5.4 Groundwater Resources

Groundwater is a vital water supply resource in California that is greatly influenced by human actions. In some areas, groundwater is in overdraft conditions, which can result in land subsidence and poor groundwater quality. In other areas, groundwater basin management has helped to ensure the continued beneficial use of this valuable resource.

5.4 Groundwater Resources

5.4.1 SUMMARY

Groundwater provides about 30% of California's water supply during average years; that percentage increases during drought conditions. Although the amount of water in California's aquifers is greater than that stored in the state's surface water reservoirs, only a small percentage of the groundwater resources can be economically and practically extracted. Overall, the CALFED Bay-Delta Program (Program) would benefit this crucial resource, but there is some potential for significant adverse impacts, depending on water supply conditions and options exercised. Mitigation strategies are available to reduce the potentially significant adverse impacts to less-than-significant levels.

Groundwater provides about 30% of California's water supply during average years; that percentage increases during drought conditions.

Preferred Program Alternative. The Preferred Program Alternative would benefit groundwater resources by providing opportunities for groundwater recharge. In areas with groundwater overdraft, more recharge can lead to better groundwater quality, reduced land subsidence, more dependable long-term water supply reliability, and reduced groundwater pumping. Under the Ecosystem Restoration and Levee System Integrity Programs, land conversion could benefit groundwater resources by reducing the amount of groundwater used on that land and reducing subsidence, additional groundwater recharge, and a reduction of salt-water intrusion in some areas. Potentially significant adverse impacts on groundwater resources from these programs could include reduced groundwater recharge as less agricultural drainage or irrigation water is used and returned to the system. The Water Use Efficiency Program could result in a reduced demand for groundwater supplies, which in turn could result in better quality groundwater. However, this program also could reduce the amount of water available in some areas for groundwater recharge. The Water Transfer Program could result in such potentially significant adverse impacts as increased groundwater pumping in areas where it previously had not occurred, reduced amount of water available for groundwater recharge, lower groundwater levels and higher pumping costs, degraded groundwater quality, and an increased dependence on groundwater supplies in areas receiving the transferred water. Mitigation strategies are available to reduce the potentially significant adverse impacts to less-than-significant levels.

The Storage element could benefit groundwater resources by increasing water supply reliability, increasing groundwater levels and thereby decreasing pumping costs, and reducing or reversing the effects of groundwater overdraft—primarily land subsidence and water quality degradation. However, potentially significant adverse impacts from the Storage element could include increased pumping and higher pumping costs, land subsidence, and poor-quality water, as well as reduced well yields and streamflow depletions. The Conveyance element could result in a potentially significant adverse impact related to the unlined canal that is associated with the proposed pilot diversion facility near Hood. An unlined canal could leak, depending on the soil permeability, and cause soils along the canal to waterlog.

Changes in project operations may result in a potentially significant adverse impact on groundwater resources in the Other SWP and CVP Service Areas. The potential range of changes in supply for this area could result in increased groundwater pumping; however, these same changes could lead to beneficial results in this area, depending on how the resources were managed. Mitigation strategies are available to reduce the potentially significant adverse impacts to less-than-significant levels.

Alternatives 1, 2, and 3. Alternatives 1, 2, and 3 would result in similar benefits and adverse impacts as those described for the Preferred Program Alternative. Alternatives 2 and 3 have greater potential for beneficial and adverse impacts than the Preferred Program Alternative or Alternative 1 because of their additional conveyance features.

The following table presents the potentially significant adverse impacts and mitigation strategies associated with the Preferred Program Alternative. Mitigation strategies that correlate to each listed impact are noted in parentheses after the impact.

Potentially Significant Adverse Impacts and Mitigation Strategies Associated with Preferred Program Alternative

Potentially Significant Adverse Impacts

Changes in groundwater levels (1,2,3,4,5,6).

Increased demand for groundwater supplies (1,2,3, 7,9).

Increased groundwater overdraft (4,8,10,11,14,15,16, 19,20).

Increased land subsidence (4,8,10,11,12,13,14,15,16, 19,20).

Increased degradation of groundwater quality from contaminant movement, salt-water intrusion, or naturally poor-quality water drawn into the aquifer (2,8,10,11,14,15,16,17,18,19,20).

Impacts from groundwater recharge and storage system operations (19).

Mitigation Strategies

1. Creating additional groundwater or surface water storage facilities to meet demand without resorting to overdraft.

2. Importing water from other basins.

3. Purchasing water rights from willing sellers (including transferring water rights between sectors—for example, from agriculture to municipal uses).

4. Regulating groundwater withdrawals to avoid overdraft.

Potentially Significant Adverse Impacts and Mitigation Strategies Associated with the Preferred Program Alternative (continued)

5. Implementing conservation measures to reduce demand.
6. Integrating Ecosystem Restoration Program floodplain restoration efforts with setback levees.
7. Increasing water supplies from recycling.
8. Increasing regulations regarding new and existing domestic wells and septic systems.
9. Developing alternative water supplies.
10. Monitoring and testing groundwater wells and aquifers.
11. Limiting new septic tank systems in vulnerable areas.
12. Allowing water levels to increase periodically.
13. Importing new soil (including dredged spoil) to raise land surface.
14. Reducing or discontinuing groundwater pumping.
15. Recharging vulnerable aquifers through injection wells (confined aquifers) or percolation ponds (unconfined aquifers).
16. Distributing groundwater pumping over a wide region rather than to a concentrated area to minimize drawdown of the aquifer.
17. Treating extracted groundwater at the well head.
18. Diluting poor-quality groundwater with higher quality water.
19. Developing groundwater basin management plans, including defining objectives, project boundaries, responsibilities, operations and maintenance specifications and procedures, and conditions under which corrective action must be taken.
20. Temporarily removing the recharge system from service.

No potentially significant unavoidable impacts on groundwater are associated with the Preferred Program Alternative.

5.4.2 AREAS OF CONTROVERSY

Areas of controversy as defined by CEQA involve differences of opinion among technical experts or information that is not available and cannot be readily obtained. According to this definition, no areas of controversy relate to groundwater resources.

There are a number of concerns over groundwater resources. The Program has initiated a groundwater outreach component to help identify and address stakeholder concerns about groundwater use and management with special emphasis on conjunctive use projects. The Program has contacted and met with dozens of individuals, including private citizens, water managers, water district board members, and elected officials to learn about local concerns regarding conjunctive use programs, and to determine which areas would be interested in participating in a locally-controlled conjunctive use program.

The Program has initiated a groundwater outreach component to help identify and address stakeholder concerns about groundwater use and management with special emphasis on conjunctive use projects.

Additionally, the Program has participated in workshops in both the Sacramento and San Joaquin Valleys to present the status of the groundwater program and to solicit additional comments and concerns regarding conjunctive use.

The CALFED Groundwater Outreach Program has resulted in a greater awareness of stakeholder concerns regarding potential negative impacts resulting from conjunctive use programs. While these impacts are specific to each area, they essentially fall into the following categories:

- Reduced well yields
- Subsidence
- Water quality degradation
- Increased pumping costs
- Costs for lowering pumps or deepening wells
- Changes in stream flow
- Overdrafted basins
- Loss of water rights
- Wetlands impacts

Stakeholder concerns relate to the following categories: reduced well yields, subsidence, water quality degradation, increased pumping costs, costs for lowering pumps or deepening wells, changes in stream flow, overdrafted basins, loss of water rights, and wetlands impacts

In addition to these potential impacts, many stakeholders have questions regarding the implementation of conjunctive use projects, such as:

- Who authorizes a conjunctive use project?
- Who controls the amount of water extracted?
- Who monitors and protects water quality?
- How are area of origin rights protected?
- Who allows water to be transferred and under what authority?
- How is conjunctive use integrated with existing management?
- How are the cumulative effects of all the projects monitored and evaluated?
- How are mitigation of impacts carried out?

The Program recognizes that these are real concerns, many of which are based on direct experiences with conjunctive use programs that in the past were not structured to identify or mitigate for negative impacts. As a result, the Program is developing guiding principles for conjunctive use programs to ensure that local concerns and potential impacts are fully addressed prior to implementing a conjunctive use operation.

5.4.3 AFFECTED ENVIRONMENT/ EXISTING CONDITIONS

About 30% of runoff from rainfall and snowmelt moves quickly over the ground surface and flows into stream channels.

Groundwater Hydrology. About 30% of runoff from rainfall and snowmelt moves quickly over the ground surface and flows into stream channels. Some of the runoff from the upper watershed is transferred out of the watershed in canals or pipelines, but some of the runoff and streamflow is able to percolate below the ground surface and recharge subsurface aquifers. Aquifers may be limited in their lateral extent, thickness, and ability to discharge water due to geologic and structural constraints.

Water that percolates deeply enough can reach the groundwater table. At this point, the slope of the groundwater table determines in which direction groundwater will flow. Often the slope of the water table mimics the slope of the land surface, but this is not always the case. After travel through the aquifer, some of the groundwater may discharge at the surface further downslope in springs, lakes, or streams.

Groundwater from wells drilled into aquifers are used by private and municipal users for consumption as drinking water, for irrigation water, and for industrial uses. Thin soils and steep slopes in upper watershed areas often limit the groundwater storage capacity of aquifers in these areas.

Groundwater from wells drilled into aquifers are used by private and municipal users for consumption as drinking water, for irrigation water, and for industrial uses.

Groundwater also is present in significant quantities in fractured rock aquifers that lie outside identified groundwater basins. This water is extensively used within upper watershed areas, particularly in the Sierra foothills, for homesite development and some agricultural development. Well yields are typically low, and water quality may be affected by local pollutant sources, such as septic tank effluent.

Groundwater Use. Current groundwater conditions in California are the result of human actions superimposed on the physical environment defined by geologic and hydrologic conditions and processes. The human component in this equation is influenced by a complex system of rules and overlapping jurisdictions, some of which are incorporated in the California Water Code, local ordinances, Regional Water Quality Control Board Basin Plans, the California Code of Regulations, and various federal laws. No summary could adequately encompass the legal and regulatory framework that conditions that portion of human activities that fall into the realm of groundwater "management." Among the pertinent features of the regulatory framework of groundwater management are the following:

Current groundwater conditions in California are the result of human actions superimposed on the physical environment defined by geologic and hydrologic conditions and processes.

- California landowners have a correlative right to extract as much groundwater as they can put to beneficial use. In some basins, that correlative right has been formally defined by a court. But the State does not have statutory authority to manage groundwater, and no systematic state-wide groundwater management program currently exists.

- The State's groundwater is actively managed under a formal groundwater management program. Some groundwater management programs have been developed on an ad hoc basis in response to local initiative. Legislation (Assembly Bill [AB] 3030) also allows certain existing local agencies to manage groundwater. More recently, several cities and counties have adopted ordinances giving them authority to manage groundwater.

The State's groundwater is actively managed under a formal groundwater management program.

