions includes a regional description of groundwater occurrence and movement, estimates of spring 2005 to spring 2010 change in groundwater 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 water from streams, canals, and other surface water systems. Groundwater moves from higher to lower elevations. Under predevelopment conditions, the occurrence and movement of groundwater was largely controlled by the surface and subsurface geology, the size and distribution of the natural surface water systems, the average annual hydrology, and the regional topography. But under current levels of development, years of extracting groundwater in excess of the natural rate of aquifer recharge has influenced the natural occurrence and movement of groundwater on a seasonal and, in some areas, continuous basis. Groundwater extraction over portions of western Glenn County, southern Tehama County, Butte County (between Chico and Durham), southern Colusa County, and Yolo, Solano, and Sacramento counties have created a patchwork of groundwater table depressions that serve to redirect and capture groundwater flow that may otherwise have contributed to nearby surface water systems. Deviation from natural groundwater flow conditions is also influenced by thousands of large production wells screened over multiple aquifer zones, creating a conduit for vertical aquifer mixing. In areas providing surface water for agricultural use, infiltration along miles of unlined water conveyance canals and percolation of applied irrigation water can also influence groundwater movement by creating significant areas of groundwater recharge where none previously existed.

Groundwater occurrence and movement in the Sacramento River 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, and aquifer recharge from winter rainfall 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. As mentioned, groundwater levels are affected by a number of variables; as a result, the depth-to-water and groundwater elevation maps should be considered regional approximations with potentially varying local conditions.

Groundwater contour maps were developed using groundwater-level data 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 Sacramento River region is publically available from the USGS National Water Information System (http://waterdata.usgs.gov/nwis/gw), and from several local groundwater management entities in the region.

Northern Sacramento Valley groundwater contour maps are developed annually by DWR's Northern and North Central Region offices. The map products are available online and can be viewed at DWR's Groundwater Information Center (http://www.water.ca.gov/groundwater).

The following sections provide an overview of the Sacramento River region's depth to groundwater, groundwater elevations, 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.

Depth to Groundwater

Understanding the local depth to groundwater provides a better awareness of these factors:

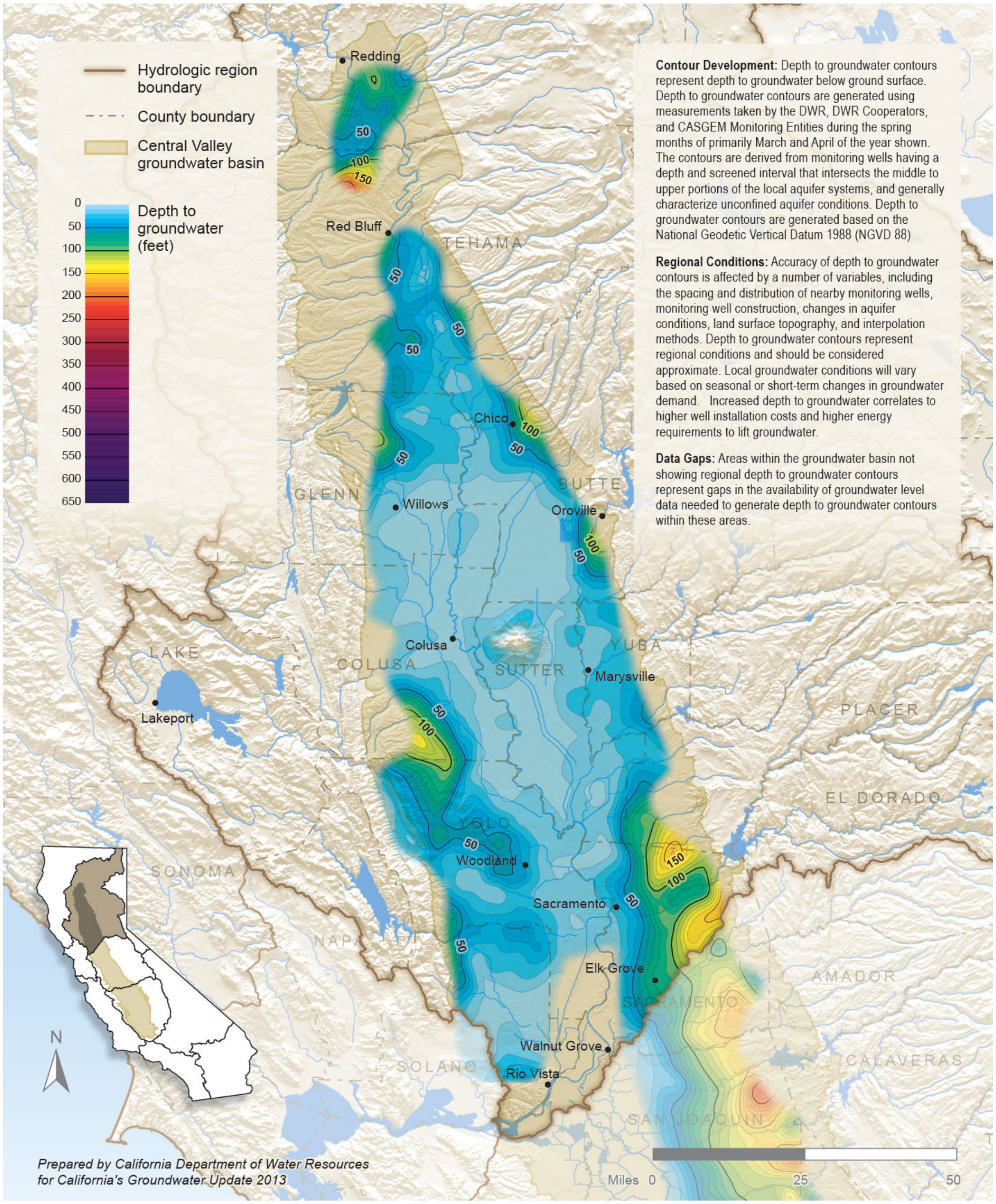
- Potential interaction between groundwater and surface water systems.
- Relationship between land use and groundwater levels.
- Potential for land subsidence.
- Groundwater contributions to the local ecosystems.
- Costs associated with well installation and groundwater extraction.

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 groundwater and ground surface elevation will commonly start to break down and show significant variability. This can occur even in areas with little change in ground surface elevation.

Figure 7-12 is a spring 2010 depth-to-groundwater contour map for the Sacramento Valley (5-21) and Redding Area (5-6) groundwater basins. The contour lines in Figure 7-12 represent the areas having similar spring 2010 depth-to-groundwater measurements. Areas having sufficient spring 2010 data to develop depth-to-groundwater contours are highlighted in Figure 7-12 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 sufficient groundwater-level data. Most of the areas with limited groundwater data fall within the Redding Area Groundwater Basin, the northwestern portion of the Sacramento Valley Groundwater Basin, and the Delta region in the southernmost portion of the Sacramento River region.

In the Redding Area Groundwater Basin, Figure 7-12 shows that about one-third of the basin is characterized by a spring 2010 depth to groundwater of about 40 to 60 feet bgs. The areas of shallower groundwater typically occur over the center of the basin and adjacent to major surface water systems.

Figure 7-12 Spring 2010 Depth-to-Groundwater Contours for the Sacramento River Hydrologic Region



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.

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Groundwater recharge associated with coarse-grained deposits along perennial streams and unlined agricultural distribution systems contributes to groundwater levels of less than 20 feet bgs in many smaller, localized areas. Toward the edges of the basin, as the ground surface elevation increases, the depth to groundwater quickly increases to over 100 feet bgs, reaching a maximum of about 200 feet bgs near the southern most end of the Redding Area Groundwater Basin. A lack of groundwater-level data near the edges of the Redding Area Groundwater Basin limits the basin-wide characterization of local depth-to-water conditions.

Figure 7-12 shows that the spring 2010 depth to groundwater is highly variable in the Sacramento Valley Groundwater Basin, ranging from a low of 10 feet bgs in areas adjacent to the Sacramento and Feather rivers, to a maximum depth of about 160 feet bgs in the North American Subbasin between Sacramento and Roseville.

Large portions of the Sacramento Valley Groundwater Basin are characterized by spring 2010 groundwater depths less than or equal to 20 feet bgs. Much of the shallow groundwater occurs in basin areas surrounding the Sutter Buttes, where surface water is applied for rice production, and southward along the axis of the valley adjacent to the Sacramento River. A shallow groundwater table adjacent to surface water systems indicates interconnection between surface water and groundwater systems.

The correlation of depth to groundwater with ground surface elevation is fairly high for most areas in the basin, indicating a natural trend of increasing depth to groundwater as ground surface elevations increase; however, several exceptions exists. One exception to this trend is in the North American Subbasin, where the depth to groundwater quickly increases from a low of 10 feet bgs along the western edge of the basin, to a high of 160 feet bgs just southwest of Roseville. Groundwater extraction to meet urban water demand is the likely contributor to increases in the depth to groundwater for this area.

Along the west side of the Sacramento Valley, adjacent to Interstate 5 between Williams and Zamora, the depth to groundwater is greater than areas closer to the Sacramento River. This is likely because of a higher reliance on groundwater supplies for these areas, combined with relatively low recharge along the east-facing slope of the Coast Ranges. Local trends of increased depth to groundwater are also seen near the cities of Woodland and Davis, which rely entirely on groundwater for municipal water supplies. Smaller areas of increasing depth to groundwater trends also exist along the west side of Glenn and Tehama counties, in Butte County near Chico, and south of Chico near Durham; however, the spring 2010 depth to groundwater map data for these areas is somewhat limited.

Depth to groundwater maps were not compiled for Sacramento River region basin outside the Central Valley. Additional information regarding depth to groundwater in these areas may be obtained online through the DWR Water Data Library (http://www.water.ca.gov/waterdatalibrary/).

Groundwater Elevations

Depth-to-groundwater measurements can be converted to groundwater elevations if the elevation of the ground surface is known. Groundwater elevation contours provide a good regional estimate of the occurrence and movement of groundwater in the Sacramento Valley Groundwater basin portion of the Sacramento River region. 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 pattern that converges on the stream. Along losing stream reaches (streams that lose water to the aquifer), the groundwater contours will show a groundwater flow pattern that diverges from the stream.

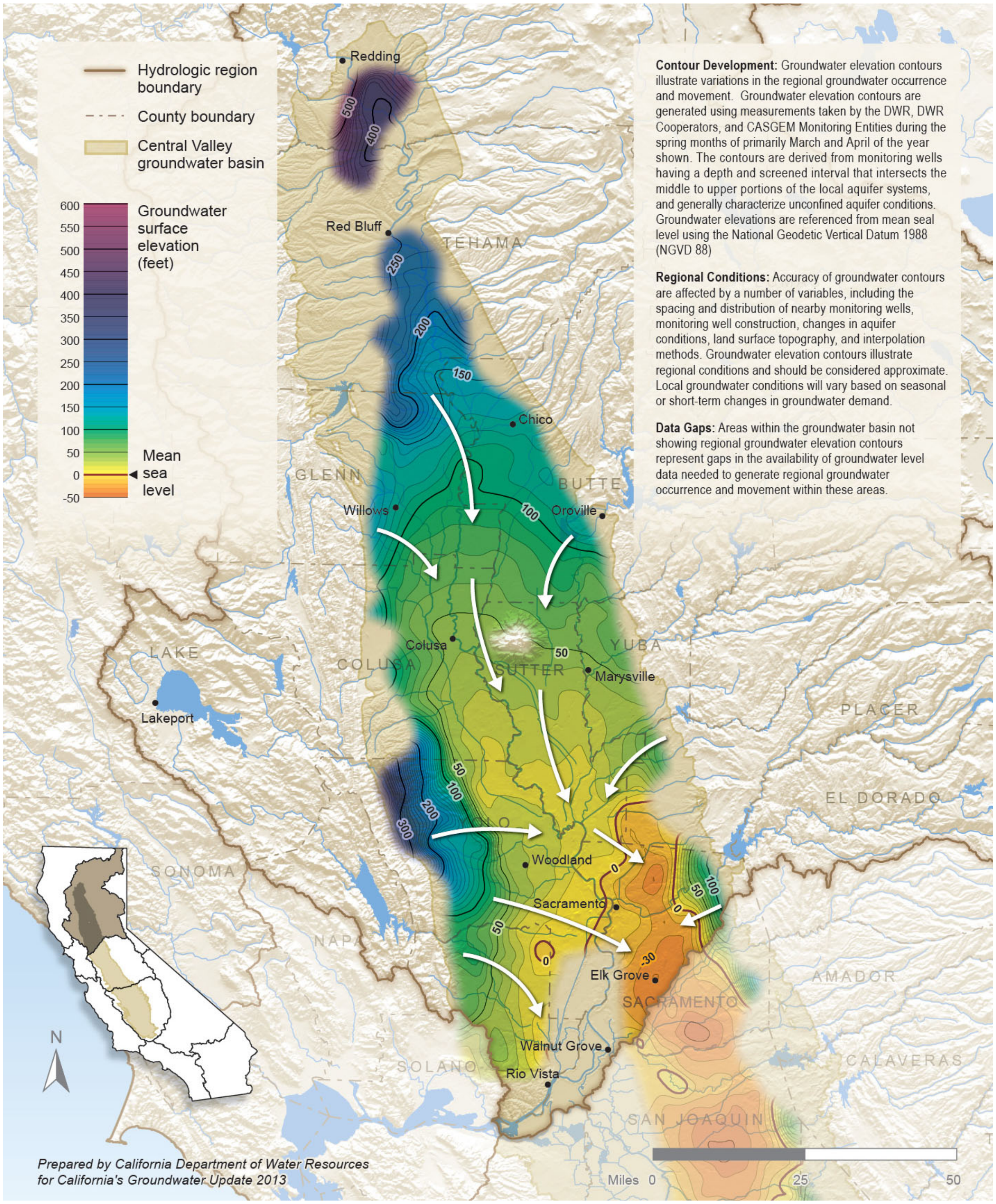
Figure 7-13 is a spring 2010 groundwater elevation contour map for the Sacramento Valley and Redding Area groundwater basins. The contour lines shown in Figure 7-13 are generally indicative of the unconfined portion of the aquifer system, and approximate the elevation of the groundwater table. The estimated direction of horizontal groundwater movement is shown in Figure 7-13 as a series of arrows along the groundwater flow path. Note that these flow direction arrows do not provide information regarding the vertical movement (up or down) of groundwater within the unconfined aquifer system.

Similar to the spring 2010 depth-to-groundwater contours, groundwater-elevation contour lines in Figure 7-13 were developed for those areas having sufficient groundwater-level data and is characterized by unconfined to semi-confined aquifer conditions.

In the Redding Area Groundwater Basin, Figure 7-13 shows that springtime groundwater elevations range from a low of about 390 feet above mean sea level (msl) adjacent to the Sacramento River, to a high of about 590 feet above msl in the northwestern foothill portions of the basin. In the northern Sacramento Valley, the regional groundwater movement follows a relatively natural flow path from the edges of the basin to the Sacramento River and nearby drainages. The groundwater flow gradient remains relatively flat along the Sacramento River where topographic relief is low. The groundwater flow gradients increase rapidly at the edges of the basin as the topographic relief increases. Lack of groundwater monitoring in the South Battle Creek Groundwater Subbasin, and limited data in the Millville, Rosewood, and Bowman groundwater subbasins, prohibits additional analysis in these areas. Additional groundwater level and modeling information for the Redding Area Groundwater Basin indicates a strong connection between surface water and groundwater systems along the center of the basin, and a significant contribution from the shallow aquifer systems to the base flow of nearby streams and rivers.

The Sacramento Valley Groundwater Basin portion of Figure 7-13 shows a slightly more complicated pattern of groundwater movement and occurrence. Groundwater elevations range from below sea level near the Sacramento-San Joaquin Delta and in portions of the North and South American subbasins, to over 300 feet above msl along the western and northern portions of the basin.

Figure 7-13 Spring 2010 Groundwater Elevation Contours for the Sacramento River 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.

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Spring 2010 groundwater contours for the majority of the Sacramento Valley Groundwater Basin generally follow the valley topography, with groundwater flowing from the edges of the basin toward the Sacramento and Feather rivers and then southward along the valley axis. From Red Bluff to Colusa, the spring 2010 pattern of groundwater movement points to the Sacramento River as a gaining stream and the main corridor of groundwater discharge in the valley. Between Colusa and Knights Landing, the pattern of groundwater flow begins to change, indicating a transition whereby the Sacramento River begins to serve as a major source of recharge to the local aquifer systems.