- Twelve groundwater management districts have been established through special legislation. Of the six that are within the Program study area, five are within the

Other SWP and CVP Service Areas, and one is in the watershed of the Sacramento River Region.

- In some groundwater basins, disputes over how much groundwater can rightfully be extracted by each landowner have been adjudicated by the courts. In these adjudicated basins, the court defines the basin boundaries and appoints a watermaster to oversee the court judgement. Two adjudicated basins (the Cummings Basin and the Tehachapi Basin) are located in the upper watershed of the southern San Joaquin Valley. One of the adjudicated basins is outside the Program study area, in the North Coast Region. The remaining 13 adjudicated basins are within the Other SWP and CVP Service Areas.

Identification and characterization of groundwater basins is the responsibility of DWR. The first comprehensive inventory of the groundwater basins in the state was completed in 1975 and published as Bulletin 118. Bulletin 118 was revised in 1980 in response to legislation requiring that DWR "identify the State's groundwater basins on the basis of geological and hydrological conditions and consideration of political boundary lines whenever practical." DWR also was asked to identify basins subject to "critical conditions of overdraft." Bulletin 118-80 identified 450 groundwater basins, 11 of which were found to be subject to critical conditions of overdraft. One of these, the Eastern San Joaquin County Basin, is located in the Delta Region, and extends into the San Joaquin River Region. Figure 5.4-1 shows the distribution of geologic materials that have been defined as groundwater basins.

The first comprehensive inventory of the groundwater basins in the state was completed in 1975 and published as Bulletin 118.

DWR recently has revised the descriptions of some groundwater basins, which will be published in a future edition of Bulletin 118. The description of groundwater basins presented in this report is based, to the extent possible, on the working definitions currently used by DWR staff.

5.4.3.1 DELTA REGION

The Delta Region is underlain by organic-rich, fine-grained alluvial soils. Peat deposits more than 20 feet thick are found in the central Delta. These deposits have been mined in some areas for use as a soil amendment. Beneath the young surficial deposits are up to 3,000 feet of unconsolidated non-marine sediments. These deposits contain the principal regional aquifer in the Delta.

Beneath the young surficial deposits are up to 3,000 feet of unconsolidated non-marine sediments. These deposits contain the principal regional aquifer in the Delta.

In the central Delta, the aquifer consists of many poorly connected sand and gravel units that are locally confined by silt and clay layers. Both low yields to wells and poor water quality limit the use of groundwater in the central Delta. Groundwater from depths of less than 100 feet is too saline for most beneficial uses in an area covering over 200 square miles of the central Delta.

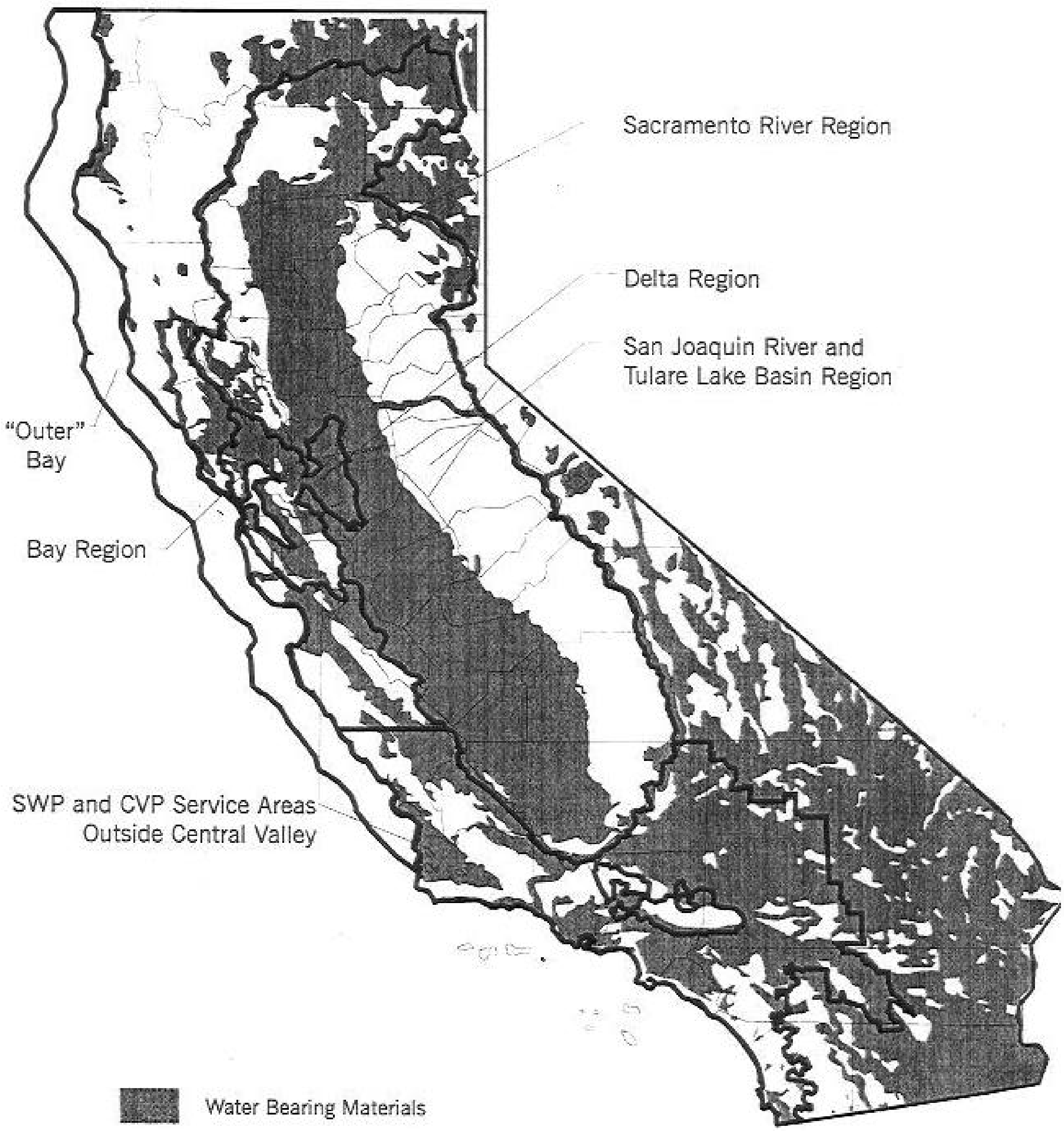


Figure 5.4-1. Distribution of Groundwater Basins in California

Information on use of groundwater in the Delta Region is limited. Historically, groundwater pumping in the central Delta has been used to drain waterlogged soils for agriculture. Groundwater use has been limited to the upland areas on the Delta periphery.

Most of the current groundwater pumping on Delta islands is for the purpose of draining crop lands. The land surface on many Delta islands lies below the elevation of water in the surrounding channels and would be flooded if groundwater levels were not lowered by pumping. The Delta aquifer is recharged primarily by streamflow and to a lesser degree by underflow from adjacent aquifers.

Most of the current groundwater pumping on Delta islands is for the purpose of draining crop lands.

One type of land subsidence is associated mainly with loss of peat soils. As water levels decline, oxygen from the atmosphere enters the pore space once occupied by water. The oxygen reacts with the peat, which is composed of plant material, and slowly causes it to oxidize, which is a chemical process like burning. The byproducts of oxidation of peat are carbon dioxide and water. As a result, the peat disappears and no longer supports the overlying soil, resulting in subsidence.

Around the margins of the Delta Region both the quality and yield of groundwater are higher than in the central Delta lowlands. Groundwater is relied on in the peripheral Delta uplands for both domestic and agricultural uses. Average annual groundwater withdrawals are estimated to range from 100 to 150 thousand acre-feet (TAF) in upland areas of the Delta.

5.4.3.2 BAY REGION

Within the Bay Region, groundwater is found in both alluvial aquifers and in fractured rock. Alluvial basin deposits near the Bay range in thickness up to 1,000 feet. Well yields typically range from less than 100 to over 3,000 gallons per minute. Recharge to the alluvial basins occurs primarily from infiltration of rainfall along stream channels. Artificial recharge in Santa Clara County and the Niles Cone Basin also account for significant local groundwater recharge.

Within the Bay Region, groundwater is found in both alluvial aquifers and in fractured rock.

Total average groundwater use in the region is estimated at about 190 TAF per year. The estimated groundwater storage in the North Bay is estimated at 1.7 MAF. Groundwater storage in the South Bay is estimated at 6.5 MAF.

A portion of groundwater resources in basin areas of the Bay Region have been subject to overdraft conditions, leading to salt-water intrusion and subsidence, and pollutant loading from urban-industrial sources. Basin aquifers generally are protected from surface contamination to some extent by thick clay deposits.

Groundwater conditions in the Santa Clara County Basin are an exceptional example of the range of problems encountered elsewhere in the Bay Region. The basin aquifers were heavily pumped to meet agricultural and municipal demands prior to the 1960s, causing land subsidence, increased flooding potential, and salt-water intrusion in portions of the basin. A county-wide groundwater management program was implemented, including construction of artificial recharge basins to replenish groundwater, well registration to control cross-contamination of aquifers by intruding salt water, and a groundwater extraction monitoring and pumping fee program to track withdrawals and fund the replenishment program. Widespread groundwater pollution from industrial sources also occurred as the region underwent intense industrial development and urban expansion. Large-scale, long-term groundwater extraction and treatment projects have been undertaken to remediate some of the groundwater contamination sites. Outside the Santa Clara County Basin and the Niles Cone area, groundwater is not widely used and has not experienced sea-water intrusion or subsidence.

Groundwater use in the Bay Region has decreased, and surface water use has increased as the region has undergone urban expansion. Surface water is imported from the Delta through the CVP and SWP, and from other sources. However, groundwater use tends to increase during low rainfall periods. During the 1987-92 drought, for example, groundwater use increased substantially to make up for decreased surface water supplies.

Groundwater use in the Bay Region has decreased, and surface water use has increased as the region has undergone urban expansion.

Groundwater quality may be affected by a number of processes. Contaminants may reach groundwater from surface or subsurface sources, such as hazardous waste sites, underground storage tanks, or polluted streams. Groundwater pumping may induce poor quality groundwater from one area to migrate into another area. Salt-water intrusion caused by groundwater pumping in coastal areas is an example of this condition.

Groundwater quality varies throughout the Bay Region, depending on local geological and land use conditions.

In the North Bay, water quality is generally good, although some areas experience elevated iron, boron, hardness, total dissolved solids (TDS), and chloride. Elevated concentrations of nitrates occur in the Napa and Petaluma Basins, where fertilizers are used intensively. In the southern Suisun-Fairfield Basin, salt-water intrusion has occurred due to over-extraction of groundwater.