Figure 7-13 also illustrates a series of depressions in the North and South American subbasins, likely the result of groundwater development for urban use in the Sacramento and Davis urban areas. These radiating depressions in the groundwater table tend to induce infiltration from overlying surface water systems and capture adjacent groundwater underflow that may otherwise have discharged to nearby surface water systems, contributing toward the base flow of those systems.

A smaller groundwater depression and distortion of the natural pattern of groundwater flow occurs around the city of Woodland, and to the adjacent areas toward the north. The depression in this area is likely caused by groundwater extraction for urban, agricultural, and industrial uses. By diverting and capturing the surrounding groundwater flow, these series of groundwater depressions can reduce amount of surface flow in streams.

Figure 7-13 also illustrates several radiating patterns of groundwater recharge associated with key Sacramento Valley surface water systems. Key areas of spring recharge include Stony Creek, between the Corning and Colusa subbasins; the Thermalito Afterbay, near where the Feather River enters the Sacramento Valley Groundwater Basin; the Yuba River, adjacent to the North and South Yuba subbasin divide; the Bear River, along the northern border of the North American Subbasin; Cache Creek as it exits the Capay Valley west of Woodland; and Putah Creek near Winters.

The topographic low point of the Sacramento River region includes the Sacramento-San Joaquin Delta in the southernmost portion of the valley. This area has limited groundwater-level data; however, existing data indicates that delta groundwater elevations are generally at or slightly below sea level, which averages from 2 to 10 feet bgs.

As previously mentioned, the springtime groundwater levels shown in Figures 7-12 and 7-13 typically represent the highest groundwater levels of the year, and a time when annual groundwater demands are at a minimum and aquifer recharge is at the annual maximum. Additional assessment of spring compared with summer or fall groundwater levels is highly recommended to more fully understand seasonal variations of groundwater occurrence and movement, and how these variations are affected by changes in annual precipitation, surface water deliveries, and demand. Summer groundwater elevation contours developed by DWR for the northern portion of the Sacramento Valley Groundwater Basin indicate that large reaches of the Sacramento River system that appear to be gaining flow during the spring months, because of shallow groundwater discharge to the river, typically give way to losing reaches of the river (discharging surface water to adjacent aquifer systems) north to Red Bluff during the summer months.

Seasonal changes in groundwater levels in the Sacramento Valley fluctuate over 50 feet in some locations. Discussion of groundwater hydrographs in the following section will provide a better illustration of seasonal and long-term changes, and tell the story of aquifer response to changing groundwater demands within the Sacramento River region.

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 in each groundwater basin, and because of the variable nature of annual groundwater extraction, recharge, and surrounding land-use practices, the hydrographs selected for discussion do not illustrate or depict average aquifer conditions over a broad region. Rather, 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 Number (SWN) system. The SWN identifies a well by its location using the U.S. Public Lands 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 7-14 shows hydrograph examples for 10 selected groundwater-elevation-monitoring wells in the Sacramento River region and provides a brief explanation of the hydrograph's story. Detailed information about each hydrograph can be found in the following paragraphs.

Hydrograph 38N07E23E001M

Figure 7-14a is a hydrograph for Well 38N07E23E001M located in the Big Valley Groundwater Basin (5-4) in the upper portion of the Sacramento River region. Big Valley is a rural cattle ranching and hay cropping area largely dependent on groundwater for irrigation during dry years. Well 38N07E23E001M is a domestic well that was constructed in the unconfined upper aquifer system, possessing spring and fall groundwater-level measurements dating back to the 1978. The land use in the area immediately surrounding the monitoring well is a small residential community. Big Valley Groundwater Basin is designated as a CASGEM medium-priority groundwater basin.

Figure 7-14a shows seasonal fluctuations in shallow-aquifer groundwater levels of about 5 to 8 feet during years of normal precipitation, and approximately 15 to 20 feet during drought periods. A long-term comparison of spring-to-spring groundwater levels shows a gradual decline and recovery of groundwater levels associated with the 1987-93 drought, and a partial recovery from the 2001 drought. Since 2000, spring-to-spring groundwater levels in this portion of the aquifer system show a fairly steady trend of declining groundwater levels, even during years of normal precipitation, and an increase in the seasonal groundwater-level fluctuations as a result of increased groundwater use. Although the average annual rate of groundwater-level decline since 2000 is about 1 foot per year, these declines indicate that the annual rates of groundwater extraction are outpacing aquifer recharge at this location. The hydrograph for Well 38N07E23E001M does indicate some aquifer recovery associated with above average precipitation during the 2010-11 water year. Additional groundwater-level versus groundwater-extraction data is required to help forecast future aquifer response to agricultural groundwater demand in this area.

Hydrograph 24N02W24D002-4M

Figure 7-14b shows a hydrograph for Multi-Completion Well 24N02W24D002-4M, located in Tehama County within the northern portion of the Vina Groundwater Subbasin (5-21.57) near the Sacramento River. This monitoring well is located between idle land or pastures to the east and predominantly orchards to the west. The Vina Groundwater Subbasin is designated as a CASGEM high-priority groundwater basin.

This multi-completion monitoring well monitors three discrete aquifer zones with screened depths ranging from 345 feet to 1,000 feet bgs. Well 24N02W24D002 is screened from 990-1,000 feet bgs, Well 24N02W24D003 is screened from 731-741 feet bgs, and Well 24N02W24D004 is screened from 345-355 feet bgs, generally reflecting a deep, intermediate deep, and intermediate aquifer zone, as the shallowest well is screened 355 feet bgs and is not considered a shallow groundwater monitoring well. The hydrograph shows the potentiometric surface for each of the confined aquifer zones. The difference in groundwater elevations shown on the hydrograph is because of the increase in head pressure caused by different degrees of aquifer confinement in the different aquifers. In this case, the pressure increases with depth, as the deepest well (Well 24N02W24D002) shows the shallowest water levels (greatest pressure) and the shallowest well (Well 24N02W24D004) shows the deepest water levels, indicating an upward gradient of groundwater flow, characterizing this location as a potential groundwater discharge versus recharge area.

The groundwater levels in each aquifer zone generally follow the same seasonal trend of lower groundwater levels during the summer and fall, and higher groundwater levels during the winter and spring. The high and low points in the shallowest well, Well 24N02W24D004, have a slightly greater magnitude than the two deeper wells, suggesting that this aquifer is affected to a greater extent by nearby groundwater pumping. The overall trend in each zone of this multi-completion well from 2006 to 2010 is downward approximately 1 foot per year.

Between 2005 and 2010, the average annual groundwater extraction from aquifers within Tehama County was 248 taf per year, which accounts for 67 percent of Tehama County’s average annual total water supply.

Hydrograph 23N03W13C003-7M

Figure 7-14c is a hydrograph is for Multi-Completion Well 23N03W13C003-7M, located in the Corning Groundwater Subbasin (5-21.51), which is part of the Sacramento Valley Groundwater Basin and within Tehama County near its southern border. The land use in the surrounding area is mixed with small orchards, pastures, idle land, and rural communities that all rely on groundwater for their primary water source. The Corning Groundwater Subbasin is designated as a CASGEM medium-priority groundwater basin.

This set of monitoring wells monitor groundwater elevations in five discrete aquifer zones, from screen intervals ranging from 25 feet to 970 feet bgs. The hydrograph in Figure 7-14c shows the groundwater levels associated with four of the five aquifer zones; groundwater elevations in the deepest well (Well 23N03EW13C003 [screen interval of 900-910 feet bgs and 960-970 feet bgs]) almost identically match the groundwater elevations in the deep intermediate well (Well 23N03EW13C004 [screen interval of 815-825 feet bgs]). Well 23N03EW13C003M is not shown on the hydrograph in Figure 7-14c.

Figure 7-14 Groundwater Hydrographs for the Sacramento River Hydrologic Region

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.

Ⓐ **Hydrograph 38N07E23E001M:** shows a well with long term declining groundwater levels. The increasing seasonal fluctuations in the recent years indicate increased groundwater use.

Ⓑ **Hydrograph 24N02W24D002-4M:** large seasonal fluctuations at the shallow monitoring level show that most of the pumping activity is concentrated in the shallower aquifer zone. Increasing potentiometric head with depth indicates an upward gradient of groundwater flow, characterizing this location as a potential groundwater discharge versus recharge area.

Ⓒ **Hydrograph 23N03W13C003-7M:** large fluctuations in the intermediate and deep monitoring levels show that pumping activity is largely concentrated in the intermediate and deep aquifer zones. Decreasing potentiometric head with depth indicates downward gradient of groundwater flow, characterizing this location as a potential groundwater recharge area.

Ⓓ **Hydrograph 21N03W33A004M:** illustrates a well with declining groundwater levels as a result of increased irrigation pumping due to drought or dry conditions. More recently there have been significant changes in land use and irrigation methods that further increased local groundwater demand.

Ⓔ **Hydrograph 22N01E28J003M:** shows the effect dry periods have on groundwater levels in areas of heavy reliance on groundwater. During the dry periods, groundwater withdraws tend to outpace recharge resulting in declining groundwater elevation. At this well, the recovery was weak or missing following the last two dry periods.

Ⓕ **Hydrograph 14N01E14G001M:** shows a very stable water table with a seasonal fluctuation of generally less than 10 feet. The land use in area is dominated by agricultural rice production that uses predominantly surface water.

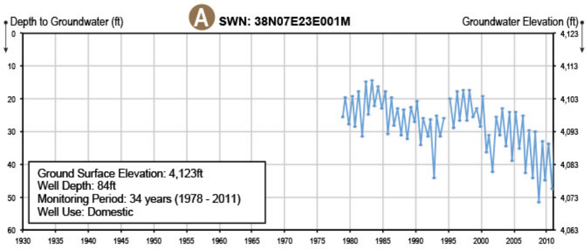
Ⓖ **Hydrograph 15N04E28D001M:** shows the successful recovery of groundwater levels through the introduction of surface water supply in early 1980's, which resulted in reducing groundwater demand and facilitating in-lieu groundwater recharge.

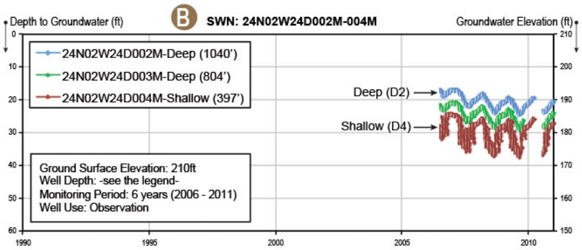
Ⓗ **Hydrograph 10N01W06D001M:** highlights the impact of drought conditions on groundwater elevations. The seasonal measurements fluctuate more during dry years than during wet years.

Regional locator map

Ⓘ **Hydrograph 06N01W24N001M:** shows the successful recovery of groundwater levels through the introduction of surface water supply in 1959, which resulted in reducing groundwater demand and facilitating in-lieu groundwater recharge.

Ⓙ **Hydrograph 07N06E08H001M:** illustrates the typical groundwater level trends observed in the wells located in Zone 40 portion of Sacramento County. The groundwater levels declined prior to the 1980s due to intensive groundwater use for domestic and agricultural purposes. After 1980s, the groundwater levels stabilized as surface water supplies became available for domestic use and as some of the agricultural land was transitioned into new residential developments.





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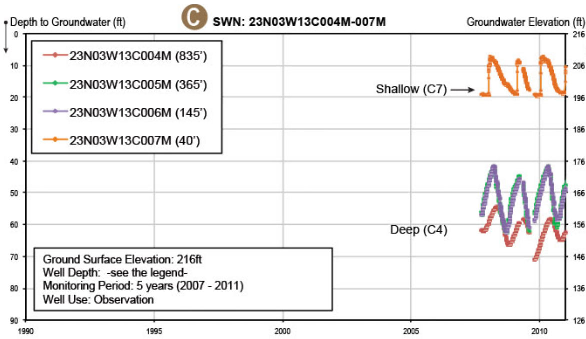
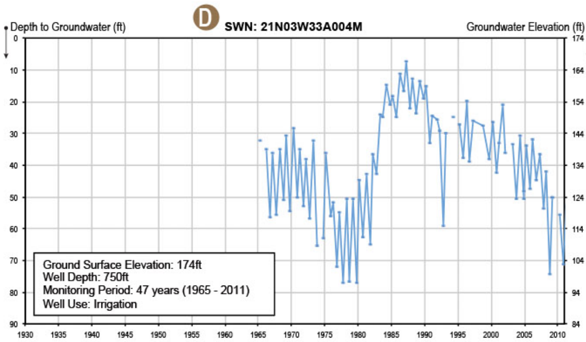


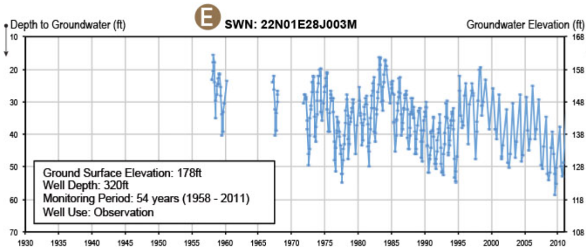
SWN: 23N03W13C004M-007M

Ground Surface Elevation: 216ft
Well Depth: -see the legend-
Monitoring Period: 5 years (2007 - 2011)
Well Use: Observation



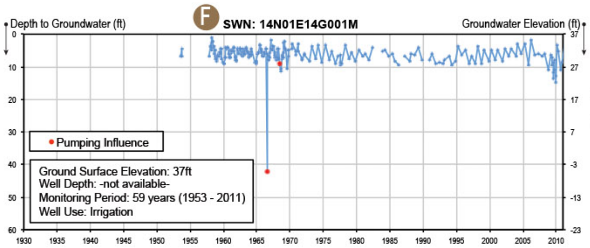
SWN: 21N03W33A004M

Ground Surface Elevation: 174ft
Well Depth: 750ft
Monitoring Period: 47 years (1965 - 2011)
Well Use: Irrigation



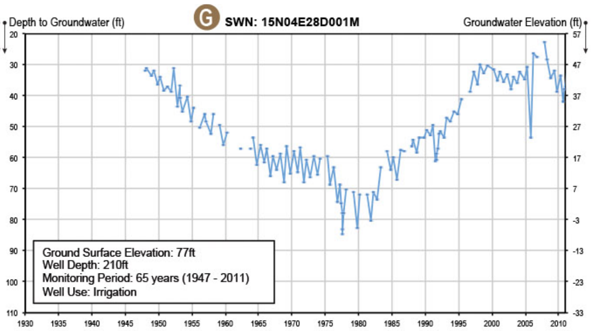
SWN: 22N01E28J003M

Ground Surface Elevation: 178ft
Well Depth: 320ft
Monitoring Period: 54 years (1958 - 2011)
Well Use: Observation



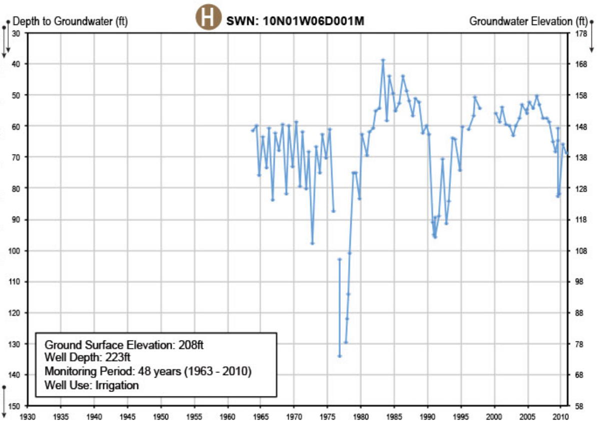
SWN: 14N01E14G001M

Ground Surface Elevation: 37ft
Well Depth: -not available-
Monitoring Period: 59 years (1953 - 2011)
Well Use: Irrigation



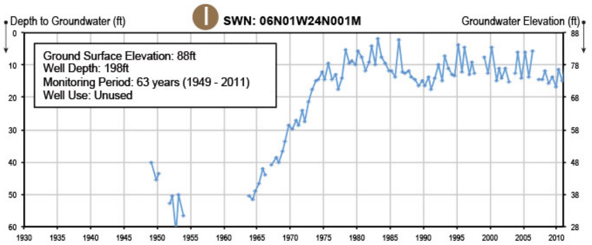
SWN: 15N04E28D001M

Ground Surface Elevation: 77ft
Well Depth: 210ft
Monitoring Period: 65 years (1947 - 2011)
Well Use: Irrigation



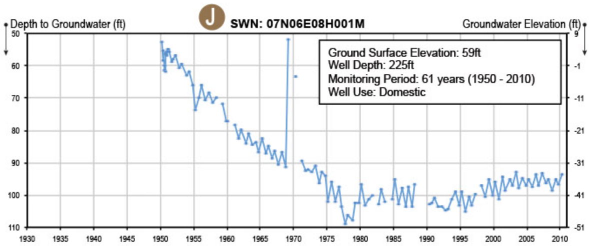
SWN: 10N01W06D001M

Ground Surface Elevation: 208ft
Well Depth: 223ft
Monitoring Period: 48 years (1963 - 2010)
Well Use: Irrigation



SWN: 06N01W24N001M

Ground Surface Elevation: 88ft
Well Depth: 198ft
Monitoring Period: 63 years (1949 - 2011)
Well Use: Unused



SWN: 07N06E08H001M

Ground Surface Elevation: 59ft
Well Depth: 225ft
Monitoring Period: 61 years (1950 - 2010)
Well Use: Domestic

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Well 23N03W13C007M (the shallowest well) is monitoring groundwater from the shallowest aquifer, an unconfined aquifer that appears to be in direct communication with nearby surface water sources, as the water table seasonally fluctuates less than 15 feet, between 6 and 20 feet bgs. Water levels in the shallow well respond rapidly to changes in percolation associated with precipitation, applied irrigation water, and nearby surface water systems, and likely pumping from nearby wells.