Groundwater quality is poor in many parts of the South Bay. Elevated levels of TDS, chloride, boron, and hardness occur in the Livermore Basin. In the San Mateo, Santa Clara County, Pittsburg Plain, and Niles Cone Basins, salt-water intrusion induced by over-extraction of groundwater has been a problem in the past and now is being addressed through artificial groundwater recharge and monitoring groundwater withdrawals.

5.4.3.3 Sacramento River Region

Seepage from applied irrigation and from irrigation distribution canals is an important component of groundwater recharge in some parts of the Sacramento Valley.

For discussion purposes, groundwater sub-basins located within the floor of the Sacramento Valley, between Redding and the Delta Region, are considered together as one unit herein called the Sacramento Valley Alluvial Basin. Depth to the base of fresh water in the Sacramento Valley Alluvial Basin ranges from 1,000 feet in the Orland area to nearly 3,000 feet in the Sacramento area. Most recharge to the basin occurs along the north and east boundaries of the Sacramento Valley, where runoff is greatest. Seepage from applied irrigation and from irrigation distribution canals is an important component of groundwater recharge in some parts of the Sacramento Valley. Usable storage capacity is currently estimated at 40 MAF. The perennial yield (the amount of groundwater that can be extracted indefinitely from an aquifer without long-term adverse impacts) has been estimated at 2.4 MAF per year. Current groundwater withdrawals from the alluvial basins are estimated to total 2.6 MAF. Although total withdrawals are not much greater than the estimated perennial yield, local groundwater depressions have developed in some areas due to the uneven distribution of pumping. Figure 5.4-2 shows recent groundwater levels in the Sacramento Valley.

Prior to development, aquifer recharge to the Sacramento Valley Basin was mainly from infiltration along streambeds and from subsurface inflow along basin boundaries. With the introduction of agriculture to the region, seepage from irrigation canals and deep percolation of applied irrigation water contributed to recharge.

Prior to development, aquifer recharge to the Sacramento Valley Basin was mainly from infiltration along streambeds and from subsurface inflow along basin boundaries.

Historical data show that surface water and groundwater are closely linked in many parts of the basin. When the water table rises above the level of water in a stream channel, groundwater tends to flow from the aquifer to the stream (gaining stream). When groundwater levels fall, the stream loses water by seepage to the underlying aquifer (losing stream), contributing to groundwater recharge. The gaining component of a stream depends on cyclic changes in recharge and is an indicator of the unfilled storage capacity of the upper aquifer. A study of stream gains and losses from 1961 to 1977, an average recharge period, indicated that streams in the central and eastern Sacramento Valley were generally gaining streams, while west side streams and the American River were losing streams.

In some areas, near the Sacramento River, the stream channel is higher in elevation than the surrounding land surface. This condition can result in waterlogging of lands adjacent to the river and consequent crop losses due to seepage from the stream channel. DWR has identified several areas where this problem occurs.

Over the long term, if the amount of water stored in a groundwater basin is to remain constant, the outflow from a basin cannot be greater than the recharge to the basin. A long-term decline in groundwater storage, which would be observed as a general decline in regional water levels, is the result of more outflow than inflow. Recharge can include infiltration of surface water, groundwater underflow, or groundwater injection. Outflows include groundwater underflow, discharge to surface water bodies (springs, streams, and lakes), groundwater pumping, and evapotranspiration.

Over the long term, if the amount of water stored in a groundwater basin is to remain constant, the outflow from a basin cannot be greater than the recharge to the basin.

In fall 1960, regional groundwater levels north of the Sutter Buttes were similar to water levels observed in the early 1900s. However, south of the Sutter Buttes, groundwater levels in several areas of Yolo, Solano, and Sacramento Counties had dropped nearly 50 feet since the early 1900s. Groundwater levels in areas north of the Sutter Buttes

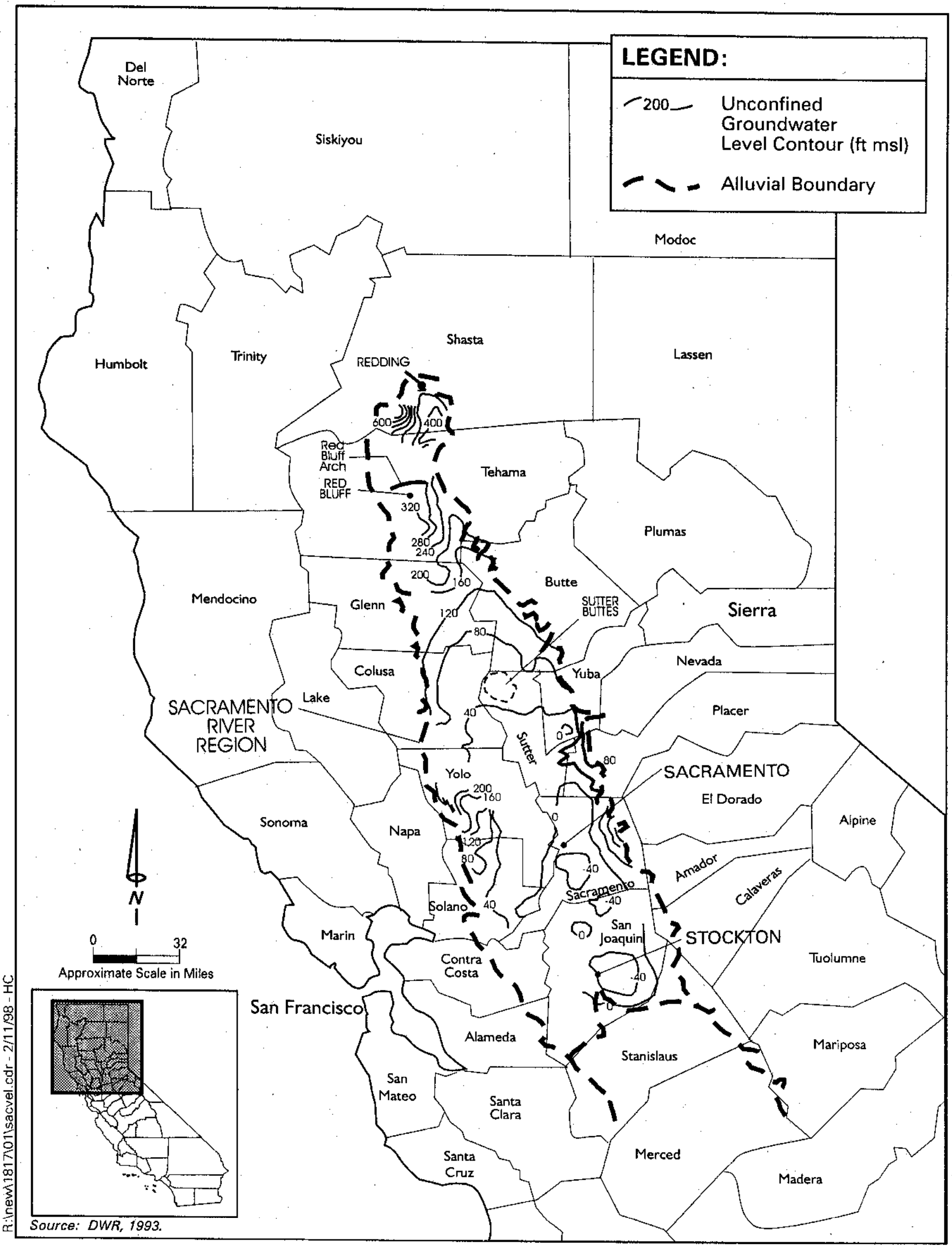


Figure 5.4-2. Groundwater Elevations in the Sacramento Valley

continued to show little sign of long-term declines through the mid 1970s. By spring 1974, groundwater levels south of the Sutter Buttes had recovered somewhat, due to above normal runoff. However, continued groundwater development in Sacramento County and in the Marysville area east of Sutter Buttes resulted in additional declines between 1960 and 1974.

Groundwater levels in spring 1986 indicated little change from 1974 levels. Spring 1993 water level data indicated the presence of a pumping depression in Sacramento County. Groundwater levels in much of the western part of both Sacramento and San Joaquin Counties were more than 40 feet below sea level. In all other areas of the Sacramento Valley Alluvial Basin, above- normal runoff during the 1992-93 wet season resulted in nearly full recovery of groundwater levels to pre-drought (1987-92) conditions.

Depending on specific conditions in the basin, a long-term decline in groundwater storage can result in secondary impacts, such as land subsidence, increased cost of pumping, permanent reduction in permeability of aquifers, and reduction in water quality.

Depending on specific conditions in the basin, a long-term decline in ground-water storage can result in secondary impacts, such as land subsidence, increased cost of pumping, permanent reduction in permeability of aquifers, and re-duction in water quality.

Declining water levels may cause land subsidence in at least two ways. In some aquifers, the sand and silt particles that form the matrix of the aquifer are kept slightly separated from each by the buoyancy effects of water. The water prevents the particles from compressing under the weight of the overlying soil. When the water is removed, however, the particles settle closer together. Subsidence is the combined effect of all of the settling of particles within the aquifer. The more water that is removed, the more subsidence occurs. Some of this compression is irreversible, so that even if groundwater returns to its previous level, the pore space between particles will remain smaller than before the compression occurred. Subsidence can cause damage to structures and increase flooding potential on low-lying land. Reduction in the pore space in the aquifer also may reduce the permeability of the aquifer, reducing the rate of groundwater flow under pumping pressure.

Land subsidence due to groundwater declines exceeded 2 feet by 1973 in the area east of Zamora and west of Arbuckle. Subsidence exceeded 1 foot near Davis by 1973. Localized land subsidence continued to occur in the Davis-Zamora area during the 1987-92 drought. Figure 5.4-3 shows areas of historical land subsidence.

Groundwater quality in the upper watersheds of the Sierra Nevada is good; recharge is generally high, and groundwater resources are relatively undeveloped. In some areas, however, wells drilled in fractured rock provide the water supply for permanent or recreational homesites. Due to the low porosity of rock fractures, the rapid flow along fractures, and the potential for fractures to intercept surface sources of pollutants, development of groundwater in fractured rock has led to problems of interference between wells and contamination from septic tank effluent. The Sierra Valley Basin has been identified as a special problem basin. Drilling of large agricultural wells and growth of housing subdivisions also has caused water levels in the formerly artesian aquifer to drop below the ground surface, complicating the problem of providing winter water for cattle.

Groundwater quality in the upper water-sheds of the Sierra Nevada is good; recharge is generally high, and ground-water resources are relatively undevel-oped.

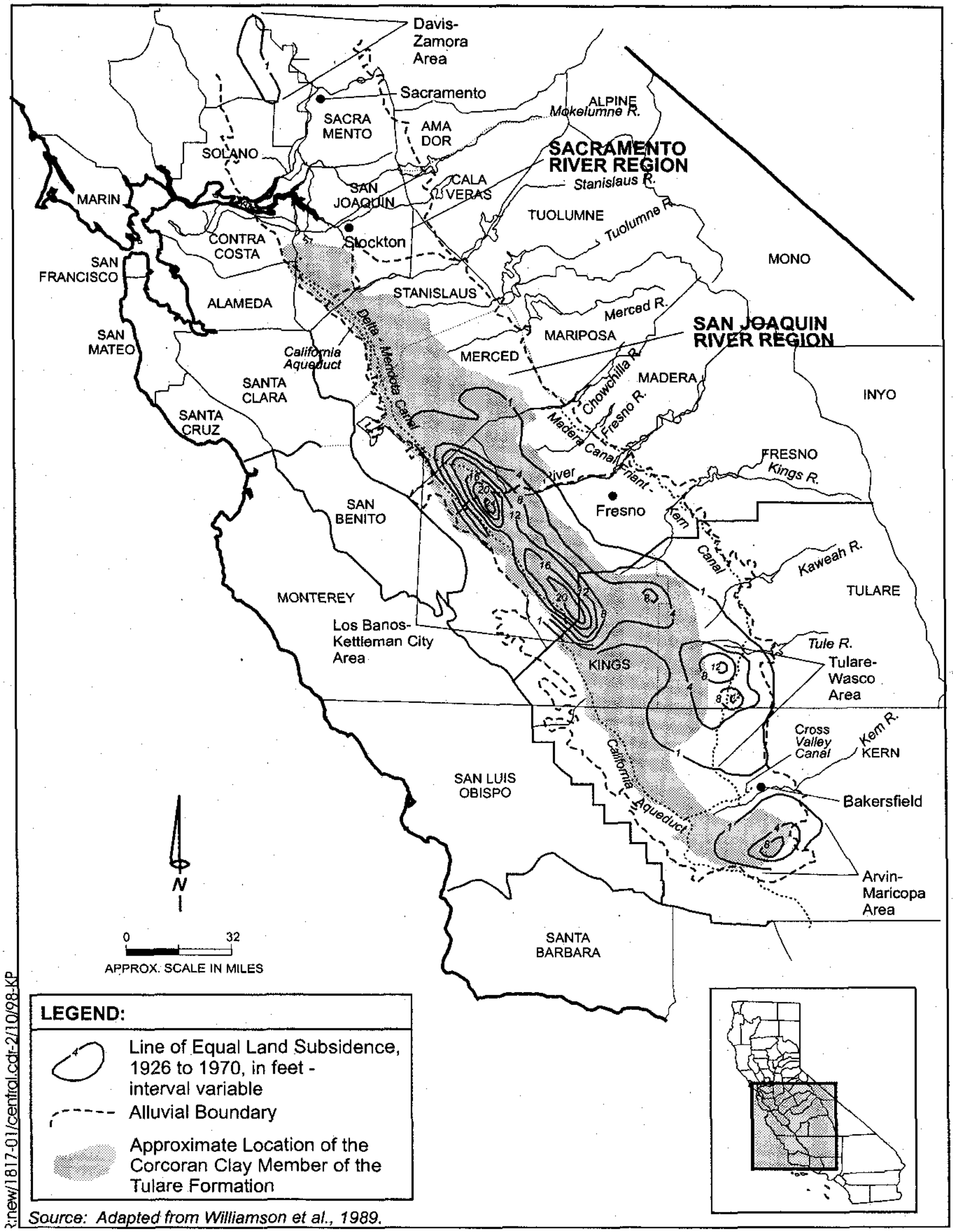


Figure 5.4-3. Extent of Land Subsidence in the Central Valley due to Groundwater Level Decline

Natural groundwater quality is generally excellent in most of the Sacramento Valley and is suitable for most uses. The concentration of TDS is a general indicator of water quality. TDS is less than 300 milligrams per liter (mg/L) in most areas of the Sacramento Valley. However, TDS has been reported above the short-term drinking water standard of 1,500 mg/L in groundwater samples from wells south of the Sutter Buttes and west of Sacramento. Iron and manganese concentrations from mineral sources have been reported in excess of drinking water standards in some wells in the Butte, Sutter, and Colusa Sub-Basins and in the southern Sacramento Valley. Levels of boron in the range of 0.75 mg/L, which is sufficiently high to affect boron-sensitive plants, have been observed in a wide region of the southern Sacramento Valley that includes Vacaville, Rio Vista, and West Sacramento, and also east of Red Bluff.

Natural groundwater quality is generally excellent in most of the Sacramento Valley and is suitable for most uses. Elevated concentrations of introduced contaminants have been observed in some areas.

Elevated concentrations of introduced contaminants have been observed in some areas. Nitrate concentrations from dispersed sources have exceeded the primary drinking water standard of 45 mg/L in some wells in the Butte and Colusa Sub-Basins, in the Chico area, and in the southern Sacramento Valley. Pesticides have been observed sporadically in wells in the Butte Sub-Basin. The pesticides bentazon and dibromochloropropane (DBCP) have been widely reported in groundwater in Sutter County. Various pesticides are widely reported in wells in the Colusa Sub-Basin. Bentazon is reported throughout the Feather River Basin in Butte, Yuba, Placer, and Sutter Counties, and in isolated wells in the Yuba and American Sub-Basins. Elsewhere, groundwater contamination generally is limited to specific contaminant release sites.

5.4.3.4 SAN JOAQUIN RIVER REGION

For purposes of this report, the groundwater basins that occupy the floor of the Central Valley in the San Joaquin River Region are referred to as the San Joaquin Alluvial Basin. This is the most important basin in the region, although a number of small, isolated basins also exist in the upland margins of the valley. Although the aquifers underlying the entire San Joaquin Alluvial Basin are able to drain north to the Delta Region, the southern portion of the basin (roughly south of the Kings River) is sufficiently isolated from the northern portion of the basin that it can be thought of as a distinct groundwater basin called the Tulare Basin.

Because the Modified E clay and other clay layers prevent recharge of the confined aquifer in the central portion of the valley, most recharge to the confined aquifer occurs along the margin of the valley. Recharge to the shallow unconfined and semi-confined aquifers is contributed by seepage from stream channels, deep percolation of applied irrigation water, and seepage from irrigation distribution and drainage canals.

Large-scale groundwater development during the 1960s and 1970s, combined with the introduction of imported surface water supplies, has modified the regional groundwater flow pattern, creating small groundwater depressions and mounds.

Prior to development, streams were typically in hydraulic connection with shallow groundwater. Agricultural development has caused groundwater levels to decline in many areas, so that most streams lose water from seepage rather than gaining water from groundwater. Prior to development, groundwater in the San Joaquin River Region flowed from the valley flanks to the axis, then north toward the Delta. Large-scale groundwater development during the 1960s and 1970s, combined with the introduction of imported surface water supplies, has modified the regional groundwater flow pattern, creating small groundwater depressions and mounds. Also, thousands of wells perforated both above and below confining layers have increased the connection between distinct aquifer units.

From the 1920s until the mid-1960s, the use of groundwater for irrigation of crops in the San Joaquin Valley increased rapidly. Declines in groundwater levels due to this increased groundwater use caused land subsidence throughout the west side and southern portions of the valley. From 1920 to 1970, almost 5,200 square miles of irrigated land in the San Joaquin River Region registered at least 1 foot of land subsidence. Land subsidence has been concentrated in areas underlain by Corcoran clay, where pumping from the confined aquifer resulted in dramatic reductions in the confining pressure that supported the overlying deposits. The effect is less pronounced in areas underlain only by an unconfined or semi-confined aquifer. Figure 5.4-3 shows areas of subsidence in the San Joaquin River Region from 1926 to 1970. The largest area is the Los Banos-Kettleman Hills area, which covers 2,600 square miles from Merced County to Kings County. Subsidence of up to 30 feet has been measured in parts of northwest Fresno County.

From the 1920s until the mid-1960s, the use of groundwater for irrigation of crops in the San Joaquin Valley increased rapidly.

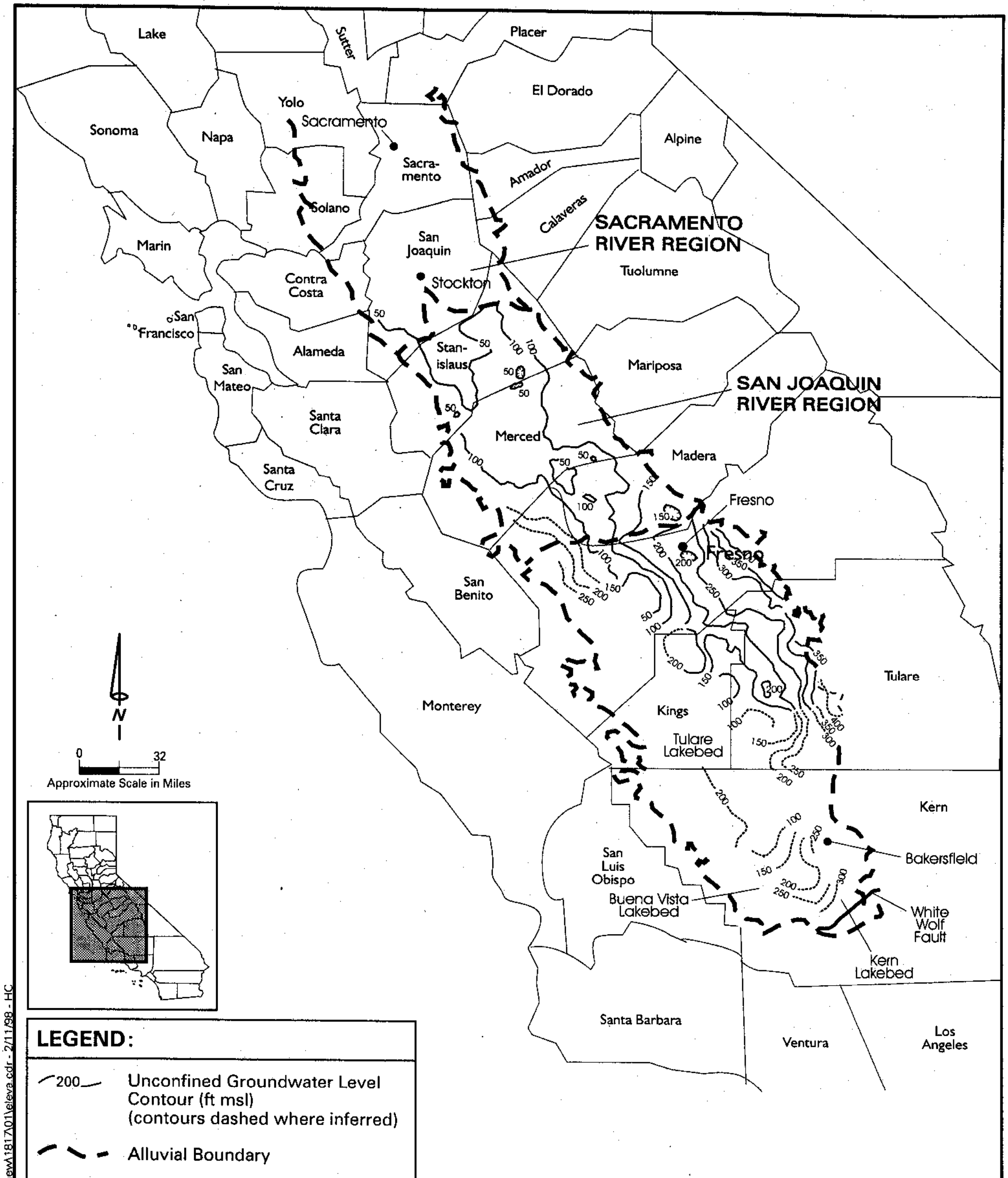
From 1984 to 1996, land subsidence has been reported along the Delta-Mendota Canal. About 1.3 feet of land subsidence occurred near the Mendota Pool, and about 2.0 feet of subsidence occurred about 25 miles northeast of the Mendota Pool. From 1990 to 1995, up to 2.0 feet of subsidence was reported in the Westlands Irrigation District along the California Aqueduct.