The shallow intermediate zone (screen interval of 95-105 feet bgs and 125-135 feet bgs) and intermediate zone (screen interval of 345-355 feet bgs), are depicted by the hydrographs for Wells 23N03W13C006M and 23N03W13C005M, respectively; these two zones also show similar groundwater elevations over time, are increasingly separated from surface recharge sources, and show an increasingly muted and delayed response to seasonal fluctuations associated with winter recharge water. These wells are likely monitoring groundwater from a semi-confined aquifer, as the water depths in these wells, representing a potentiometric surface rather than an actual shallow water table, are generally 30-35 feet lower than the water table depicted in the shallow well. There is a seasonal fluctuation of approximately 20-25 feet in the shallow-intermediate-zone and intermediate-zone wells. Although the screen intervals in these two wells are more than 200 feet apart, irrigation wells in the area tend to have long and continuous screens that span several hundred feet. As a result, pumping from local and regional irrigation wells would influence water levels in the shallow-intermediate zone and intermediate-zone in a similar fashion.

The deep-intermediate zone (and deep zone), shown on the hydrograph for Well 23N03W13C004, likely depicts a potentiometric surface from a confined aquifer, or at least an aquifer system under greater pressure than the aquifer above it, separated by several hundred feet of alluvial material. The water levels in the deep-intermediate well and deep well are generally 15 feet lower than the wells monitoring the intermediate-shallow zone and intermediate zone, and show a seasonal fluctuation of approximately 10 feet, which is less than the aquifer system located above it. Overall, for each of the zones depicted on the hydrograph, there is little net difference from year to year, suggesting that water from these aquifers is being sustainably recharged.

The average annual groundwater extraction from aquifers within Glenn County, for the period between 2005 and 2010, is 292 taf per year, which accounts for 27 percent of Glenn County's average annual total water supply.

Hydrograph 21N03W33A004M

Figure 7-14d is a hydrograph for Well 21N03W33A004M, an irrigation well located in the Colusa County portion of the Colusa Groundwater Subbasin (5-21.52). The Colusa Groundwater Subbasin consists of mostly agriculture, pastures, and idle land. There are also several small urban centers. This well is located in the center of the upper portion of the groundwater subbasin, midway between the cities of Orland and Willows. The land use in the area of the well is predominately agriculture. The well is 750 feet deep and is constructed in the semi-confined to confined portions of the aquifer system. Groundwater levels in this well have been monitored monthly from 1958 to 1995, and three to four times per year since 1995. Colusa Groundwater Subbasin is designated as a CASGEM medium-priority groundwater basin.

The hydrograph shows a decline in groundwater levels during the 1970s, prior to bringing in surface water through the Tehama-Colusa Canal. During the 1980s, groundwater levels increased as a result of the combination of switching from groundwater to surface water use, and because of the wet hydrology associated with the 1982-1984 water years. The decline in groundwater levels in the early 1990s is likely the result of surface water cutbacks, increased surface water pricing, and limited dry-year water reliability combined with drought conditions, causing many farmers to switch back to groundwater instead of surface water supply.

The most recent decrease in groundwater levels in the early 2000s is likely a result of the recent trend of converting pasture, annual crops, and idle land to permanent orchard crops irrigated with groundwater. Between 2003 and 2009, permanent crops increased 17,000 acres county wide, while an equal amount of field crops, grasses, and idle and pasture land decreased. The majority of the trend toward permanent crops using groundwater has occurred along the west side of Colusa County, in the general vicinity of this well. Changes in irrigation methods have also contributed to the observed declines. Between 2003 and 2009, surface drip and micro-sprinkler irrigation has increased by 18,000 acres, and methods such as wild flooding, furrow irrigation, and border strip irrigation decreased by an equal amount of acreage. The former methods rely on groundwater and the latter rely on surface water deliveries.

Groundwater is the preferred source of water for micro sprinklers and drips, because surface water, having more suspended particles, tends to plug the equipment. Other side effects of these crop and irrigation changes are the reduced amounts of water being applied via micro or drip sprinklers, which virtually eliminate any applied water that would have percolated down to the groundwater as recharge. During periods of reduced surface water, permanent crops eliminate the possibly of idling the land.

The hydrograph for the well shows that the seasonal fluctuation in groundwater levels can be as much as 70 feet over the period of record beginning in 1965. The lowest groundwater levels were during the drought in the late 1970s. Since 2009, the trend of declining groundwater levels has continued, and for many wells along the west side of the Sacramento Valley, groundwater levels are either at or are approaching an all-time low.

The average annual groundwater extraction from aquifers within Colusa County, for the period between 2005 and 2010, is 247 taf per year, which accounts for 18 percent of Solano County’s average annual total water supply.

Hydrograph 22N01E28J003M

Figure 7-14e is a hydrograph for Well 22N01E28J003M, an observation well located in the Vina Groundwater Subbasin (5-21.57) within the city of Chico, Butte County. The Vina Groundwater Subbasin consists of agriculture, pastures, and a portion of a large urban center. This well is located along the western edge of Chico and along the southern edge of the groundwater subbasin, and is influenced by urban groundwater use to the east and agricultural groundwater use to the west. The local land use immediate to this well is almost 100-percent reliant on groundwater for urban and agricultural uses. Well 22N01E28J003M is an observation well, constructed in the semi-confined portion of the aquifer system. Groundwater levels in this well have been monitored monthly from 1958 to 1995, and three to four times per year since 1995. Vina Groundwater Subbasin is designated as a CASGEM high-priority groundwater basin.

The hydrograph for the observation shows seasonal fluctuations in groundwater levels of about 15 feet during years of normal precipitation, and as much as approximately 20 feet during drought periods. A long-term comparison of spring-to-spring groundwater levels shows a gradual decline and recovery of groundwater levels associated with the 1975-77 and 1986-94 droughts, and partial recovery associated with the 2001 drought. The hydrograph also shows groundwater levels recovering from the 2007-2009 drought period because of an above-average water year during 2010-2011.

During years of normal precipitation, spring-to-spring groundwater levels in this portion of the aquifer system show a trend of slightly declining groundwater levels since the mid-1980s, indicating that groundwater withdrawal is outpacing groundwater recharge.

The average annual groundwater extraction from aquifers within Butte County, for the period between 2005 and 2010, is 428 taf per year, which accounts for 32 percent of Butte County’s average annual total water supply.

Hydrograph 14N01E14G001M

Figure 7-14f is a hydrograph for Well 14N01E14G001M, located southwest of the Sutter Buttes in the Sutter Groundwater Subbasin (5-21.62). The well is located in Sutter County less than 0.5 mile east of the Sacramento River. The surrounding land use is dominated by agricultural rice production that mostly utilizes surface water. The Sutter Groundwater Subbasin is designated as a CASGEM medium-priority groundwater basin.

Some areas within the Sacramento River region are characterized by very little seasonal and long-term groundwater-level change, as exhibited in the hydrograph for Well 14N01E14G001M. Seasonal groundwater-level measurements since 1953 have shown a very stable water table with a seasonal fluctuation of generally less than 10 feet. Although some domestic supplies use groundwater from the Sutter Groundwater Subbasin, there is a very low population density in this area.

Between 2005 and 2010, the average annual groundwater extraction from aquifers within Sutter County was 262 taf per year, accounting for 24 percent of Solano County’s average annual total water supply.

Hydrograph 15N04E28D001M

Figure 7-14g is a hydrograph for Well 15N04E28D001M, located within the Sacramento Valley Groundwater Basin in the South Yuba Groundwater Subbasin (5-21.61) in Yuba County. The hydrograph presents a typical groundwater response for an in-lieu groundwater recharge operation, while also reflecting seasonal fluctuations and long-term water level trends from a rural well near the town of Linda. Well 15N04E28D001M is an irrigation well completed to a depth of 210 feet that has been monitored seasonally since 1947.

Prior to approximately 1983, groundwater was the primary water source used for irrigation and other purposes in the South Yuba Groundwater Subbasin, which over time created a widespread cone of depression within the aquifer. As shown on Figure 7-14g, the depth to groundwater at this location increased from approximately 30 feet below ground surface in 1947 to almost 85 feet bgs in 1977, a decline of almost 2 feet per year. In 1983, surface water for irrigation was introduced into the South Yuba Groundwater Subbasin by the Yuba County Water Agency and the depth to groundwater in

Well 15N04E28D001M began to recover to its historic high of 25 feet bgs in 2008, an increase of almost 2 feet per year. Throughout the period of record, the seasonal fluctuation of groundwater levels was generally within ±10 feet.

The average annual groundwater extraction from aquifers within Yuba County, for the period between 2005 and 2010, is 94 taf per year, which accounts for 24 percent of Yuba County's average annual total water supply. The South Yuba Groundwater Subbasin is designated as a CASGEM medium-priority groundwater basin.

Hydrograph 10N01W06D001M

Figure 7-14h is a hydrograph for Well 10N01W06D001M, located in the Colusa Groundwater Subbasin (5-21.52) in Yolo County along the western boundary of the Sacramento Valley and approximately 2 miles north of Cache Creek. The hydrograph for Well 10N01W06D001M shows the impact of drought conditions on groundwater elevations in an irrigation well completed to a total depth of 223 feet. Prior to the 1976-1977 drought, groundwater elevations in Well 10N01W06D001M seasonally fluctuated 20 to 30 feet but were generally stable from year to year. However, between 1975 and 1977, the depth to groundwater declined from approximately 60 feet bgs in 1975 to 135 feet bgs in 1977. Following the dry years of the late 1970s were the wet years of the early 1980s, which are also represented on the hydrograph for Well 10N01W06D001M. The effect of the drought on groundwater elevations in this well was eliminated by 1980, and as shown on the hydrograph, the historical high groundwater elevation was observed in 1983. Drought conditions are also represented on the hydrograph for the early 1990s and 2009. The year-to-year measurements show a greater seasonal fluctuation during the dry years, and a much smaller seasonal fluctuation during the wet years.

Between 2005 and 2010, the average annual groundwater extraction from aquifers within Yolo County was 399 taf per year, which accounts for 44 percent of Yolo County's average annual total water supply. The Colusa Groundwater Subbasin is designated as a CASGEM medium-priority groundwater basin.

Hydrograph 06N01W24N001M

Figure 7-14i is a hydrograph for Well 06N01W24N001M, located in the Solano Groundwater Subbasin (5-21.66), within the southernmost portion of the Sacramento Valley Groundwater Basin, and also within the northern portion of the Sacramento-San Joaquin Delta, near the city of Vacaville. Well 06N01W24N001M is an unused well, completed to a depth of 198 feet, and first monitored for groundwater levels in 1949. Although the records between 1953 and 1963 for this well are incomplete, the groundwater-level data included on the hydrograph after 1963 show a groundwater table recovery from more than 50 feet below the ground surface to levels 10 feet or less below the ground surface by 1975, with groundwater levels at, or just below the ground surface, occurring numerous times through 2010.

Groundwater levels in Well 06N01W24N001M recovered because of the introduction of surface water supplies to the area. In 1959, Vacaville began receiving Solano Project water through an agreement with the Solano County Water Agency. Prior to completion of the Solano Project, which was constructed in 1957 to store surface water in Lake Berryessa, all water supplies for municipal and irrigation uses were developed from local groundwater. Prior to 1959, the groundwater levels in Well

06N01W24N001M were declining at rates of approximately 5 feet per year or more, and likely reached depths far greater than the historical low of more than 60 feet bgs, which was observed in 1953.

Between 2005 and 2010, the average annual groundwater extraction from aquifers within Solano County was 275 taf per year, which accounts for 43 percent of Solano County's average annual total water supply. The Solano Groundwater Subbasin is designated as a CASGEM medium-priority groundwater basin.

Hydrograph 07N06E08H001M

Figure 7-14j is a hydrograph for Well 07N06E08H001M, located in the South American Groundwater Subbasin (5-21.65) in the central portion of rural Sacramento County. Well 07N06E08H001M is a domestic well, completed to a depth of 225 feet and has been measured seasonally since 1950. The hydrograph shows a consistent groundwater-level decline of almost 60 feet from approximately 1950 until around 1980. From 1980 through 2010, the depth to groundwater has been relatively stable, with a seasonal fluctuation of ±10 feet or less. This hydrograph is consistent with the hydrographs from other nearby wells in the Zone 40 portion of Sacramento County.

Prior to the 1980s, groundwater levels declined because of the intensive use of groundwater, which was the primary, if not only, source of water in the area for domestic and agricultural purposes. Although development in the area continued to occur, the stabilization of the groundwater levels are attributed to the higher use of surface water supplies that became available to residential developments, and the fallowing of agricultural areas as they transitioned into new developments in accordance with the County's general plan. In this case, groundwater levels have not recovered to 1950 levels because groundwater is continuing to be used for domestic and agricultural purposes; however, as shown by the stable hydrographs, groundwater and surface water supplies appear to be used in balance, consistent with the objectives of the area's groundwater management plan.

Between 2005 and 2010, the average annual groundwater extraction from aquifers within Sacramento County was 371 taf per year, which accounts for 47 percent of Sacramento County's average annual total water supply. The South American Groundwater Subbasin is designated as a CASGEM high-priority groundwater basin.

Change in Groundwater in 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 monitoring periods, by the overlying groundwater basin area, and by the estimated specific yield or volume of pore space from which water may be extracted.

Examining 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 volumetric change 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; typically, some additional investigation is 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 risks 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-in-groundwater-in-storage estimates for the Sacramento Valley portion of the Sacramento River region was calculated between 2005 and 2010, using spring groundwater-elevation-monitoring data, a range of specific yield values for the aquifer, and a standardized geographic information system (GIS) data processing tool. Spring groundwater levels were used because of the tendency toward aquifer stability during the spring months. *California Water Plan Update 2013* focuses primarily on 2006 to 2010 water years; however, the change-in-groundwater-in-storage analysis used a 2005 to 2010 time interval. Groundwater-level data from spring 2005 was used instead of 2006, because the overall hydrology for 2005 more closely approximated long-term average conditions than that of 2006. Beginning the change in storage calculation in 2005 provided for better comparison of the annual and cumulative change in storage values in subsequent years.

Minimum and maximum specific yield (Sy) values of 0.07 and 0.17 were determined to be a good approximation of the range of regional aquifer storage parameters. As with the groundwater elevation and depth-to-water 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; as a result, changes of groundwater in storage were not estimated for these areas.

A standardized GIS approach to developing annual groundwater elevation contours and subsequent change-in-storage estimates was developed for the *California Water Plan Update 2013*. The primary goal of using a standardized GIS approach was to implement a repeatable and transparent process for compiling groundwater elevation data and analyzing change-in-storage data. The selected methods are intended to be used for basin-wide scale assessment of change of groundwater in storage and are not intended for local scale project analysis.

Change in groundwater in storage was calculated using groundwater-level data 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 Sacramento River 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 Sacramento River region, and has been estimated 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.

The following discussion of change in aquifer storage in the Sacramento River region focuses on the Redding Area and Sacramento Valley groundwater subbasins within the Sacramento Valley Groundwater Basin. Detailed evaluation of change in storage for each groundwater basin within the Sacramento River region is beyond the scope of this study.