Currently, heavy groundwater pumping in some parts of the San Joaquin Valley, combined with reductions in recharge, has created local cones of depression that draw groundwater from surrounding areas into the regions of concentrated pumping. Regional groundwater level contours from wells completed in the unconfined or semi-confined aquifer zone are shown in Figure 5.4-4 to illustrate the compartmentalized flow pattern in the shallow aquifer. Similar conditions occur in the confined aquifer.

Currently, heavy groundwater pumping in some parts of the San Joaquin Valley, combined with reductions in recharge, has created local cones of depression that draw groundwater from surrounding areas into the regions of concentrated pumping.

Cones of depression can be seen in Figure 5.4-4 in the vicinity of Fresno and near Merced, while a groundwater high mound, shown as a closed 200-foot contour, can be seen near the boundary between Fresno and Kings County. This groundwater high, due to inflow from the alluvial fan of the Kings River, acts as a hydraulic barrier and prevents groundwater from the Tulare Lake basin from flowing north into the Kings River basin.

Northwest of the groundwater high mound and southwest of Fresno, a groundwater depression is shown by the open 50-foot elevation contour. The depression prevents groundwater in the vicinity of the Kings River from flowing north into the Chowchilla area. Further to the north, another groundwater depression is shown by a closed 50-foot contour. This depression captures water in the Chowchilla area and prevents it from moving north into the Merced area.



Source: Adapted from Bertoldi et al., 1991.

Figure 5.4-4. Groundwater Elevations in the San Joaquin Valley, Spring 1993

Usable groundwater storage capacity for the northern portion of the San Joaquin Valley is estimated at approximately 24 MAF. The perennial yield is estimated at approximately 3.3 MAF per year. Average annual groundwater withdrawals are estimated at 3.2 MAF, of which about 70% is used for agriculture.

Total groundwater overdrafts in the northern San Joaquin Valley recently were estimated at about 0.2 MAF per year for 1990 normalized conditions. Conditions are normalized to a 1990 level of development and adjusted to remove unusual conditions affecting water supply and demand to facilitate identification of long-term trends.

Groundwater level declines in the lower confined aquifer of more than 400 feet have been observed along the west side of the region. The declines were partially reversed after the introduction of imported water supplies.

In some areas, high groundwater levels rather than declining water levels are the principal concern. In the lower reaches of the San Joaquin River, the confluences of major tributaries and in certain other areas, a high water table reduces use of land for agriculture. In the western portion of the Stanislaus River watershed, groundwater pumping historically has been used to control high groundwater levels. Along the San Joaquin River from the confluence with the Tuolumne River through the south Delta, flood control operations in conjunction with spring pulse flow requirements recently have contributed to seepage-induced waterlogging damage of low-lying farmland.

In the lower reaches of the San Joaquin River, the confluences of major tributaries and in certain other areas, a high water table reduces use of land for agriculture. In the western portion of the Stanislaus River watershed, groundwater pumping historically has been used to control high groundwater levels.

TDS concentrations in groundwater along the east side of the San Joaquin Valley are generally lower than along the west side. The difference is mainly due to differences in quality of aquifer recharge. On the west side of the valley, concentrations range from 500 to 2,000 mg/L. The concentrations in excess of 2,000 mg/L typically occur above the Modified E clay layer, in the semi-confined zone. In the center and east side of the valley, concentrations are generally less than 500 mg/L.

Use of groundwater from above the Modified E clay by agriculture is limited in the western portion of Fresno and Kings Counties due to high TDS concentrations. Municipal use of groundwater is limited by TDS concentrations in scattered locations throughout the San Joaquin Valley.

High boron concentrations occur in the northwestern part of the San Joaquin River Region. Agricultural use of groundwater is limited by boron in eastern Stanislaus and Merced Counties, and in western Fresno and Kings Counties. In the southern portion of the Tulare Lake Basin, high concentrations of boron are generally found in areas southwest of Bakersfield (greater than 3 mg/L) and southeast of Bakersfield (1-4 mg/L). Concentrations as high as 4.2 mg/L have been measured near Buttonwillow Ridge and Buena Vista Slough.

Elevated concentrations of TDS, boron, arsenic, selenium, and pesticides limit municipal and agricultural use of groundwater in portions of the San Joaquin River Region.

Arsenic is a naturally occurring trace element that can be toxic to both plants and animals. Arsenic concentrations should generally be less than 1.0 mg/L for irrigation use, while the primary drinking water standard is 0.050 mg/L. Arsenic concentrations limit the use of groundwater as a source of drinking water in eastern Contra Costa, Stanislaus, and Merced Counties; in western San Joaquin County; and in the southwest corner of the Tulare Lake Basin. Agricultural use of groundwater is impaired due to elevated arsenic concentrations in the Tulare Lake Basin, particularly in areas of the Kern Basin near Bakersfield.

Naturally high concentrations of selenium occur in soils and groundwater on the west side of the San Joaquin River Region. Selenium and other mineral constituents are leached from soils by irrigation and may be concentrated in shallow groundwater or agricultural drain water. The primary drinking water standard for selenium is 0.050 mg/L, but the EPA has identified chronic and acute threshold concentrations for protection of wildlife and aquatic organisms of 5 and 20 micrograms per liter (μg/L), respectively, while the RWQCB has set monthly mean and daily maximum selenium objectives of 5 and 12 μg/L, respectively. Selenium concentrations in groundwater in the western part of Fresno and Kings Counties have limited its use as a drinking water supply.

Naturally high concentrations of selenium occur in soils and groundwater on the west side of the San Joaquin River Region. Selenium and other mineral constituents are leached from soils by irrigation and may be concentrated in shallow groundwater or agricultural drain water.

In the Tulare Basin and in large areas of eastern Fresno and Tulare Counties, the pesticides DBCP and ethylene dibromide (EDB) have exceeded primary drinking water standards, resulting in limitations on groundwater use.

Groundwater in the Yosemite Valley Basin is not widely used.

5.4.3.5 OTHER SWP AND CVP SERVICE AREAS

Two distinct, noncontiguous areas are included in the Other SWP and CVP Service Areas: in the north are the San Felipe Division's CVP and the South Bay SWP service areas; in the south are the SWP service areas. The northern section of this region encompasses parts of the central coast counties of Santa Clara, San Benito, Santa Cruz, and Monterey. The southern portion includes parts of the Imperial, Los Angeles, Orange, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara, and Ventura Counties.

The CVP and the SWP supply water to water agencies inside and outside the Central Valley. Contractor agency jurisdictions typically are large enough to include several groundwater basins. Some groundwater basins extend beyond the boundaries of one contractor agency into an adjacent contractor area, while portions of other groundwater basins lie outside any SWP contractor area boundary. Since CVP and SWP water potentially contributes to groundwater recharge or may be used in lieu of groundwater (and vice versa), the mismatch of jurisdictional boundaries presents a potential problem for the conjunctive management of surface water and groundwater.

The CVP and the SWP supply water to water agencies inside and outside the Central Valley.

Of the CVP service area, only the San Felipe Division lies outside the Central Valley. The San Felipe Division overlaps several distinct groundwater basins.

In the northern central coast, groundwater is the primary source of water for both urban and agricultural use. The Carmel, Pajaro, and Salinas Rivers provide most of the groundwater recharge for the area. Extraction of groundwater in excess of recharge has resulted in groundwater level declines and sea-water intrusion in coastal areas. Within the Pajaro Valley, groundwater withdrawals are estimated at about 64 TAF per year. About 550 TAF per year are extracted from the Salinas Valley.

In the northern central coast, groundwater is the primary source of water for both urban and agricultural use.

The SWP service area overlaps the CVP's San Felipe Division service area in Santa Clara County and includes more than 15 million additional acres outside the Central Valley. Units of the SWP service area outside the Central Valley include parts of the North Bay and South Bay service areas, and the entire central coastal and southern California service areas. These service areas are briefly described below.

The North Bay service area, which includes the Napa County and Solano County Water Agency, overlaps groundwater basins in Napa and Solano Counties. The South Bay service area includes the Santa Clara Valley Water District (SCVWD), the Alameda County Flood Control and Water Conservation District, Zone 7, and the Alameda County Water District. These districts overlap several distinct groundwater basins in Santa Clara and Alameda Counties.

The Central Coastal service area of the SWP includes the San Luis Obispo and Santa Barbara County Flood Control and Water Conservation Districts, and overlaps a number of distinct groundwater basins.

In the inland desert areas, groundwater is the principal source of water. Relatively low recharge rates in comparison to their large storage capacities has led to groundwater extraction in excess of recharge in many desert basins.

A large number of distinct groundwater basins lie within the southern California service area of the SWP. Much of this area (over 3 million acres), is in the service area of MWD, the San Bernardino Valley Municipal Water District (over 200,000 acres), or the San Gorgonio Pass Water Agency (140,000 acres). This heavily urbanized area relies less on groundwater and more on surface water imports. However, past uncontrolled groundwater use has led to declining groundwater levels and sea-water intrusion in some basins. Most of the major groundwater basins have been adjudicated, or groundwater use is restricted through a basin-wide planning process.

A large number of distinct groundwater basins lie within the southern California service area of the SWP. Past uncontrolled groundwater use has led to declining groundwater levels and sea-water intrusion in some basins.

Contamination is another factor limiting the use of groundwater in some parts of the region, including the San Fernando, San Gabriel, Upper Santa Ana Valley, and San Jacinto areas, and scattered portions of San Diego County.

Two of the principal water contracting agencies in the Lahontan Region are the Mojave Water Agency, which serves an area of over 3 million acres, and the Antelope Valley-East Kern Water Agency, which serves an area of over 1.5 million acres. Approximately the northern half of the Colorado Desert Region is in the service area of the Mojave Water Agency, while the southern half represents the service areas of the Coachella Valley

County Water Agency (about 600,000 acres) and the Desert Water Agency (about 200,000 acres).

5.4.4 ASSESSMENT METHODS

Both qualitative and quantitative methods were used to assess the potential impacts of the Program alternatives on groundwater resources. In general, qualitative methods were used to assess impacts from implementation of the Ecosystem Restoration, Water Quality, Levee System Integrity, Water Use Efficiency, Water Transfer and Watershed Programs. Qualitative methods were also used to assess impacts from implementation of the Storage element and Conveyance element in all Program regions except the San Joaquin River Region. In the San Joaquin River Region, potential changes in SWP and CVP Delta deliveries warranted the use of quantitative methods. Furthermore, Alternative 1 (with storage conditions) is used as a surrogate for the assessment of impacts associated with the Preferred Program Alternative and Alternatives 2 and 3. Impacts on groundwater resources associated with Alternative 1 (with storage conditions) represents the likely range that could occur in the San Joaquin River Region under all Program alternatives.

Particular focus was given to concerns that have been identified through the CALFED Groundwater Outreach Program.

5.4.4.1 TOOLS

Potential impacts on groundwater resources in the San Joaquin River Region were analyzed with the Central Valley Groundwater and Surface Water model (CVGSM). CVGSM covers the entire Central Valley area, as shown in Figure 5.4-5. CVGSM is a monthly planning model that simulates groundwater flow in the Central Valley regional aquifer system. Groundwater conditions were simulated using a 69-year hydrologic sequence (water years 1922-1990). The 69-year sequence spans dry, wet, and normal hydrologic conditions. Imposing these conditions on the regional aquifer system provides a range of possible impacts. These quantitative groundwater impacts are summarized as changes in groundwater pumping and groundwater levels, as compared to the No Action Alternative. These conditions represent the general response of the groundwater basins to changes in surface water and groundwater use.

Declining groundwater levels also can be indicative of potential land subsidence in areas where clay and silt lenses susceptible to compaction are prevalent. The occurrence of land subsidence can damage water conveyance facilities, flood control and drainage levee systems, groundwater well casings, and other infrastructure. The potential for land subsidence is prevalent in the San Joaquin River Region, primarily along the west side of the region. For the purposes of this programmatic analysis, the potential differences in possible land subsidence will be inferred from the changes in groundwater levels observed.

Declining groundwater levels can be indicative of potential land subsidence in areas where clay and silt lenses susceptible to compaction are prevalent.

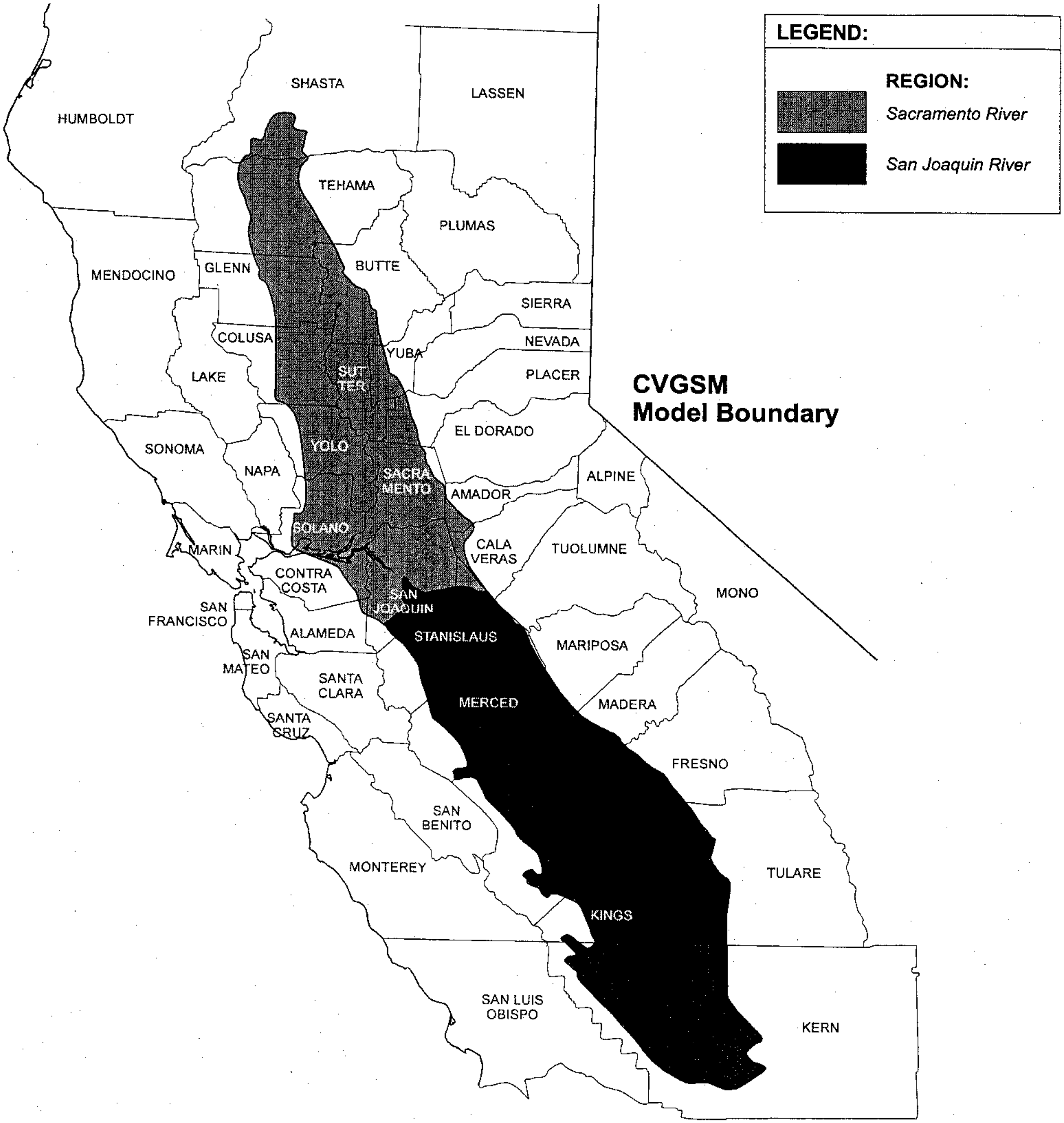


Figure 5.4-5. Groundwater Model Area

5.4.4.2 ADDRESSING UNCERTAINTY

Many of the issues regarding uncertainty that are discussed in Section 5.1.4.2 of Section 5.1, "Water Supply and Water Management," also apply to the assessment of groundwater resources. As mentioned under this previous discussion, efforts are under way to address these issue. This is being accomplished in part by increasing the level of groundwater analysis as part of further assessments of alternative water management strategies.

> Many of the issues regarding uncertainty also apply to the assessment of groundwater resources.

For this programmatic analysis of groundwater resources, and specifically for the quantitative assessment of the San Joaquin River Region, the range of uncertainty has been addressed by considering two distinct sets of water management assumptions. These assumptions were discussed previously in Section 5.1.4.2, and are referred to as Criterion A and Criterion B. Concerning the assessment of groundwater resources, the significant difference between the two criteria is the assumption of approximately 10% greater demands under Criterion B.

5.4.4.3 MODELING ASSUMPTIONS

A summary description of the Program alternative assumptions was provided previously in Table 5.1-2. In some instances, specific assumptions are required for modeling purposes. For the assessment of groundwater resources using CVGSM, specific assumptions include:

- Land and water use conditions in CVGSM are based on projected conditions consistent with those assumed for the DWRSIM analysis (see Attachment A).

- Consistent with current California law governing groundwater usage in the Central Valley, no restrictions are placed on groundwater pumping in CVGSM.

- All water demands not met by surface water supplies are assumed to be met by groundwater pumping. This groundwater pumping is estimated by CVGSM during the simulation process.

- CVP and SWP Delta exports to the San Joaquin River Region were obtained from DWRSIM and used in the CVGSM analysis. All other input parameters required by CVGSM for a water management analysis are assumed to be unchanged between the No Action Alternative and Alternative 1. This includes surface water supplies in the Sacramento River Region of the model, surface water supplies along the east side of the San Joaquin River Region (Friant service area deliveries and local surface water supplies), and modeled stream flow throughout the CVGSM model area.

- CVGSM requires the Sacramento River Region groundwater system to be simulated dynamically with the San Joaquin River Region. However, groundwater conditions in the Sacramento River Region are not assessed using CVGSM. The use of results from CVGSM is limited to output covering only the San Joaquin River Region.

5.4.4.4 CVGSM Modeling Results

The qualitative analysis of groundwater conditions in the San Joaquin River Region was performed using Alternative 1 (with storage conditions) in comparison to the No Action Alternative. Furthermore, both bookend water management criteria assumption sets (Criteria A and B) were used to define the range of uncertainty associated with this assessment.

> The qualitative analysis of ground-water conditions in the San Joaquin River Region was performed using Alternative 1 (with storage conditions) in comparison to the No Action Alternative.

Programmatic comparisons of deliveries to the South-of-Delta SWP and CVP Service Areas were made for the No Action Alternative given the possible range of demands represented under Criteria A and B. As a result of this range of deliveries, average annual groundwater pumping in the San Joaquin River Region could vary under the No Action Alternative by approximately 350 TAF/year, Criterion A having the greater amount of groundwater pumping. This would result in greater declines in groundwater levels under Criterion A relative to conditions under Criterion B.

Using CVGSM to simulate this range of possible conditions, it was determined that average declines in regional groundwater levels could be approximately 10-20 feet lower under Criterion A. In considering simulated groundwater conditions observed at the end of the 69-year hydrologic sequence, declines at a local level could be as much as 90 feet lower under Criterion A. This is depicted regionally in Figure 5.4-6, which shows contours of differences in groundwater levels at the end of the simulation (a positive difference contour indicates groundwater levels are higher under Criterion B relative to Criterion A).

The range of groundwater pumping and groundwater levels under the No Action Alternative were compared with the range expected under Alternative 1. Groundwater pumping was reduced approximately 60-100 TAF/year under Alternative 1 in response to increased SWP and CVP deliveries to the region, with the greatest reduction occurring under Criterion B water management assumptions. Regional long-term average groundwater levels would be approximately 5-10 feet higher under Alternative 1 with storage conditions, as compared to the No Action Alternative. The upper range would occur under Criterion B water management assumptions.

> The range of ground-water pumping and groundwater levels under the No Action Alternative were compared with the range expected under Alternative 1.