Spring 2005 to Spring 2010 Change in Groundwater in Storage

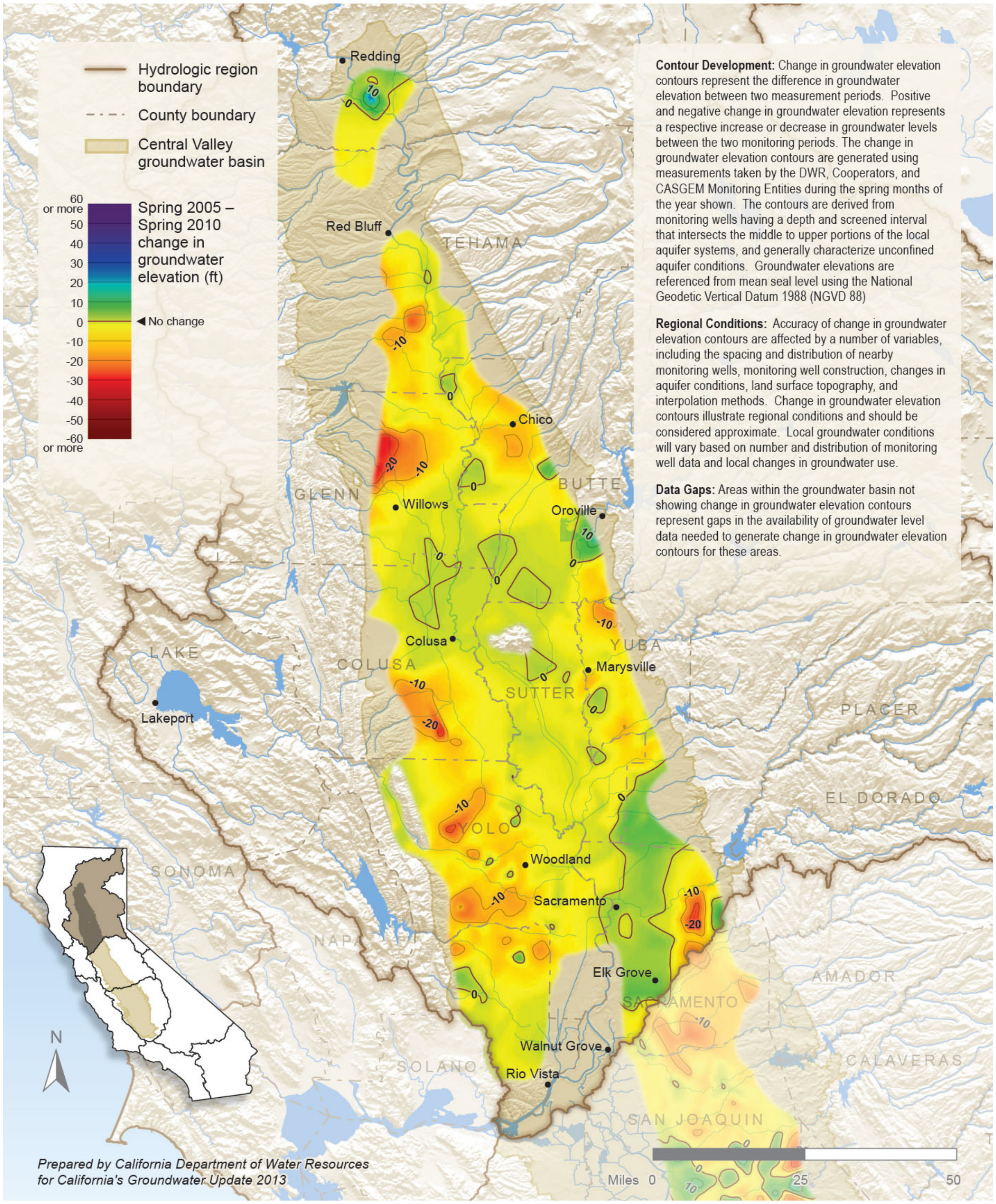
The change in groundwater in storage discussion for the Sacramento River region is limited to the Sacramento Valley. Figure 7-15 presents a change in groundwater-elevation contour map for the Sacramento Valley portion of the Sacramento River region for the 2005-2010 period, which includes the Redding Area Groundwater Basin and the Sacramento Valley Groundwater Basin. Figure 7-16 and Table 7-12 summarize the change-in-groundwater-in-storage estimates for the entire Sacramento Valley portion of the Sacramento River region for the period of 2005-2010. Tables and figures similar to Table 7-12 and Figure 7-16 have been developed for the regional groundwater subbasin groups discussed below and are provided in Appendix E.

The Redding Area Groundwater Basin is comprised of six groundwater subbasins, the Bowman, Rosewood, Anderson, Enterprise, Millville, and South Battle Creek groundwater subbasins. Review of the reporting area versus non-reporting area indicates that about 50 percent of the Redding Area Groundwater Basin is reportable because of limited monitoring well coverage. The South Battle Creek Groundwater Subbasin does not have sufficient depth-to-water data for contouring and estimating change in groundwater in storage and, as a result, is considered a non-reporting area. Because of the limited number of monitoring wells and smaller reporting area for the Redding Area Groundwater Basin, localized declines in groundwater levels tend to have a greater influence on change-in-groundwater-in-storage estimates. Efforts to improve these estimates will require additional groundwater-level monitoring throughout the basin.

The Sacramento Valley Groundwater Basin includes 18 subbasins and covers over 10 times the area as the Redding Area Groundwater Basin. The overall density of groundwater-level monitoring within the high groundwater-use portions of the basin is considered good, with about 65 percent of the total basin area being identified as reportable. Much of the non-reportable areas include the western portions of the Red Bluff and Corning groundwater subbasins, as well as the Delta region where there is limited groundwater demand.

Groundwater contours in Figure 7-15 show the overall groundwater elevation change in the Sacramento Valley between spring 2005 and spring 2010. Table 7-12 lists the average annual change in groundwater elevation and the estimated range of groundwater-in-storage change calculations based on the minimum (0.07) and maximum (0.17) estimates of Sy. Table 7-12 also shows the "Reporting" and "Non-Reporting" areas used to calculate the change-in-groundwater-in-storage estimates. Figure 7-16 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 7-12 and illustrated in Figure 7-15. The bottom of Figure 7-16 shows the generalized water year type (wet, normal, below normal, dry, and critically dry) for the region, based on the Sacramento River Water Year Index.

Figure 7-15 **Change in Groundwater Elevation Contour Map for Sacramento Valley Portion of the Sacramento River 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.

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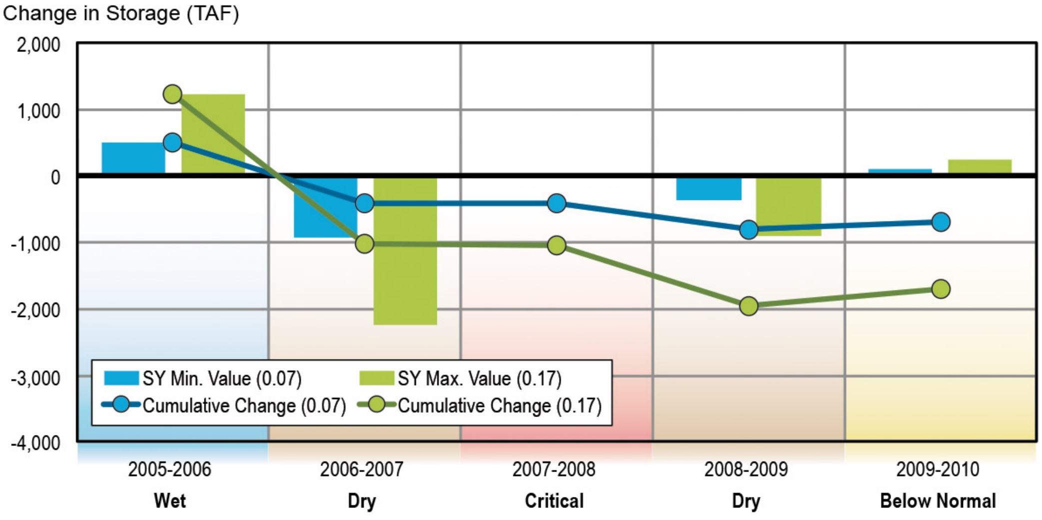
Table 7-12 Annual Change in Groundwater in Storage for the Sacramento Valley Portion of the Sacramento River Hydrologic Region (Spring 2005-Spring 2010)

Period Spring/Spring	Average Change in Groundwater Elevation (ft)	Estimated Change in Storage (taf)	
		Assuming Specific Yield = 0.07	Assuming Specific Yield = 0.17
2005-2006	2.3	503	1,221
2006-2007	-4.3	-929	-2,255
2007-2008	0.0	-2	-4
2008-2009	-1.8	-378	-918
2009-2010	0.5	103	250
Total (2005-2010)	**-3.3**	**-703**	**-1,706**

Notes:
ft = feet, taf = thousand acre feet
Groundwater elevation and change in storage estimates are calculated within reporting area.
Reporting area: 3,070,427 acres.
Non-reporting area: 1,033,705 acres.

Figure 7-16 Annual Change in Groundwater in Storage for the Sacramento Valley Portion of the Sacramento River Hydrologic Region (Spring 2005-Spring 2010)



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

For reporting purposes, the 18 groundwater subbasins for the Sacramento Valley Groundwater Basin were combined into seven regional subbasin groups, while the six subbasins in Redding Area Groundwater Basin were combined into one regional group. The Sacramento Valley groups include:

- Redding area.
- North Sacramento Valley: Glenn-Tehama area.
- Northeast Sacramento Valley: Los Molinos area.
- West Sacramento Valley: Colusa area.
- Central Sacramento Valley: Sutter area.
- East Sacramento Valley: Yuba area.

- Southwest Sacramento Valley: Yolo-Solano area.
- Southeast Sacramento Valley: American Basin area.

Figure 7-16 and Table 7-12, along with the tables and charts provided in Appendix E, show some variability in how the Sacramento Valley groundwater basins and subbasins responded to the changing hydrology and groundwater demand between 2005 and 2010. Between spring 2005 and 2006, average groundwater levels over the Sacramento Valley increased by 2.3 feet, with a corresponding increase of groundwater in storage between about 503 taf and 1,221 taf. All of the subbasin groups in the Sacramento Valley Groundwater Basin showed an increase in groundwater levels and associated storage of groundwater during the 2005-2006 period. The groundwater elevation increases ranged from 1.6 feet for the Western Sacramento Valley (Colusa Area) group to 3.6 feet for the East Sacramento Valley (Yuba Area) group. During this time, groundwater elevations in the Redding Area group increased an average of 3.0 feet, while the corresponding increase of groundwater in storage ranged from about 36 taf to 88 taf.

The gain in groundwater in storage associated with the wet 2005-2006 period was quickly erased during the dry conditions observed in 2007. Overall, the 2006-2007 groundwater levels decreased an average of about 4.3 feet throughout the Sacramento Valley, while the reduction of groundwater in aquifer storage ranged from about 929 taf to 2,255 taf. In the Sacramento Valley Groundwater Basin, the West Sacramento Valley (Colusa Area) group showed the largest 2006-2007 drop in groundwater levels, with about 6.3 feet of groundwater-level decline and with an estimated change of groundwater in storage of about -323 taf to -785 taf. The Southeast Sacramento Valley (American Groundwater Basin Area) group showed the smallest drop in groundwater levels, with about 1.3 feet of groundwater-level decline and an estimated reduction of groundwater in storage of about 49 taf to about 118 taf. The Redding Area group showed a decrease in groundwater elevation of 2.7 feet and a corresponding reduction of groundwater in aquifer storage between about 32 taf and 78 taf during the 2006-2007 period.

Critically dry conditions during 2007-2008 resulted in relatively small changes in the Sacramento Valley aquifer storage calculations, despite declining groundwater levels in five of the seven Sacramento Valley subbasin groups and the Redding Area group. However, the transition from a critically dry to a dry year between 2008 and 2009 resulted in a decline in groundwater levels and corresponding groundwater in aquifer storage estimates for the entire Sacramento Valley.

During the 2008-2009 spring periods, groundwater levels in the Sacramento Valley declined about 1.8 feet and groundwater in aquifer storage decreased between about 378 taf and about 918 taf. The North Sacramento Valley (Glenn-Tehama Area) group showed the largest 2008-2009 drop in groundwater levels, with 3.7 feet of groundwater-level decline and an estimated reduction of groundwater in storage of about 58 taf and 140 taf. For the 2008-2009 period, the Southeast Sacramento Valley (American Groundwater Basin Area) group showed the smallest drop in groundwater levels, with about 0.7 feet of groundwater-level decline and an estimated reduction of groundwater in storage of about 25 taf and 60 taf. The Redding Area group reported a groundwater elevation decrease of about 1.8 feet and a loss of groundwater in aquifer storage between about 22 taf and about 53 taf during the 2008-2009 period.

The return to almost normal hydrologic conditions and above-average precipitation in 2010 resulted in an increase of groundwater in aquifer storage for all of the groups in Sacramento Valley, except the East Sacramento (Yuba Area) group. Throughout the Sacramento Valley, the 2009-2010 change in groundwater levels was an increase of about 0.5 feet, with a corresponding increase of groundwater in aquifer storage between about 103 taf and about 250 taf.

Overall, the 2005 to 2010 net decline in groundwater levels for the Sacramento Valley was about 3.3 feet, with a corresponding reduction of groundwater in storage ranging between 703 taf and 1,706 taf. For comparison, as previously noted, the 2005-2010 average annual groundwater supply for the Sacramento River region is approximately 2,743 taf.

Groundwater Quality

Groundwater quality in the Sacramento River region is generally good. But, there are areas with local groundwater problems. Naturally occurring water-quality impairments take place at the north end of the Sacramento Valley in the Redding Area Groundwater Basin and along the margins of the valley and around the Sutter Buttes, places where Cretaceous marine sedimentary rocks containing brackish-to-saline water are near the surface. Water from the older underlying sediments mixes with the fresh water in the younger alluvial aquifer and degrades the quality. Wells constructed in these areas typically have high total dissolved solids (TDS).

High concentrations of arsenic have been found in wells located in the center of the Sacramento Valley along the Sacramento and Feather rivers, and in wells located in the Sacramento-San Joaquin Delta. The primary source of arsenic in groundwater is minerals eroded from the volcanic and granitic rocks of the Sierra Nevada to the east. Groundwater in the Quaternary alluvial deposits along the river and in the Delta commonly has low dissolved oxygen content (reducing conditions), and reducing conditions are correlated with elevated arsenic concentrations in Sacramento Valley groundwater (U.S. Geological Survey 2011).

Boron has been found at levels greater than the human-health notification level of 1,000 micrograms per liter in the southern and middle portions of the Sacramento Valley. High concentrations of boron found in wells located along Cache and Putah creeks are likely associated with old marine sediments from the Coast Ranges. High concentrations of boron found in wells located near the outlet of the Delta to Suisun Bay are likely associated with estuarine sediments of the San Francisco Bay and Sacramento-San Joaquin Delta system (U.S. Geological Survey 2011).

Other local natural impairments are moderate levels of hydrogen sulfide in the groundwater of the volcanic and geothermal areas in the western portion of the region. In the Sierra foothills, there is potential for encountering uranium and radon-bearing rock or sulfide mineral deposits containing heavy metals. Human-induced impairments are generally associated with individual septic system development in shallow, unconfined portions of aquifers or in fractured hard-rock areas where insufficient soil depths are available to properly leach effluent before it reaches the local groundwater supply.

Several State and federal GAMA-related groundwater quality reports that help assess and outline the groundwater quality conditions for the Sacramento River region are listed in Table 7-13.

Table 7-13 GAMA Groundwater Quality Reports for the Sacramento River Hydrologic Region

Data Summary Reports

- Cascade Range and Modoc Plateau
  http://pubs.usgs.gov/ds/688/pdf/ds688.pdf
- Northern Sacramento Valley
  http://www.waterboards.ca.gov/gama/docs/nsac_data.pdf
- Middle Sacramento Valley
  http://www.waterboards.ca.gov/gama/docs/dsr_midsac.pdf
- Southern Sacramento Valley
  http://www.waterboards.ca.gov/gama/docs/ds285.pdf
- Sierra Nevada
  http://www.waterboards.ca.gov/gama/docs/dsr_sierra_regional.pdf
- Northern Coast Ranges
  http://www.waterboards.ca.gov/gama/docs/northern_coast_ranges_dsr.pdf

Assessment Reports

- Status groundwater quality in the Southern, Middle, and Northern Sacramento Valley study units
  http://pubs.usgs.gov/sir/2011/5002/pdf/sir20115002.pdf

Fact Sheets

- Groundwater Quality in the Northern Sacramento Valley
  http://www.waterboards.ca.gov/gama/docs/nosac_fs.pdf
- Groundwater Quality in the Middle Sacramento Valley
  http://www.waterboards.ca.gov/gama/docs/mosac_fs.pdf
- Groundwater Quality in the Southern Sacramento Valley
  http://www.waterboards.ca.gov/gama/docs/sosac_fs.pdf

Domestic Well Project

- El Dorado County Focus Area
  http://www.waterboards.ca.gov/gama/docs/edc_draft120905version.pdf
- Tehama County Focus Area
  http://www.waterboards.ca.gov/gama/docs/tehama_focus_area_draft_datareport.pdf
- Yuba County Focus Area
  http://www.waterboards.ca.gov/gama/docs/yubareportsummary.pdf

Other Relevant Reports

- Communities that Rely on a Contaminated Groundwater Source for Drinking Water
  http://www.waterboards.ca.gov/water_issues/programs/gama/ab2222/index.shtml

Groundwater Quality at Community Drinking Water Wells

The SWRCB recently completed its report to the Legislature, titled *Communities That Rely on a Contaminated Groundwater Source for Drinking Water* (State Water Resources Control Board 2013). The report focused on chemical contaminants found in active groundwater wells used by a CWS. A *CWS* is defined, under the California Health & 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 served by the system." The findings of this report reflect the raw, untreated groundwater quality and do not necessarily reflect the final quality of groundwater served to these communities.