Simulated groundwater levels observed at the end of the 69-year hydrologic simulation sequence indicate local increases as high as 15-30 feet under Alternative 1 with storage conditions, as compared to the No Action Alternative, the upper range occurring under Criterion B water management assumptions. These conditions are depicted regionally in Figures 5.4-7 and 5.4-8 for Criterion A and Criterion B, respectively. These two figures show contours the of differences in groundwater levels between Alternative 1 and the No Action Alternative at the end of the simulation (a positive difference contour indicates

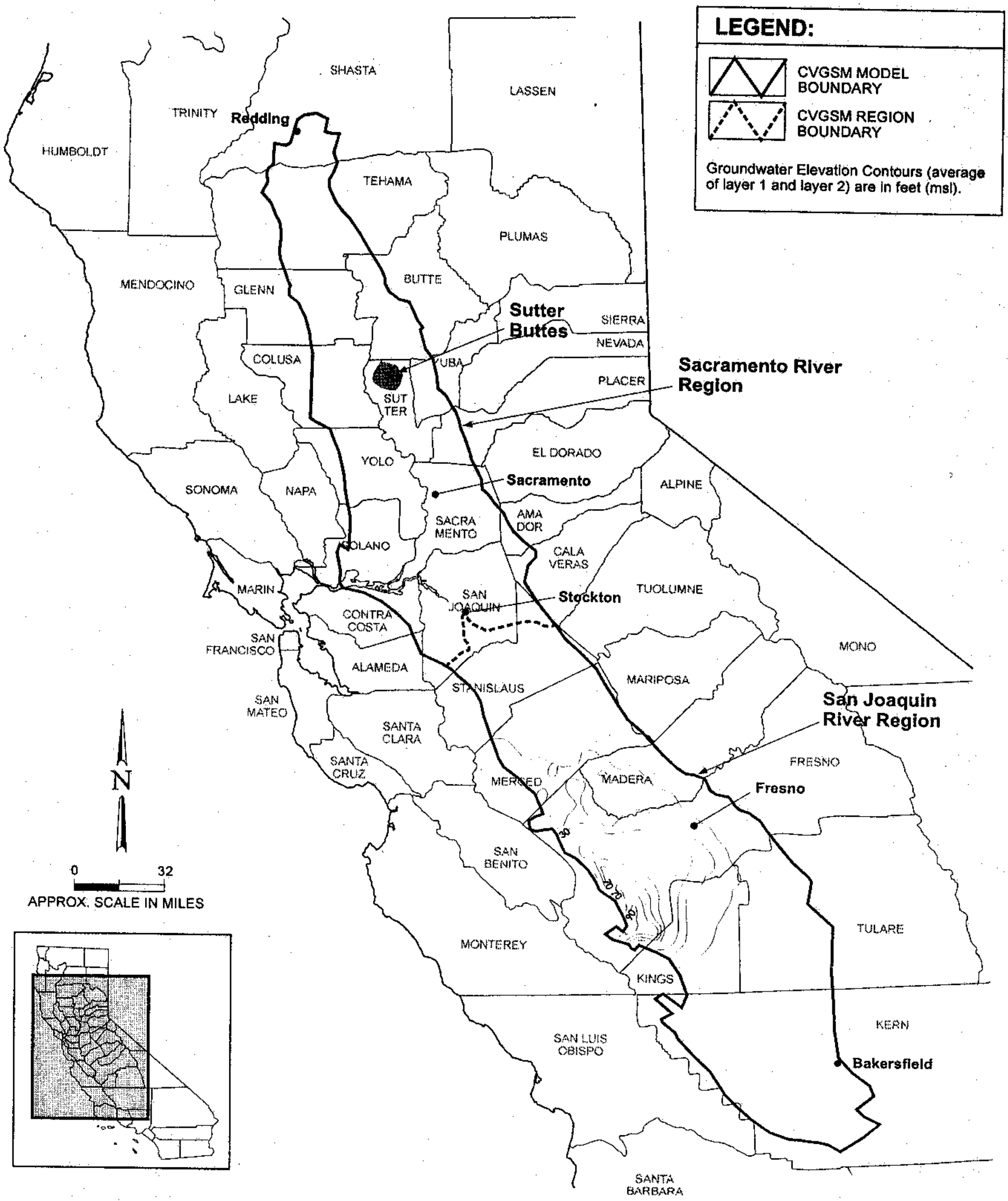


Figure 5.4-6. Differences in End of Simulation Groundwater Elevations for Criteria A and B under the No-Action Alternative

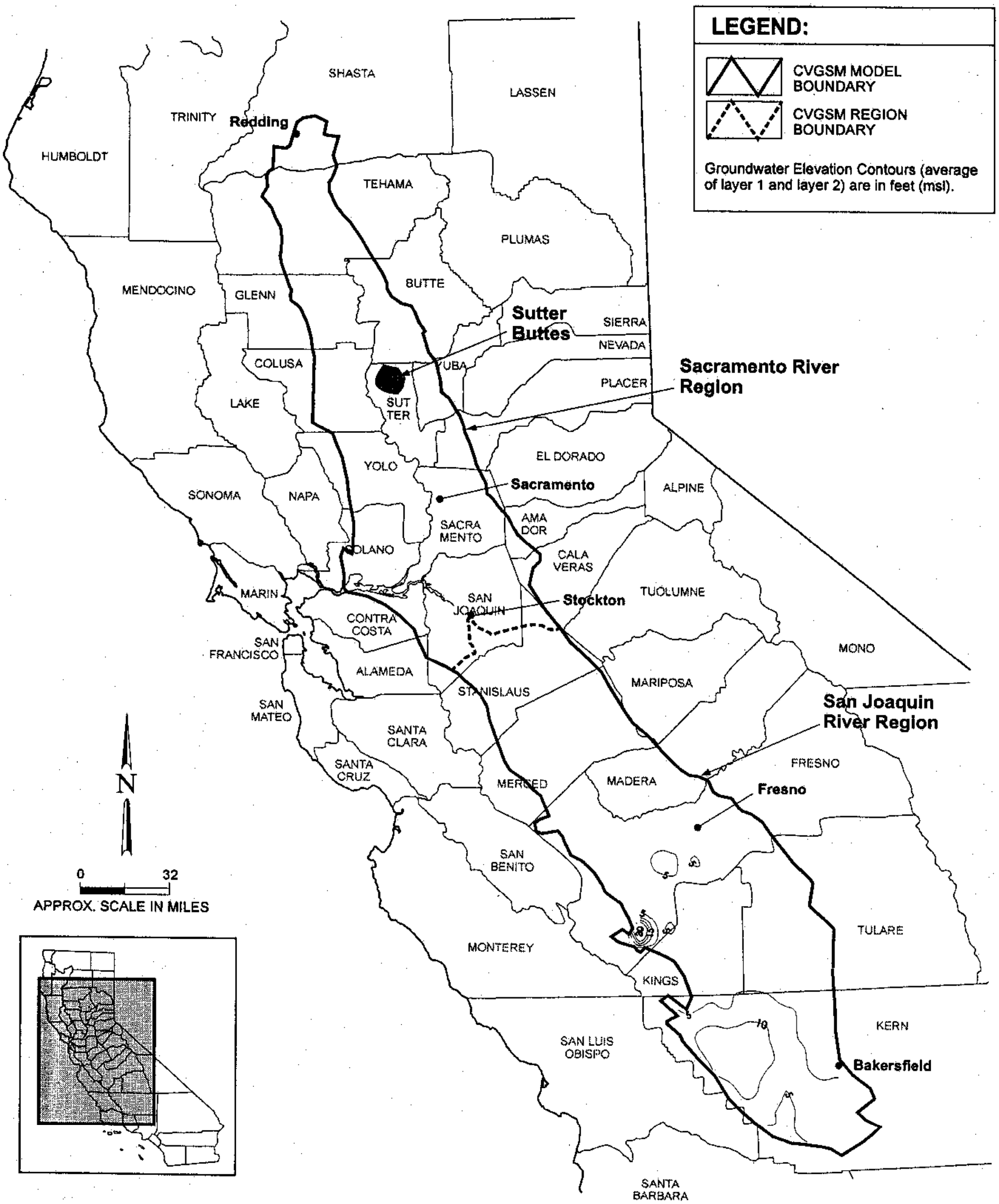


Figure 5.4-7. Differences in End of Simulation Groundwater Elevations for Criterion A under Alternative 1 and the No-Action Alternative

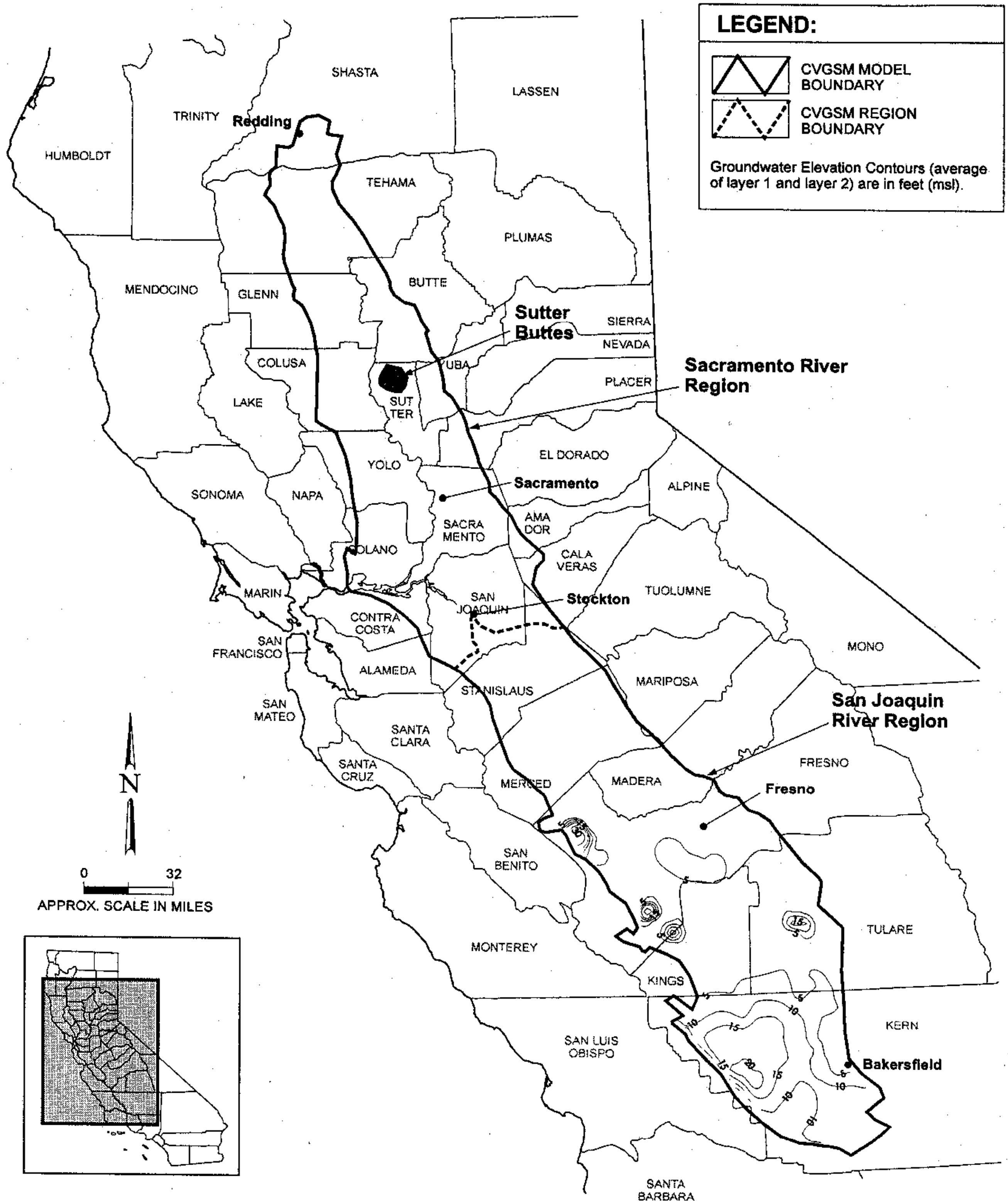


Figure 5.4-8. Differences in End of Simulation Groundwater Elevations for Criterion B under Alternative 1 and the No-Action Alternative

groundwater levels are higher under Alternative 1). With an increase in groundwater levels in portions of the San Joaquin River Region, the possible reduction or reversal of the adverse effects of past overdrafting of groundwater, such as land subsidence and water quality degradation could be reduced.