In the Sacramento River region there are an estimated 504 CWSs and 1,199 active wells. Table 7-14 shows that 101 of the 1,199 wells (8 percent) are affected by one or more chemical contaminants that exceed an MCL and require treatment. The affected wells are used by 61 CWSs in the region, with 45 of the 61 affected CWSs serving small communities, which commonly require financial assistance to construct water treatment facilities or create alternative solutions to meet drinking water standards (Table 7-15). The most prevalent groundwater contaminants affecting community drinking water wells in the region include arsenic, nitrate, PCE, and gross alpha-particle activity (Table 7-16). In addition, two of the CWSs' 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 of operating and maintaining a treatment system, and as a result, some are unable to provide drinking water that meets primary drinking water standards. As of February 2013, there were 19 small CWSs in the Sacramento River Hydrologic Region that violate a primary drinking water standard primarily because of groundwater contaminants. Fifteen of these small CWS are affected by arsenic (California Department of Public Health 2013).

Chromium-VI is another groundwater contaminant 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 environmental at low levels. There are also areas of contamination in the state, the result of 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 7-10.

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 is grouped into 35 groundwater basin groups statewide called "study units" and is being implemented by the SWRCB, the USGS, and the LLNL.

The GAMA Priority Basin Project tests for constituents of 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.

Table 7-14 Summary of Community Drinking Water Wells that Exceed a Primary Maximum Contaminant Level Prior to Treatment in the Sacramento River Hydrologic Region

Well Information	Community Water System[a] Wells
Number of Affected Wells[b]	101
Total Wells in the Region	1199
Percentage of Affected Wells[b]	8%

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 means 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 and did not consider uranium correction.

Table 7-15 Community Drinking Water Systems that Rely on Contaminated Groundwater Wells in the Sacramento River 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	45	418	11%
Medium Systems Population 3,301-10,000	5	42	12%
Large Systems Population > 10,000	11	44	25%
Total	**61**	**504**	**12%**

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 means 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 and did not consider uranium correction.

For the Sacramento River region, the USGS has completed data summary reports for the following study units:

- Cascade Range and Modoc Plateau.
- North Sacramento Valley.
- Middle Sacramento Valley.
- Southern Sacramento Valley.
- Sierra Nevada.
- Northern Coast Ranges.

Table 7-16 Contaminants Affecting Community Drinking Water Systems in the Sacramento River Hydrologic Region

Principal Contaminant (PC)	Number of Affected Water Systems[b] (PC exceeds the Primary MCL[d])	Number of Affected Wells[c,d] (PC exceeds the Primary MCL)
Arsenic	41	73
Nitrate	9	9
Tetrachloroethylene (PCE)	7	10
Gross alpha particle activity	3	4
Benzene	2	2
Aluminum	1	1
Methyl tertiary butyl ether (MTBE)	1	1
Perchlorate	1	1
Uranium	1	2

Source: State Water Resources 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 drinking water system means 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 and did not consider uranium correction.
[c] 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 and did not consider uranium correction.
[d] Two wells are affected by two contaminants.

Of the six study units, three (North, Middle and Southern Sacramento Valley) reside entirely in the Sacramento River region. The other three study units cover multiple hydrologic regions. The Cascade Range and Modoc Plateau Study Unit includes wells in the North Coast, Sacramento River, and North Lahontan hydrologic regions. The Sierra Nevada Study Unit includes wells in the Sacramento River, San Joaquin River, Tulare Lake, and North Lahontan hydrologic regions. The Northern Coast Ranges Study Unit primarily includes wells in the North Coast Hydrologic Region; however, nine wells are in the Sacramento River Hydrologic Region.

For comparison purposes only, groundwater quality results from these data summary reports were compared with the following public drinking water standards established by CDPH and/or the U.S. Environmental Protection Agency (EPA). These standards included MCLs, secondary maximum contaminant levels (SMCLs), notification levels (NLs), and lifetime health advisory levels (HALs). A summary of untreated groundwater quality results for these study units is listed on Table 7-17. In addition to these data summary reports, USGS has completed some assessment reports and fact sheets for groundwater basins in the Sacramento River Hydrologic Region. SWRCB completed a fact sheet listed in Table 7-10.

Table 7-17 Summary of Groundwater Quality Results from GAMA Data Summary Reports for the Sacramento River Hydrologic Region

Constituent	**Health Based Threshold**	**Number of Detections Greater Than Health Based Threshold**									
		Cascade Range and Modoc Plateau[a]			**Northern Sacramento Valley**		**Middle Sacramento Valley[b]**		**Southern Sacramento Valley**	**Sierra Nevada Study Unit[c]**	**North Coast Ranges Study Unit Interior Basins[d]**
		Quaternary and Tertiary Volcanic Areas	**Sacramento Valley Eastside**	**Cascade Range and Modoc Plateau Low Use Basins**	**Northern Sacramento Valley Study Area**	**Redding Study Area**	**West Study Area**	**East Study Area**			
Number of wells		23	15	10	34	32	55	53	83	83	9
Inorganic Constituents											
Arsenic	MCL	-	-	-	2	1	1	10	9	5	1
Barium	MCL	-	-	-	-	-		1	1	-	1
Boron	NL	-	-	-	-	-	3	2	10	2	2
Fluoride	MCL	-	-	-	-	-		-	-	1	-
Nitrate	MCL	-	-	-	-	-	1	1	1	-	-
Selenium	MCL	-	-	-	-	-		-	-	1	-
Uranium	MCL	-	-	-	-	-		-	-	2	-
Organic Constituents											
VOCs	MCL	0	0	0	0	0	0	0	0	0	0
Pesticides	MCL	0	0	0	0	0	0	0	0	0	0
Constituents of Special Interest											
Perchlorate	MCL	0	0	0	0	0	0	0	0	0	0
NDMA	NL	NA	NA	NA	1	0	0	0	0	0	NA
Trichloropropane	NL	NA	NA	NA	NA	NA	0	0	1	NA	NA
Radioactive Constituents											
Gross Alpha	MCL	0	0	0	0	0	0	0	0	4	0
Secondary Standards											
Chloride[e]	SMCL	-	-	-	-	-	1	2	2	-	-
Iron	SMCL	-	1	1	-	-	1	2	2	7	3
Manganese	SMCL	1	-	1	-	3	9	13	10	8	-
Sulfate[e]	SMCL	-	-	-	-	-	5	-	-	-	-
Total Dissolved Solids[e]	SMCL	-	-	-	-	-	13	6	9	4	4

Sources: U.S. Geological Survey Report on Ground-Water Quality Data in the Southern Sacramento Valley, 2005, U.S. Geological Survey Report on Ground-Water Quality Data in the Middle Sacramento Valley Study Unit, 2006, U.S. Geological Survey Report on Ground-Water Quality Data for the Northern Sacramento Valley, 2007, U.S. Geological Survey Report on Ground-Water Quality Data for the Sierra Nevada Study Unit, 2008, U.S. Geological Survey Report on Ground-Water Quality Data in the Cascade Range and Modoc Plateau Study Unit, 2010.

Notes:

HAL = lifetime health advisory level (U.S. Environmental Protection Agency), MCL = maximum contaminant level (State and/or federal), NA = not analyzed, NL = notification level (State), SMCL = secondary maximum contaminant level (State), TDS = total dissolved solids, VOC = volatile organic compound, X = data not available

[a] The Cascade Range and Modoc Plateau Study Unit includes 90 wells in the North Coast, Sacramento River, and North Lahontan hydrologic regions. Forty-eight wells are in the Sacramento River region (shown on U.S. Geological Survey Report Figures 4C, 4D & 4E. Well ID Nos. ES-01 thru 15, QV-03, 05, 07 thru 15, TV-02 thru 07, 09 thru 15, and LU-03, 04, 05, 06, 09, 11 thru 15).

[b] The Middle Sacramento Valley Study is divided into 2 areas. The West Study Area Well ID Nos. WSAC 01 thru 36, WSAC-FP 01 thru 08, RICE 10 thru 18, 21, 22. The East Study Area Well ID Nos. ESAC 01 thru 35, ESAC-FP 01 thru 07, RICE 01 thru 09, 19, 20.

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

[d] The North Coast Ranges Study Unit includes 58 wells in the North Coast and Sacramento River regions. Nine wells are in the Sacramento River region (shown on U.S. Geological Survey Report Figures 2A, 2B, and 2C. Well ID Nos. NOCO-IN 17,18, 20, 21, 22, 24, 25, 26, 27).

[e] Wells that exceed SMCLs for chloride, sulfate and TDS are greater than recommended levels.

Groundwater Quality at Domestic Wells

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

The GAMA Domestic Well Project tests for chemicals 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, methyl tertiary butyl ether [MTBE], and others).

In addition to the above 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 the Sacramento River region, the GAMA Domestic Well Project has completed sampling in El Dorado, Tehama, and Yuba counties. A total of 398 wells were sampled in El Dorado County, 223 were sampled in Tehama County, and 128 wells were sampled in Yuba County. Tehama and Yuba counties are located entirely within the Sacramento River region. Portions of El Dorado County are in the Sacramento River region, and other portions are in the San Joaquin River region. Summarized sample results for El Dorado County include wells from both regions. For comparison purposes, groundwater quality results were compared with public drinking water standards established by CDPH. These standards included primary MCLs, SMCLs, and NLs. A summary of the untreated groundwater quality sampling results for the three counties in Sacramento River region are shown on Table 7-18.

Table 7-18 Summary of Groundwater Quality Results for the El Dorado, Tehama, and Yuba County Domestic Well Project

Constituent	Health Based Threshold	Number of Detections Greater Than Health Based Threshold		
		El Dorado County Domestic Wells[a]	Tehama County Domestic Wells	Yuba County Domestic Wells
Number of Wells		398	223	128
Microbial Contaminants				
Total Coliform	Presence	111	56	31
Fecal Coliform	Presence	14	3	4
Inorganic Constituents				
Aluminum	MCL	1	-	3
Antimony	MCL	2	-	1
Arsenic	MCL	15	29	7
Chromium (Total)	MCL	-	1	-
Lead	NL	-	2	2
Nickel	MCL	1	-	2
Nitrate	MCL	7	2	2
Nitrite	MCL	-	2	-
Thallium	MCL	-	-	1
Organic Constituents				
VOCs	MCL	1	-	1
Radioactive Constituents				
Gross Alpha	MCL	-	-	-
Secondary Standards				
Aluminum	SMCL	11	6	26
Iron	SMCL	81	31	21
Manganese	SMCL	98	19	39
Total Dissolved Solids	SMCL	-	-	2

Sources: State Water Resources Control Board Groundwater Ambient Monitoring and Assessment Program — Voluntary Domestic Well Assessment Project, El Dorado County Data Summary Report, 2005, State Water Resources Control Board Groundwater Ambient Monitoring and Assessment Program — Domestic Well Project, Groundwater Quality Data Report Tehama County Focus Area, 2009, State Water Resources Control Board Groundwater Ambient Monitoring and Assessment Program — Domestic Well Project, Groundwater Quality Data Report Yuba County Focus Area, 2010.

Notes:
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), VOC = volatile organic compound

[a] The wells sampled in El Dorado County are located in the Sacramento River and San Joaquin River hydrologic regions.

Groundwater Quality Protection

In the Central Valley region, 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 groundwater 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 regarding groundwater quality protection concerns in the entire Central Valley region, including the Sacramento River region. In 2010, the Central Valley RWQCB approved the following recommended actions:

- Develop salt and nutrient management plan.
- Implement 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 (CAFOs).
- Implementation of long-term irrigated lands regulatory program.
  - Coordinate with the California Department of Food and Agriculture (CDFA) 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 and 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 all sources of salt and nutrients on a basin- or watershed-wide basis. This policy requires the development of regional or sub-regional Salt and Nutrient Management Plans for every groundwater basin/subbasin in California, and each plan must include monitoring, source identification, and implementation measures.

Throughout the Central Valley, participating in the development of the salt and nitrate management plan is of paramount importance in improving water quality in the region and providing for a sustainable economic and environmental future. CV-SALTS is a strategic initiative to address problems with salinity and nitrates in surface water and groundwater in the Central 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 affects all water users (stakeholders) in the Central Valley, it is important that all stakeholders participate in CV-SALTS in order to be part of the development and have input on the implementation of salt and nitrate management within the Central Valley. For the Central Valley, the accepted 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 salt and nitrate management plans will provide guidance across all of the Central Valley RWQCB's regulatory and non-regulatory programs regarding how to address salinity and nitrate concerns.

The salt and nitrate management plan will include groundwater 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 insure a sustainable future (Central Valley Salinity Alternatives for Long-Term Sustainability 2012a, 2012b).

Additional information on CV-SALTS is available at: http://cvsalinity.org/ and http://www.waterboards.ca.gov/centralvalley/water_issues/salinity/index.shtml.

Land Subsidence

In the Sacramento River region, land subsidence associated with groundwater withdrawal has been documented in the North American and Yolo groundwater subbasins. Figure 7-11 shows a map of the 11 extensometers that DWR monitors, as well as the GPS monitoring grid within the Sacramento Valley. Table 7-19 lists the depth, extensometer type, recording resolution, start of record, total displacement, and the average annual subsidence at each of the 11 extensometer sites. Table 7-19 also indicates that some extensometers show land subsidence while others show a net land expansion caused by wetting of clays. DWR operates 11 extensometers in the Sacramento Valley, eight of which show no inelastic subsidence, though they do show elastic subsidence on the order of ±0.03 of a foot. The other three extensometers show no elastic subsidence, and consequently no seasonal movement.

Table 7-19 Extensometers in the Sacramento River Hydrologic Region

State Well Number	Depth (ft)	Type	Recording Resolution (ft)	Start of Record	Total Displacement (ft)	Average Annual Subsidence[a] (ft)
19N01E35B002M	1026	Cable	0.005	July 7, 2005	0.010	0.001
20N01E18L001M	1060	Cable	0.005	March 3, 2005	0.000	0.000
18N01E35L001M	1006	Cable	0.005	July 8, 2005	0.005	0.0007
16N02W05B001M	813	Cable	0.005	February 3, 2005	-0.020	-0.003
17N02W09H002M	863	Cable	0.005	August 10, 2005	0.005	0.0007
19N02W08Q001M	1000	Cable	0.005	December 1, 2005	0.000	0.000
21N02W33M001M	1020	Cable	0.005	March 2, 2005	-0.050	-0.007
22N02W15C002M	880	Cable	0.005	March 1, 2005	0.050	0.007
11N04E04N005M	800	Pipe	0.001	April 13, 1994	-0.032	-0.002
11N01E24Q008M	1003	Pipe	0.001	June 15, 1988	-1.235	-0.051
09N03E08C004M	716	Pipe	0.001	January 24, 1992	-0.064	-0.003

Notes:
ft = feet
[a] Average annual subsidence = total displacement divided by the number years from start of record.
Table represents information as of December 2010.

The greatest amount of subsidence recorded in the Sacramento Valley is from the oldest extensometer (11N01E24Q008M), located in the Zamora area within the Colusa Groundwater Subbasin; this extensometer has been providing data since 1992. Table 7-19 shows that this extensometer recorded a total negative displacement of 1.235 feet, with an average annual subsidence rate of 0.051 feet per year. Figure 7-17 shows the subsidence and groundwater-level time series graph from 11N01E24Q008M; the data from this extensometer site show a relatively stable spring groundwater level over the same time period indicating strong recharge. The seasonal drawdown of the deeper aquifers has been increasing since 2000, reaching 70-80 feet each year. This drawdown can be causing a temporary dewatering of the fine materials and contributing to the total subsidence a small amount each year.

In Yolo County, the Zamora area has undergone land subsidence caused by groundwater pumping. Leveling surveys from 1950 to 1990 indicate that more than 4 feet of subsidence has occurred midway between Knights Landing and Zamora. The Zamora extensometer (11N01E24Q008M) was installed in this area to monitor subsidence. Since 1988, more than a foot of subsidence has been recorded at this extensometer site as a result of groundwater pumping.

The Yolo County Flood Control and Water Conservation District published a Groundwater Management Plan in 2006 which covers the Yolo County portion of the Colusa Groundwater Subbasin. One of the groundwater management plan's goals is to "maintain or enhance local groundwater quantity and quality, resulting in a reliable groundwater supply for beneficial uses and avoidance of adverse subsidence" (Yolo County Flood Control and Water Conservation

District 2006). The plan includes basin management objectives (BMOs) that address the problem of land subsidence resulting from groundwater use. The BMOs have both a trigger and a response; the trigger occurs when monitoring data show that a certain condition has been reached, and the response is the action to address the condition (Yolo County Flood Control and Water Conservation District 2006). This type of action plan is a good model to follow when managing water resources in an area prone to land subsidence. By maintaining a long-term balance of groundwater production and recharge, the negative effects of land subsidence can be minimized.

Although some land subsidence is occurring in the southern portion of the Sacramento Valley, the central and northern portions of the Sacramento Valley have not yet recorded any inelastic land subsidence. Figure 7-17 shows a graph of extensometer 22N02W15C002M, which is the most northern extensometer site within the Sacramento Valley, located in the Corning Groundwater Subbasin between Orland and Hamilton City. Groundwater levels at this site are declining at an average rate of 3 feet per year in the deep aquifer zone, while subsidence is showing a slight expansion of 0.005 foot per year.

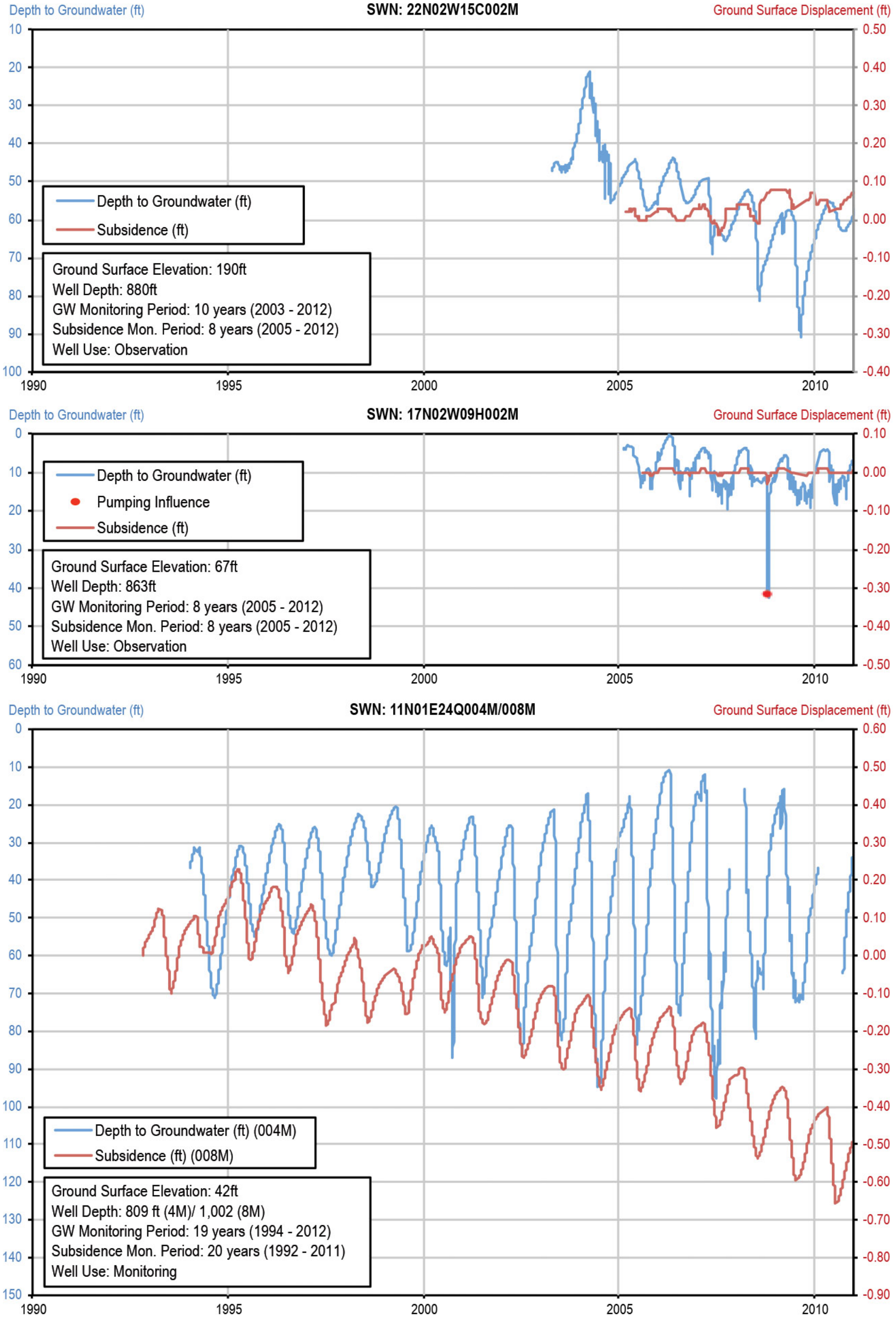
Figure 7-17 shows a graph of extensometer 17N02W09H002M, located northwest of Colusa, in the Colusa Groundwater Subbasin near the center of the Sacramento Valley. This extensometer was established in 2005. Data from that site indicate that groundwater levels from the deep aquifer zone are declining at a rate of about 0.8 foot per year while land subsidence has not yet been observed.

As groundwater pumping in the Sacramento Valley increases, the potential for land subsidence also increases. Although there is an existing land subsidence network in place, additional extensometers are needed for a complete land-subsidence monitoring grid. Two areas that show data gaps from the lack of extensometers are areas south of the Sutter Buttes and an area near Red Bluff. These areas are expanding in agriculture and extracting groundwater at an increasing rate. Additional subsidence monitoring is needed in these areas if we are to monitor our aquifers responsibly. The GPS network constructed in 2008 has not yet been resurveyed; as a result, there are no results to report from this subsidence method.

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 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.

Figure 7-17 Selected Subsidence and Groundwater Level Hydrographs for the Sacramento Hydrologic Region



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In addition to AB 3030, enacted legislation includes SB 1938, AB 359, and provisions of SB X7-6 and AB 1152. These significant pieces of legislation establish specific procedures on how GWMPs are to be developed and adopted by local agencies. They define the required and voluntary technical components that must be part of a GWMP and CASGEM groundwater-elevation monitoring plan.

AB 359, introduced in 2011, made changes to the California Water Code that requires local agencies to provide a copy of their GWMP to DWR and requires DWR to provide public access to those plans. Prior to the passage of AB 359, which went into effect on January 1, 2013, local groundwater management planning agencies were not required to submit their GWMPs to DWR. As such, the groundwater management information included in this report is based on documents that were readily available or submitted to DWR as of August 2012 and may not be all-inclusive, especially for those plans that were in the process of being finalized and adopted in 2012.

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 and 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 first step toward sustainable management of this valuable resource.

DWR's Groundwater Web site (http://water.ca.gov/groundwater/) has the latest information on California's groundwater management planning efforts and includes a summary of the Sustainable Groundwater Management Act 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). The act mandates the formation of locally-controlled groundwater sustainability agencies in high- and medium-priority groundwater basins. Many of the newly established components of the 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 in the Central Coast region.

Groundwater Management Plan Inventory

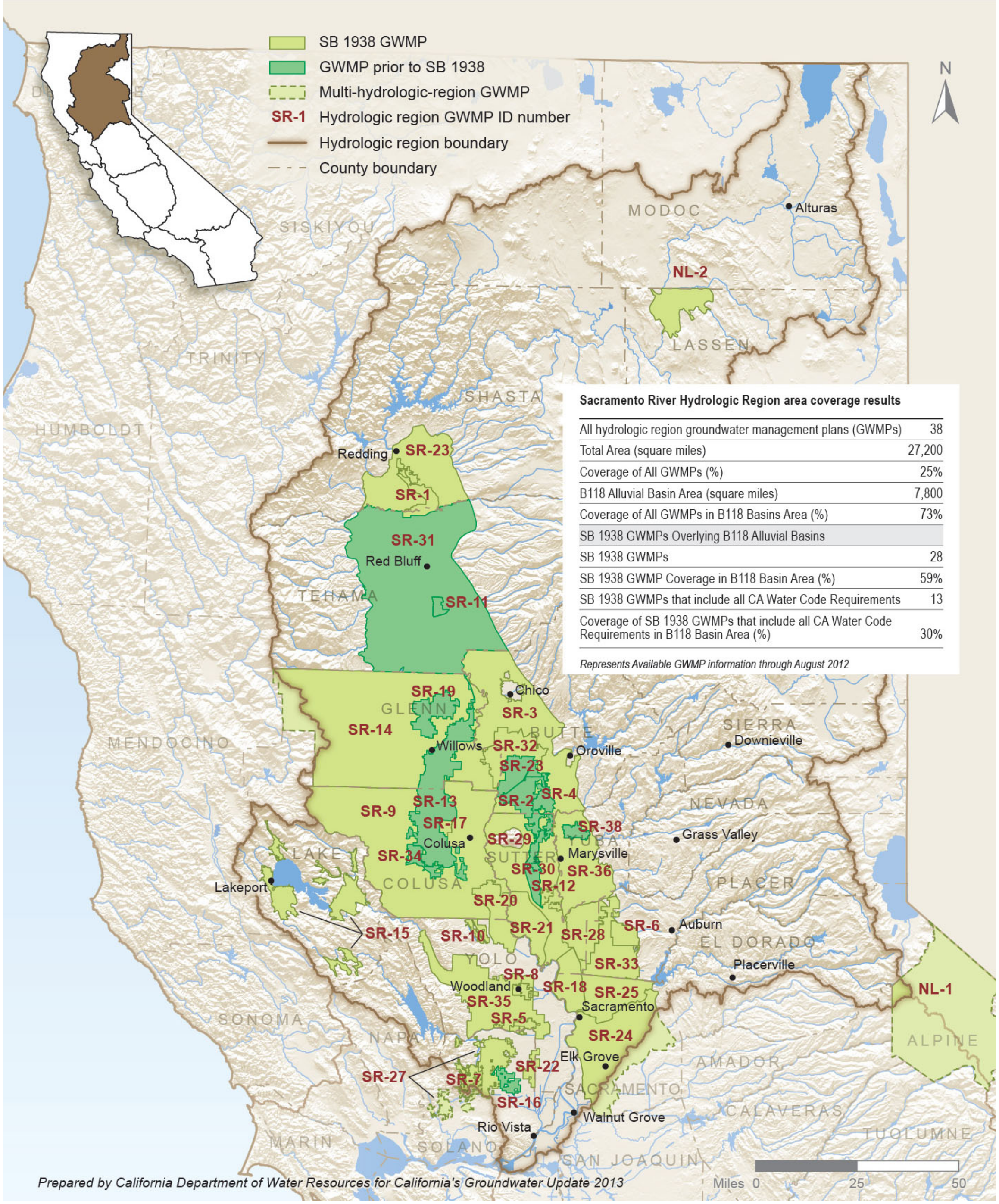
Groundwater management information included in this chapter is based on GWMP documents that were readily available or submitted to DWR as of August 2012. The inventory of GWMPs identifies adopting and signatory agencies, the date of plan adoption, the location of plans by county, and the groundwater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

The Sacramento River region includes 27,200 square miles of land area and approximately 7,800 square miles of alluvial groundwater basins recognized by Bulletin 118-2003. Figure 7-18 shows the location and distribution of the GWMPs within the Sacramento River region, and indicates which plans are pre- or post-SB 1938 GWMPs. Table 7-20 lists the results of the GWMP inventory for the region by adopting agency, signatories, plan date, and groundwater basin. There are 38 GWMPs within the Sacramento River region. Collectively, the 38 GWMPs cover about 73 percent of the alluvial groundwater basin area recognized by Bulletin 118-2003 within the region, and about 25 percent of the entire hydrologic region.

The inventory and assessment of GWMPs in the Sacramento River region determined 28 of the 38 GWMPs have been developed or updated to include the requirements of SB 1938 and are considered “active” for the purposes of GWMP assessment. The 28 active GWMPs cover about 59 percent of the alluvial groundwater basin area recognized by Bulletin 118-2003 in the Sacramento River region. Detailed review of the GWMPs in the Sacramento River region found that 13 of the 28 active GWMPs address all of the California Water Code requirements for groundwater management and cover approximately 30 percent of the alluvial groundwater basin area in the Sacramento River region.

Approximately 17 percent of California’s average annual groundwater extraction comes from the Sacramento River region. Of the 88 groundwater basins and subbasins in the Sacramento River region, five subbasins in the Sacramento Valley Groundwater Basin are identified as high priority, 16 basins and subbasins are listed as medium priority, seven basins rank a low priority, and the remaining 60 basins and subbasins in the region are very low priority. The 21 subbasins designated as high or medium priority include 89 percent of the annual groundwater use, and encompass 98 percent of the population that overlies the region’s groundwater basins.

Figure 7-18 Groundwater Management Plans in the Sacramento River Hydrologic Region



Sacramento River Hydrologic Region area coverage results

All hydrologic region groundwater management plans (GWMPs)	38
Total Area (square miles)	27,200
Coverage of All GWMPs (%)	25%
B118 Alluvial Basin Area (square miles)	7,800
Coverage of All GWMPs in B118 Basins Area (%)	73%
SB 1938 GWMPs Overlying B118 Alluvial Basins	
SB 1938 GWMPs	28
SB 1938 GWMP Coverage in B118 Basin Area (%)	59%
SB 1938 GWMPs that include all CA Water Code Requirements	13
Coverage of SB 1938 GWMPs that include all CA Water Code Requirements in B118 Basin Area (%)	30%

Represents Available GWMP information through August 2012

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Table 7-20 Groundwater Management Plans in the Sacramento River Hydrologic Region

Map Label	Agency Name	Date	County	Basin Number	Basin Name
SR-1	**Anderson-Cottonwood Irrigation District**	2006	Shasta	5-6.03	Anderson Subbasin
	No signatories on file		Tehama	5-6.04	Enterprise Subbasin
				5-6.01	Bowman Subbasin
				5-6.02	Rosewood Subbasin
SR-2	**Biggs-West Gridley Irrigation District**	1995	Butte	5-21.59	East Butte Subbasin
	No signatories on file			5-21.62	Sutter Subbasin
SR-3	**Butte County Department of Water and Resource Conservation**	2004	Butte	5-21.57	Vina Subbasin
	No signatories on file			5-21.58	West Butte Subbasin
				5-21.59	East Butte Subbasin
				5-21.60	North Yuba Subbasin
SR-4	**Butte Water District**	1996	Butte	5-21.59	East Butte Subbasin
	No signatories on file		Sutter	5-21.62	Sutter Subbasin
SR-5	**City of Davis/UC Davis**		Yolo	5-21.67	Yolo Subbasin
	No signatories on file				
SR-6	**City of Lincoln**	2003	Placer	5-21.64	North American Subbasin
	No signatories on file				
SR-7	**City of Vacaville**	2011	Solano	5-21.66	Solano Subbasin
	No signatories on file				
SR-8	**City of Woodland**	2011		5-21.67	Yolo Subbasin
	No signatories on file				Non-B118 Basin
SR-9	**Colusa County**	2008	Colusa	5-63	Stonyford Town Area Basin
	No signatories on file			5-64	Bear Valley Basin
				5-65	Little Indian Valley Basin
				5-90	Funks Creek Basin
				5-91	Antelope Creek Basin
				5-92	Blanchard Valley Basin
				5-21.52	Colusa Subbasin

Map Label	Agency Name	Date	County	Basin Number	Basin Name
				5-21.58	West Butte Subbasin
					Non-B118 Basin
SR-10	**Dunnigan Water District**	2007	Yolo	5-21.52	Colusa Subbasin
	No signatories on file				
SR-11	**El Camino Irrigation District**	1995	Tehama	5-22.50	Red Bluff Subbasin
	No signatories on file				
SR-12	**Feather Water District**	2005	Sutter	5-21.62	Sutter Subbasin
	No signatories on file				
SR-13	**Glenn Colusa Irrigation District**	1995	Colusa	5-21.52	Colusa Subbasin
	No signatories on file		Glenn	5-21.51	Corning Subbasin
					Non-B118 Basin
SR-14	**Glenn County**	2009	Glenn	5.21.52	Colusa Subbasin
	Provident Irrigation District			5-21.58	West Butte Subbasin
	Glide Water District			5.21.51	Corning Subbasin
	Willow Creek Mutual			5.61	Chrome Town Basin
	California Water Service			5-62	Elk Creek Area Basin
	Princeton-Codora-Glenn			5-63	Stonyford Town Area Basin
	Kanawha Water District			5-88	Stony Gorge Reservoir Basin
	Glenn-Colusa Irrigation District			5-89	Squaw Flat Basin
	Orland-Artois Water District			5-90	Funks Creek Basin
	Western Canal				Non-B118 Basin
	Orland Unit Water Users Association				
SR-15	**Lake County**	2006	Lake	5-13	Upper Lake Valley Basin
	No signatories on file			5-14	Scotts Valley Basin
				5-16	High Valley Basin
				5-17	Burns Valley Basin
				5-18	Coyote Valley Basin
				5-19	Collayomi Valley Basin
				5-30	Lower Lake Valley Basin

Map Label	Agency Name	Date	County	Basin Number	Basin Name
				5-31	Long Valley Basin
				5-66	Clear Lake Cache Formation Basin
				5-94	Middle Creek Basin
				1-48	Gravelley Valley Basin
SR-16	**Maine Prairie Water District**	1995	Solano	5-21.66	Solano Subbasin
	No signatories on file				
SR-17	**Maxwell Irrigation District**	2004	Colusa	5-21.52	Colusa Subbasin
	No signatories on file				
SR-18	**Natomas Central Mutual Water Company**	2009	Sutter	5-21.64	North American Subbasin
	No signatories on file		Sacramento		
SR-19	**Orland-Artois Water District**	2002	Glenn	5-21.51	Corning Subbasin
	No signatories on file				
SR-20	**Reclamation District No. 108**	2008	Colusa	5-21.52	Colusa Subbasin
	No signatories on file		Yolo		
SR-21	**Reclamation District No.1500**	2012	Sutter	5-21.62	Sutter Subbasin
	No signatories on file				
SR-22	**Reclamation District No. 2068**	2005	Solano	5-21.66	Solano Subbasin
	No signatories on file				
SR-23	**Richvale Irrigation District**	1998	Butte	5-21.59	East Butte Subbasin
	No signatories on file				
SR-24	**Sacramento Central County Water Agency**	2006	Sacramento	5-21.65	South American Subbasin
	City of Elk Grove			5-22.16	Cosumnes Subbasin
	City of Folsom				
	City of Rancho Cordova				
	City of Sacramento				
	County of Sacramento				
SR-25	**Sacramento Groundwater Authority**	2008	Sacramento	5-21.64	North American Subbasin
	California American				Non-B118 Basin

Map Label	Agency Name	Date	County	Basin Number	Basin Name
	Water				
	Carmichael Water District				
	Citrus Heights Water District				
	Del Paso Manor Water District				
	City of Folsom				
	Fair Oaks Water District				
	Natomas Central Mutual Water Company				
	Orange Vale Water Company				
	Rio Linda/Elverta Community Water District				
	City of Sacramento				
	Sacramento County				
	Sacramento Suburban Water District				
	San Juan Water District				
	Golden State Water Company				
SR-26	**Redding Area Water Council**	2007	Shasta	5-6.03	Anderson Subbasin
	Shasta County Water Agency			5-6.04	Enterprise Subbasin
	City of Anderson			5-6.05	Millville Subbasin
	City of Redding				
	City of Shasta Lake				
	Bella Vista Water District				
	Clear Creek Community Services District				
	Centerville Community Services District				
	Cottonwood Water District				
	Shasta Community Services District				
	Mountain Gate Community Services District				
	Keswick Community Services District				

Map Label	Agency Name	Date	County	Basin Number	Basin Name
	Jones Valley Community Services District				
	Anderson-Cottonwood Irrigation District				
SR-27	**Solano Irrigation District**	2006	Solano	5-21.66	Solano Subbasin
	No signatories on file			2-3	Suisun-Fairfield Valley Basin
					Non-B118 Basin
SR-28	**South Sutter Water District**	2009	Sutter	5-21.64	North American Subbasin
	No signatories on file		Placer		
SR-29	**Sutter County Public Works Department - Water Resources**	2012	Sutter	5-21.59	East Butte Subbasin
	No signatories on file			5-21.62	Sutter Subbasin
				5-21.64	North American Subbasin
				5-21.61	South Yuba Subbasin
SR-30	**Sutter Extension Water District**	1995	Sutter	5-21.62	Sutter Subbasin
	No signatories on file			5-21.59	East Butte
SR-31	**Tehama County Flood Control & Water Conservation District**	1996	Tehama	5-6.01	Bowman Subbasin
	No signatories on file			5-6.02	Rosewood Subbasin
				5-6.06	South Battle Creek Subbasin
				5-21.50	Red Bluff Subbasin
				5-21.51	Corning Subbasin
				5-21.52	Colusa Subbasin
				5-21.53	Bend Subbasin
				5-21.54	Antelope Subbasin
				5-21.55	Dye Creek Subbasin
				5-21.56	Los Molinos Subbasin
				5-21.57	Vina Subbasin
SR-32	**Western Canal Water District**	2005	Butte	5-21.59	East Butte Subbasin
	No signatories on file		Glenn	5-21.58	West Butte Subbasin
SR-33	**Western Placer County Group**	2007	Placer	5-21.64	North American Subbasin

Map Label	Agency Name	Date	County	Basin Number	Basin Name
	Placer County Water Agency				
	City of Lincoln				
	City of Roseville				
	California-American Water Company				
SR-34	**Westside Water District**	2000	Colusa	5-21.52	Colusa Subbasin
	No signatories on file				
SR-35	**Yolo County Flood Control and Water Conservation District**	2006	Yolo	5-21.67	Yolo Subbasin
	No signatories on file			5-21.68	Capay Valley Subbasin
				5-21.52	Colusa Subbasin
				5-21.66	Solano Subbasin
SR-36	**Yuba County Water Agency**	2010	Yuba	5-21.60	North Yuba Subbasin
	No signatories on file			5-21.61	South Yuba Subbasin
NL-1	**Alpine County**	2007	Alpine	6-6	Carson Valley Basin
	No signatories on file				Non-B118 Basin
NL-2	**Lassen County**	2007	Lassen	6-104	Long Valley Basin
	No signatories on file			6-2	Madeline Plains Basin
				6-3	Willow Creek Valley Basin
				6-4	Honey Lake Valley Basin
				6-94	Grasshopper Valley Basin
				6-95	Dry Valley Basin
				6-96	Eagle Lake Area Basin
				5-4	Big Valley Basin

Note:
Table reflects the plans that were received by August 2012.

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, and 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 information:

- How many of the post SB 1938 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 AB 3030 and incorporated 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. It is widely understood that effective groundwater management in California is rife with jurisdictional, institutional, technological, and fiscal challenges. DWR is committed to assisting local agencies develop and implement effective, locally planned, 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 effective local groundwater management. The overall intent of 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 were readily available or received 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 GWMP assessment effort completed for *California Water Plan Update 2013*. The following information will only address the active plans that were determined by DWR to meet some or all of the SB 1938 requirements.

Required GWMP Components

California Water Code Section 10753.7 requires 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 are:

1. **Basin Management Objectives**: Basin management objectives (BMOs) include components relating to the monitoring and managing of groundwater levels in 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. BMOs also include 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 detailing the area of the groundwater basin, as defined in DWR Bulletin 118-2003, and the area of the local agency 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 adopting the GWMP.
5. **Monitoring Protocols**: The local agency shall adopt monitoring protocols designed to detect changes in groundwater levels, groundwater quality, and inelastic surface subsidence in groundwater basins where subsidence has been identified as a potential problem. These protocols will also include 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 Groundwater Basins recognized by Bulletin 118-2003**: Plans located outside the alluvial groundwater basins recognized by Bulletin 118-2003 will incorporate the above components and shall use geologic and hydrologic principles appropriate to those areas.

Three of the six components include subcomponents that were also evaluated. The requirement to develop a map of recharge areas was not required until January 1, 2013; consequently, the requirement was not evaluated. In addition, the requirement for local agencies located outside a groundwater basin recognized by Bulletin-118-2003 was not applicable for any of the GWMPs in the Sacramento River region.

DWR determined that 13 out of the 28 active GWMPs in the region incorporated all of the required components evaluated. Table 7-21 identifies the percentage of the 28 active plans that meet the required components and subcomponents in California Water Code 10753.7. A detailed description of the individual component assessment of the GWMPs is provided below.

Basin Management Objectives

The BMO 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–groundwater interaction.

The assessment indicated that 14 of the 28 active GWMPs met the overall BMO requirement by providing measurable objectives and actions that will occur when specific conditions are met for each of the BMO subcomponents. Eleven of the 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.

Table 7-21 Assessment of GWMP Required Components in the Sacramento River Hydrologic Region

SB 1938 Required Components	Percentage of Plans that Meet Requirement
Basin Management Objectives	50%
BMO: Monitoring/Management Groundwater Levels	86%
BMO: Monitoring Groundwater Quality	89%
BMO: Inelastic Subsidence	82%
BMO: SW/GW Interaction and Affects to Groundwater Levels and Quality	57%
Agency Cooperation	96%
Map	79%
Map: Groundwater basin area	86%
Map: Area of local agency	89%
Map: Boundaries of other local agencies	75%
Recharge Areas (January 1, 2013)	Not Assessed
Monitoring Protocols	50%
MP: Changes in groundwater levels	96%
MP: Changes in groundwater quality	86%
MP: Subsidence	93%
MP: SW/GW Interaction and Affects to Groundwater Levels and Quality	50%
Met all Required Components and Subcomponents	46%

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

The most common BMO subcomponent missing or not adequately addressed within the active GWMPs is the planning requirements for the monitoring and management of surface water and groundwater interaction. This requirement was not met in 12 of the 28 plans assessed. Many of the GWMPs mentioned this requirement, but were vague about how a program would be initiated, measured, and managed.

The assessment indicated that five of the active GWMPs did not have plans in place to detect or address potential inelastic land subsidence within the management boundaries or within the groundwater basin as a whole. Several plans made the case to validate the absence of subsidence in their groundwater basin, and opted to delay the planning and implementation of this component until land subsidence became a potential issue. One agency reported that the delay in planning for inelastic land subsidence was necessary because of the high cost to implement a realtime subsidence monitoring network. A smaller subset of the reviewed GWMPs provided criteria, or triggers, that will be used to initiate future planning.

Agency Cooperation

Almost all of the GWMPs in the Sacramento River region 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 one or more maps that depict the GWMP area, the associated groundwater basin(s) recognized by Bulletin 118-2003, and all neighboring agencies located within the groundwater basin(s). The GWMP assessment determined that 22 of the 28 active GWMPs in the region met all three of the requirements for the mapping requirement. The most common detail left off the maps was identification of neighboring agencies that share the same groundwater basin.

Monitoring Protocols

The monitoring protocol component consists of four subcomponents. In accordance with SB 1938, GWMPs are required to establish monitoring protocols for assessing groundwater levels, groundwater quality, inelastic land subsidence, and surface water and groundwater interaction. Each subcomponent was assessed and an overall rating was applied.

The results of the assessment for the monitoring protocols component are similar to the BMO component. The monitoring protocols assessment determined that 14 of the 28 active GWMPs met each of the required monitoring protocol subcomponents. The assessment also determined that 13 GWMPs in the region are missing details for one or more of the subcomponents, and one GWMP did not meet any of the subcomponent requirements. Between 24 and 27 of the active GWMPs met the monitoring protocol requirements for groundwater levels, groundwater quality, and inelastic subsidence.

The assessment for surface water and groundwater interaction was the same for both the BMO and monitoring protocols; 26 of the active GWMPs have the same assessment for surface water and groundwater interaction for both BMO and monitoring protocols components. Three GWMPs have the required BMO component for the surface water and groundwater interaction but did not develop sufficient monitoring protocols that would help ensure correctness and consistency when measuring, recording, and presenting field data.

Voluntary GWMP Components

In addition to the six required components, California Water Code Section 10753.8 provides a list of 12 voluntary components that may be included in a GWMP. The voluntary components are:

1. 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. 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. Construction and operation of groundwater contamination cleanup, recharge, storage, conservation, water recycling, and extraction projects by local agencies.
11. Development of relationships with State and federal regulatory agencies.
12. Review of land use plans and coordination with land use planning agencies to assess activities which create a reasonable risk of groundwater contamination.

The percentage of GWMPs in the Sacramento River region that included the voluntary components is shown on Table 7-22. The assessment of some voluntary components was expanded to include subcomponents, which aided in determining a level of inclusion; but reporting was not done on a subcomponent level. In many cases, if the plan included one of more of the subcomponents, the plan was considered to fully meet the voluntary component.

Table 7-22 shows that components related to regulatory agencies, groundwater monitoring, and well construction policies are well represented in 90 percent or more of the active GWMPs in the Sacramento River region. GWMPs that include details for well abandonment and destruction, conjunctive use operations, overdraft, and well head protection and recharge issues are provided for in over 70 percent of the plans.

The least-included of the voluntary components was the construction and operation component. It is not clear from GWMP reviews if the low percentage was attributed to timing (occurred after plan adoption), if the lead agencies felt the topic was not relevant, or both. Based on discussions with a few local agencies, it was apparent that agencies are not always keeping GWMPs updated with future construction and operation projects. So, it is possible that some local agencies have groundwater projects that were initiated after GWMP adoption.

Land use, saline intrusion, groundwater contamination, and groundwater extraction/replenishment topics were not included in some GWMPs because the agencies did not consider the component a significant enough problem in their groundwater basin to warrant expensive planning activities, or they were coordinated outside the domain of the GWMP. In the Sacramento River region, the majority of the implemented groundwater extraction/replenishment and conjunctive use plans were more common in the southern portions of the region.

Subsequent communication with some local agencies regarding the omission of well abandonment, well destruction, and well construction components revealed that those topics were not addressed in the GWMP because the agency felt that county, State, and federal rules met the requirement. If these agencies stated this reliance on external polices and ordinances in their plans, it would have resulted in an even higher percentage of compliance.

Table 7-22 Assessment for GWMP Voluntary Components in the Sacramento River Hydrologic Region

Voluntary Components	Percentage of Plans that Include Component
Saline Intrusion	64%
Wellhead Protection and Recharge	71%
Groundwater Contamination	61%
Well Abandonment and Destruction	89%
Overdraft	75%
Groundwater Extraction and Replenishment	61%
Monitoring	100%
Conjunctive Use Operations	86%
Well Construction Policies	93%
Construction and Operation	39%
Regulatory Agencies	100%
Land Use	68%

Notes:

GWMP = groundwater management plan

Table reflects assessment results of SB 1938 plans that were received by August 2012.

GWMP Components Recommended by Bulletin 118-2003

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. The recommended components include:

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. **BMOs, 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, groundwater basin conditions, and achievements.
7. **Evaluation**: Develop periodic assessment of conditions in relation to management objectives.

Table 7-23 identifies the percentage of the Sacramento River region's 28 active GWMPs that include the seven recommended components outlined in Bulletin 118-2003. Descriptions and details for topics related to management area, future re-evaluation and reporting, and GWMP implementation were well represented in 80 percent or more of the GWMPs. Submittal of annual reports is not required and very few can be found on the Web sites of groundwater management agencies.

Of the GWMPs in the region, 75 percent of the plans include guidance details for establishing an advisory committee to guide the GWMP planning and implementation process. The same percentage of GWMPs provided a discussion of how each of the adopted management objectives helps to attain the stated goals, and described how current and planned actions by the managing entity will help meet the adopted management objectives.

Monitoring plan descriptions were included in 75 percent of the active GWMPs. The most common reason for not providing monitoring plan details in a GWMP was either the data was not available because the monitoring was being shared or handled by other organizations, or there were concerns about the privacy of participating landowners. Per the suggestions in Bulletin 118, two-thirds of the GWMPs made reference to current or future IRWM planning and participation.

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 asked to provide additional insights and list additional components, but not to rank their responses in terms of importance. Fifteen agencies from the Sacramento River region participated in the survey. Table 7-24 is a summary of the individual responses for the agencies that participated in the survey.

It was determined that none of the categories for successful GWMP implementation were unanimous. Data collection and sharing of information were selected most often as important criteria for a successful GWMP implementation. The same can be said about having adequate water supplies, water storage, and water conveyance. Additionally, communication, education, and participation were important to 75 percent of the respondents.

Additionally, three agencies supplied key components important to their GWMP implementation. Two agencies reported that conjunctive use projects and water supply management were important for their success, while two agencies identified computer models as being a great help for groundwater management by providing insights into future surface water and groundwater use and recharge scenarios.

Table 7-23 Assessment of DWR Bulletin 118-2003 Recommended Components in the Sacramento River Hydrologic Region

Recommended Components	Percentage of Plans that Include Component
GWMP Guidance	75%
Management Area	96%
BMOs, Goals, and Actions	75%
Monitoring Plan Description	75%
IRWM Planning	68%
GWMP Implementation	82%
GWMP Evaluation	86%

Notes:
BMO = basin management objective, DWR = California Department of Water Resources,
GWMP = groundwater management plan, IRWM = integrated regional water management
Table reflects assessment results of SB 1938 plans that were received by August 2012.

Table 7-24 Survey Results for Key Components Contributing to Successful GWMP Implementation in the Sacramento River Hydrologic Region

Key Components that Contributed to Success	Respondents
Sharing of ideas and information with other water resource	11
Data collection and sharing	10
Adequate surface water supplies	10
Adequate regional and local surface storage and conveyance	10
Outreach and education	9
Developing an understanding of common interest	9
Broad stakeholder participation	9
Water budget	6
Funding	6
Time	6
Additional Components Supplied by Participating Agencies	
Conjunctive Use	2
Numeric modeling of groundwater basin	2
Water supply management	2

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

DWR/ACWA Survey — Key Factors Limiting GWMP Success

Survey participants were also asked identify key factors they felt impeded implementation of their GWMP. Table 7-25 includes the survey results of the nine participants that provided details. Respondents pointed to a lack of funding as the biggest impediment to GWMP implementation. Funding is a challenging factor for many agencies because the implementation and operation of groundwater management projects are typically expensive, and because funding for projects are typically limited to either locally raised funds or grants from State and federal agencies. Unregulated pumping is also a major concern and is a hindrance to implementation of a GWMP. Finally, the lack of surface storage and conveyance and the lack of groundwater were also identified as factors that impeded or challenged GWMPs. Further research is needed to understand how the extent these limitations affect implementing effective groundwater management.

DWR/ACWA Survey — Opinions of Groundwater Sustainability

Finally, the survey asked if the respondents were confident in the long-term sustainability of their current groundwater supply. Thirteen respondents felt long-term sustainability of their groundwater supply was possible. There were no opposing views on long-term sustainability of groundwater in the region.

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*) that stipulated State law does not occupy the field of groundwater management and does not prevent cities and counties from adopting ordinances to manage and regulate groundwater. Since 1995, the *Baldwin v. Tehama County* decision has remained untested. As a result, the precise nature and extent of the authority 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 Sacramento River region. The most common ordinances are associated with groundwater wells. Of the 22 counties in the region, 19 have groundwater ordinances that regulate well construction, abandonment, and destruction; 15 of the region's counties have both. There are 12 counties that require permits to be submitted for water transfer projects, and three counties (Glenn, Butte, and Lassen) have extensive ordinances pertaining to groundwater management. The ordinances for these three counties include, but are not limited to, basin management objectives, monitoring protocols, agency cooperation, and guidance committees. Table 7-26 lists the ordinances being implemented by the 22 counties in the Sacramento River region.

Table 7-25 Survey Results for Factors that Limited the Successful GWMP Implementation in the Sacramento River Hydrologic Region

Limiting Factors	Respondents
Participation across a broad distribution of interests	1
Data collection and sharing	1
Funding for groundwater management planning	6
Funding for groundwater management projects	6
Funding to assist in stakeholder participation	5
Understanding of the local issues	3
Outreach and education	2
Groundwater Supply	-
Surface storage and conveyance capacity	1
Access to planning tools	3
Unregulated Pumping	3
Lack of Governance	-

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

Special Act Districts

Greater authority to manage groundwater has been granted to a few local agencies 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 no special act districts in the Sacramento River region.

Table 7-26 County Groundwater Ordinances in the Sacramento River Hydrologic Region

County	Groundwater Management	Guidance Committees	Export Permits	Recharge	Well Abandonment and Destruction	Well Construction Policies
Alpine	-	-	Yes	-	Yes	Yes
Amador	-	-	-	-	Yes	Yes
Butte	Yes	Yes	Yes	-	Yes	Yes
Colusa	-	-	Yes	-	-	Yes
El Dorado	-	-	-	-	Yes	Yes
Glenn	Yes	Yes	-	-	Yes	Yes
Lake	-	-	Yes	-	Yes	Yes
Lassen	Yes	Yes	Yes	-	Yes	-
Modoc	-	-	Yes	-	-	Yes
Napa	-	-	-	-	Yes	Yes
Nevada	-	-	-	-	Yes	Yes
Placer	-	-	-	-	Yes	Yes
Plumas	-	-	-	-	Yes	Yes
Sacramento	-	-	Yes	-	Yes	Yes
Shasta	-	-	Yes	-	-	-
Sierra	-	-	Yes	-	-	-
Siskiyou	-	Yes	Yes	-	Yes	-
Solano	-	-	-	-	Yes	Yes
Sutter	-	-	-	-	Yes	Yes
Tehama	-	-	Yes	-	Yes	Yes
Yolo	-	-	Yes	-	-	-
Yuba	-	-	-	-	Yes	Yes

Note:
Table represents information as of August 2012.

Court Adjudication of Groundwater Rights

Another form of groundwater management in California is through court adjudication. 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 currently 24 adjudicated groundwater basins in California; however, there are no groundwater basin adjudications in the Sacramento River region.

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 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, water quality, water-use efficiency, operational flexibility, and the stewardship of the land, 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 include creating groundwater contour maps for groundwater basin operations criteria, monitoring groundwater elevations, and monitoring groundwater quality.

Figure 7-19 shows the areas of the Sacramento River region covered by IRWM plans as of August 2012. Table 7-27 lists the status of the IRWM planning areas by hydrologic region. More information about IRWM planning can be found at http://www.water.ca.gov/irwm/index.cfm.

There are eight IRWM regions covering the majority of the Sacramento River region; four IWRM regions have adopted IRWM plans and four regions have IRWM plans in development. Two of the IRWM regions cross into two adjacent hydrologic regions. Of the four plans being implemented, one IRWM planning group says that groundwater in the region is poorly understood because of faulted and fractured geological conditions, and leaves groundwater management to city and county agencies, as well as irrigation districts. A few of the objectives of this group’s IRWM plan are to identify suitable groundwater management practices to prevent groundwater contamination, assure that groundwater recharge and extraction are balanced, and to support efforts to understand groundwater quantities and movement in the Sierra Nevada fractured-rock systems through more study and analysis.

One of the other IRWM planning regions has very little active groundwater management planning. In this region, there are no areas covered by a GWMP, but there is a groundwater management district for one area of their region. But the management district is legislated to monitor groundwater declines from groundwater pumping, and has few groundwater management components to it. This planning group does not rely on the district for groundwater management, and acknowledges that there is a need for IRWM goals and objectives to be applied to the entire IRWM region.

One of the planning groups relies on four local agencies, or authorities with active GWMPs, for their groundwater management. This IRWM planning area states that groundwater management is important to the IRWM region for reducing water rights disputes and conflicts resulting from heavy reliance on groundwater by agricultural and residential users for their water supply. A few of this IRWM region's objectives are to identify and resolve issues connected with conjunctive-use water management practices and groundwater contamination, and to evaluate the effectiveness of regional groundwater monitoring systems by identifying data gaps and making recommendations for improvements to groundwater monitoring systems. But, as stated before, active groundwater management is left to local entities.

Another IRWM plan was developed to provide guidance on water management planning and to support the implementation of projects and programs that would improve water management in the IRWM plan area. This group relies on local management of groundwater through the use of the county's SB 1938 compliant GWMP. The management group has identified groundwater management as an important issue to address, with regard to protecting and utilizing the groundwater resources in a sustainable manner. The overall goal for groundwater management in this IRWM planning region is to prevent overdraft, protect overlying groundwater rights, and ensure that the combined use of surface and groundwater resources provides for current and future water demands in a sustainable way.

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 to:

- 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 BMPs 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 are 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 updates are being evaluated. Additional information regarding urban water management and UWMPs can be found at http://www.water.ca.gov/urbanwatermanagement/.

Table 7-27 Status of Integrated Regional Water Management Plans in the Sacramento River Hydrologic Region

Hydrologic Region	IRWM Plan Name	Date	IRWM Plan Status	IRWM Map Number
Sacramento River	Northern Sacramento Valley		In Progress	22
Sacramento River	Upper Feather River Watershed	2005	Active	37
Sacramento River	Upper Pit River Watershed		In Progress	39
Sacramento River	Upper Sacramento-McCloud		In Progress	40
Sacramento River	Westside (Yolo, Solano, Napa, Lake, Colusa)		In Progress	45
Sacramento River	Yuba County	2008	Active	46
Sacramento River/San Joaquin River	American River Groundwater Basin	2006	Active	1
Sacramento River/San Joaquin River	Cosumnes, American, Bear, and Yuba Watersheds	2007	Active	6

Total Number of IRWM Planning Regions	8
Number of Active IRWM Plans	4
Number of IRWM Plans In Development	4
Number of IRWM Plans that Cross Hydrologic Boundaries	2[a]

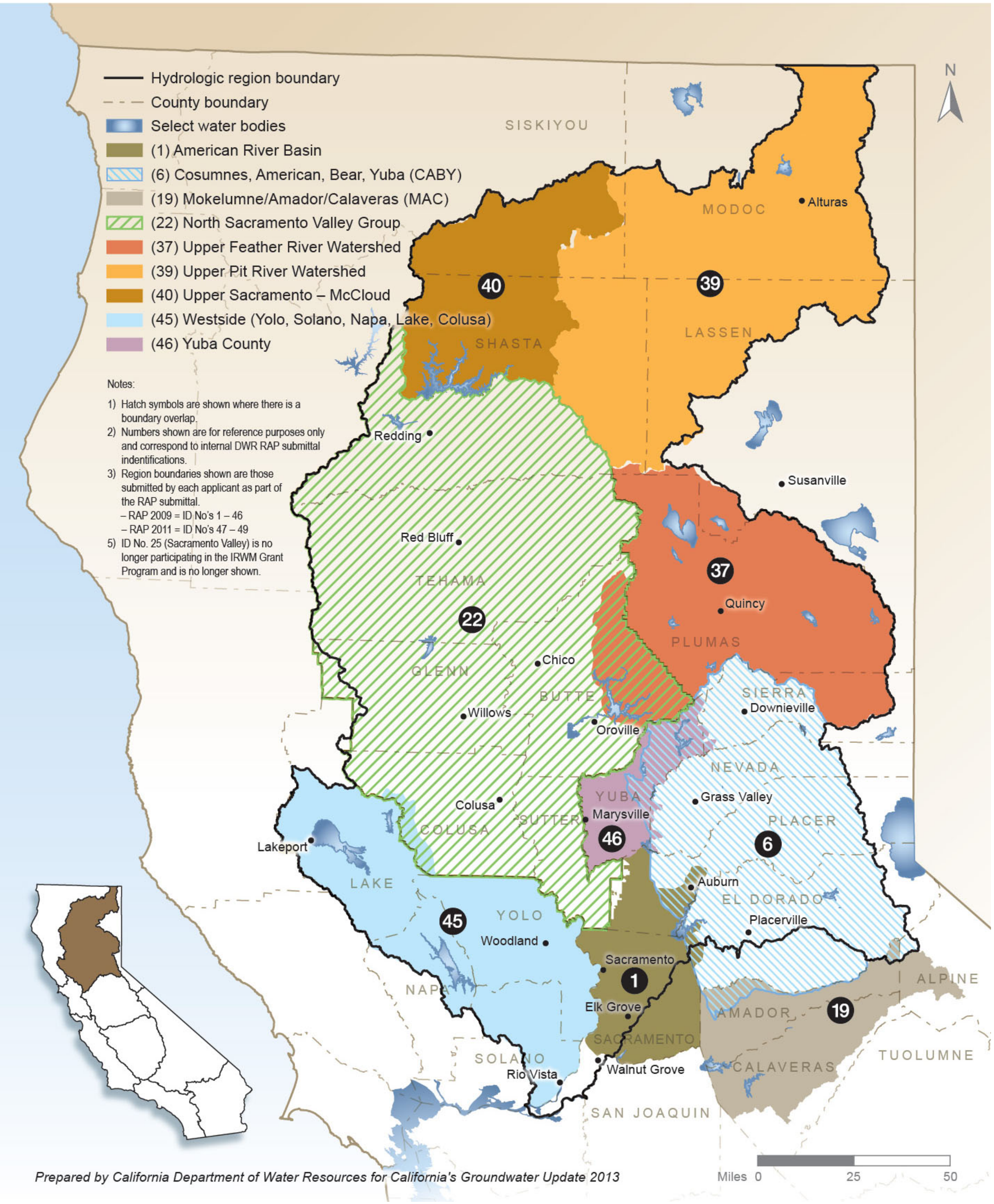
Notes:

IRWM = integrated regional water management

[a] Mokelumne/Amador/Calaveras (19) extend into the Sacramento River region, but as a result of the small area involved, the plan not included in this table. The plan area can be observed on Figure 7-19. Detailed information on Mokelumne/Amador/Calaveras (19) can be found in the San Joaquin River region report.

Table represents information as of August 2012.

Figure 7-19 Integrated Regional Water Management Plans in the Sacramento River 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
5) ID No. 25 (Sacramento Valley) is no longer participating in the IRWM Grant Program and is no longer shown.

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

Agricultural Water Management Plans

AWMPs are developed by water and irrigation districts to advance the efficiency of farm water management while providing benefits to 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. In addition, SB X7-7 requires that agricultural water suppliers:

- Report the status of AWMPs and efficient water management plans, 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 regional water supplies 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 Sacramento River region for decades.

As part of *California Water Plan Update 2013*, an inventory and assessment of conjunctive management programs 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 the challenges, successes, and opportunities for growth. The results of the inventory would be shared 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 discussion on associated benefits, costs, and issues, can be found online 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 projects 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 the conjunctive use project.
- Year the 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 DWR/ACWA online survey was encouraging, the number of survey participants and the completeness of responses were limited. In an attempt to build on the survey and develop a greater understanding of the size and diversity of conjunctive management projects in California, staff from each of DWR's four region offices in the Division of Integrated Regional Water Management contacted, either by telephone or through e-mail, each of the entities identified as having a conjunctive 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 in the planning and feasibility stage were not included in the inventory.

A statewide map and series of tables listing the conjunctive management projects identified by DWR and grouped by hydrologic region, with information specific to the 11 questions noted in this section, is provided in Appendix D. The project locations shown on the map represents the implementing agency's office address and does not represent the project location.

Conjunctive Management Inventory Results

Of the 89 agencies or programs identified as operating a conjunctive management or groundwater recharge program in California, three programs are located in the Sacramento River region. The following information summarizes the details provided to DWR by the following agencies: Yuba County Water Agency, Sacramento Suburban Water District, and City of Roseville.

Yuba County Water Agency has been operating an in-lieu groundwater recharge program in the North and South Yuba groundwater subbasins since approximately 1991. According to Yuba County Water Agency, the capacity of the in-lieu program ranges from zero to 90,000 acre-feet per year (af/yr) when adequate surface water supplies are available.

Sacramento Suburban Water District has been operating an in-lieu conjunctive management program in the North American Groundwater Subbasin since 1998. The goals and objectives of the program are to address groundwater overdraft, protect groundwater quality, and to accommodate potential water transfer opportunities. The capacity of Sacramento Suburban Water District's in-lieu program is 32,000 af/yr. On an annual basis, the in-lieu recharge volume into the groundwater basin is 12,500 to 18,000 acre-feet, with a cumulative recharge volume since 1998 of 176,800 acre-feet. The extraction estimate in a dry year is as much as 4,500 acre-feet, with a cumulative withdrawal of less than 10,000 acre-feet. According to the Water District, legal issues have been the most significant constraint for developing a conjunctive management program, with moderate constraints including political, water quality, and cost issues. Institutional constraints and limited aquifer storage were identified as minimal constraints.

The City of Roseville, to address water reliability for its system, developed an aquifer storage and recovery (ASR) program in the North American Groundwater Subbasin in 2003. The capital cost to develop the ASR program was approximately $3 million. The put and take capacity of Roseville's program is variable, but currently has a capacity, depending on water availability, of 5 million gallons per day, or as much as 4,772 af/yr.

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