With an increase in groundwater levels in portions of the San Joaquin River Region, the possible reduction or reversal of the adverse effects of past overdrafting of groundwater, such as land subsidence and water quality degradation could be reduced.

5.4.5 SIGNIFICANCE CRITERIA

Groundwater impacts include changes in groundwater quantity or quality. The following conditions would be considered significant impacts if they occurred as a result of implementing Program actions:

- Any measurable degradation in groundwater quality relative to regulatory standards or potential beneficial uses of groundwater.
- A substantial long-term decline in groundwater levels or a net reduction in groundwater storage, resulting in third-party effects.
- Detectable land subsidence caused by water level declines.

At the programmatic level, these impacts generally are identified at the scale of a groundwater basin or sub-basin. Impacts may be either adverse or beneficial. Although increases in groundwater levels are typically considered to be beneficial, increases that cause waterlogging of agricultural crop lands would be considered an adverse impact under some conditions.

At the programmatic level, these impacts generally are identified at the scale of a groundwater basin or sub-basin.

The significance of declining (or increasing) water levels depends on the duration and permanence of the impact. In the short term, groundwater levels fluctuate naturally because of changes in rainfall that affect recharge rates. Short-term changes in water levels that are within the normal range of groundwater fluctuations would not be considered significant.

In general, any long-term degradation in groundwater quality is considered significant. Under some conditions, however, a reduction in groundwater quality may be considered less than significant if it does not result in a reduction in the beneficial uses of the water resource and if it does not conflict with a promulgated regulatory standard.

5.4.6 NO ACTION ALTERNATIVE

5.4.6.1 DELTA REGION

No net change in groundwater use in the Delta is expected under the No Action Alternative. However, subsidence of Delta islands will continue as groundwater pumping

No net change in groundwater use in the Delta is expected under the No Action Alternative.

for drainage of crop lands continues. Subsidence is considered a potentially significant adverse impact that can be mitigated. No other groundwater impacts are expected in the Delta Region.

5.4.6.2 BAY REGION

Under the No Action Alternative, groundwater quality is likely to continue to improve in areas with point source pollution problems, as identified groundwater pollution sites are cleaned up and point and nonpoint sources continue to be eliminated. Water levels in areas subject to subsidence will continue to be monitored, and groundwater recharge basins will continue to be operated to prevent subsidence from groundwater withdrawals. Similarly, groundwater basins adjacent to the Bay that have been subject to salt-water intrusion will continue to improve with maintenance of hydraulic barriers.

Under the No Action Alternative, groundwater quality is likely to continue to improve in areas with point source pollution problems, as identified groundwater pollution sites are cleaned up and point and nonpoint sources continue to be eliminated.

With increasing populations and the resulting increased water demand, water agencies in the Bay Region are evaluating a number of options to increase supplies as well as to ensure reliability of their existing water sources. As part of these efforts, groundwater and surface water will continue to be used conjunctively. To what degree future supply shortages will be met by increased groundwater overdraft is unknown. However, in some areas of California, the historical response to increasing water demands has been to overdraft groundwater basins to meet those shortages.

Overdraft could lead to substantial declines in groundwater levels in areas with good-quality groundwater supplies. Increased groundwater use probably would occur mainly in rural areas, including those with expanding urban populations, where local sources of groundwater may be an economical alternative to imported surface water. Potentially significant impacts that can be mitigated probably would occur in basins such as the Livermore, Napa, and Sonoma Valleys.

Groundwater quality degradation due to salt-water intrusion may occur in shoreline areas around the Bay Region, and land subsidence may occur locally in areas where groundwater basin management plans have not been developed. However, these impacts are not likely to be significant because these problems are widely recognized, and monitoring will be conducted to identify problems before they become severe.

Overdraft could lead to substantial declines in groundwater levels in areas with good-quality groundwater supplies.

5.4.6.3 SACRAMENTO RIVER REGION

Changes in groundwater conditions are expected to occur in response to increased local demand for groundwater. Based on current trends, groundwater declines could continue in the Yolo County area of the Sacramento Valley Basin and in the Sacramento County Basin. In the Yolo County area, groundwater declines could result in additional land subsidence.

Changes in groundwater conditions are expected to occur in response to increased local demand for groundwater.

Groundwater quality could be adversely affected by expected increases in groundwater extraction in the Sutter Buttes area and in southern Yolo County. Groundwater containing relatively high concentrations of TDS (Sutter Buttes area) and boron (southern Yolo County) is expected to continue to be drawn toward groundwater pumping centers in these two areas. This is considered a potentially significant adverse impact that can be mitigated.

A reduction in groundwater recharge may result from reduced infiltration and storage in the upper watersheds as retention capacity in the watersheds continue to decrease. This is not expected to affect groundwater levels in the Sacramento River Region but could result in significant local impacts in the upper watershed. For example, a reduction in the groundwater underflow component of streamflow could cause a decline in streamflows.

Upper watershed activities may result in increased dependence on groundwater locally within the upper watersheds but will rely most heavily on increased use of surplus, unappropriated surface water from within the watershed. Increased demand for surface water in the upper watersheds may indirectly result in increased overdraft of groundwater in the Sacramento River Region.

Similarly, increased demands on groundwater resources that would occur under the No Action Alternative would continue to result in deterioration of groundwater quality, with the potential for poor-quality water to be drawn into basin pumping centers.

Increased demands on groundwater resources that would occur under the No Action Alternative would continue to result in deterioration of groundwater quality, with the potential for poor-quality water to be drawn into basin pumping centers.

Potentially significant local impacts may occur in the upper watershed due to increased use of groundwater from fractured rock aquifers, where groundwater resources are depleted and contaminants may be drawn into domestic wells.

Declining groundwater levels associated with increased demands on local aquifers in the upper watershed will reduce the economic feasibility of agriculture in some areas, such as in the Sierra Valley Basin. This decline may accelerate the shift from agriculture to more intensive land uses (homesite development), resulting in increased demands on water resources. In areas with limited groundwater resources, this decline would be considered a potentially significant adverse impact. Mitigation is available to reduce this impact to a less-than-significant level.

5.4.6.4 San Joaquin River Region

The population of the San Joaquin River Region is expected to more than double by 2020. This growth is expected to lead to conversion of some agricultural land to urban uses. The impacts on groundwater resources will depend on where this growth occurs. In general, it is likely that population growth will result in increased dependence on groundwater during dry years, when surface water storage decreases. If managed carefully, municipal wells could be strategically placed to achieve maximum regional yields while minimizing local declines in water levels that typically are caused by concentrating

The population of the San Joaquin River Region is expected to more than double by 2020. This growth is expected to lead to conversion of some agricultural land to urban uses.

production wells in a small area. Increased dependence on groundwater in areas where groundwater extraction is already at or above sustainable levels would result in a significant long-term decline in water levels.

Increased population probably would result in a reduction in the amount of surface water available to agriculture during dry periods, since municipal use is generally given higher priority than agriculture when water supplies must be rationed. This could force a shift to increased use of groundwater by agriculture. The impacts could be significant locally but probably would not be widespread, since most M&I water use in the San Joaquin Region is supplied by groundwater sources.

Increased groundwater extraction could result in increased potential for land subsidence in susceptible areas, such as along the west side of the San Joaquin River Region and in the southwestern portion of Tulare County. Land subsidence is considered a potentially significant adverse impact that can be mitigated.

Increased ground-water extraction could result in increased potential for land subsidence in sus-ceptible areas, such as along the west side of the San Joaquin River Region and in the southwestern portion of Tulare County.

In Section 5.1, programmatic comparisons of deliveries to the South-of-Delta SWP and CVP Services Areas were made for the No Action Alternative, given the possible range of demands represented under Criteria A and B. As a result of this range of deliveries, average annual groundwater pumping in the San Joaquin River Region could vary under the No Action Alternative by approximately 350 TAF/yr, Criteria A having the greater amount of groundwater pumping. This amount would result in greater declines in groundwater levels under Criterion A, relative to conditions under Criterion B.

As noted in Section 5.4.4.4, using CVGSM to simulate this range of possible conditions, it was determined that average declines in regional groundwater levels could be approximately 10 to 20 feet lower under Criterion A. In considering simulated groundwater conditions observed at the end of the 69-year hydrologic sequence, declines at a local level could be as much as 90 feet lower under Criterion A. This is depicted regionally in Figure 5.4.6-1, which shows contours of differences in groundwater levels at the end of the simulation (a positive difference contour indicates groundwater levels are higher under Criterion B relative to Criterion A).

In addition to the increased 2020 demands due to population growth, under the No Action Alternative, the CVPIA would require allocation of up to 800 TAF of water per year for environmental purposes, resulting in reduced exports to water contractors inside and outside the Central Valley. The reduction in water available for existing beneficial uses will require water contracting agencies to look elsewhere for supplemental water supplies. Although difficult to quantify, the increased demand for water and decreased availability of water is likely to result in a potentially significant adverse impacts on groundwater resources in some areas, including declines in water levels, increased potential for subsidence in severely depleted areas, and degradation of water quality through migration of poor quality water toward pumping centers. Mitigation is available to reduce these impacts to less-than-significant levels.

Shallow, unconfined aquifers are more susceptible to surface contamination than deep, confined aquifers. Increased withdrawals of high-quality water from deep aquifers will increase the potential for shallow groundwater, which may be contaminated by pesticides, fertilizers, or mineral salts, to migrate to deeper aquifers. Confining layers are seldom completely effective in preventing downward migration of groundwater because of natural discontinuities in deposition or because of man-made conduits, such as improperly sealed wells. Although it may take time, declining water levels in confined aquifers could result in gradual declines in water quality from shallow groundwater sources.

Shallow, unconfined aquifers are more susceptible to surface contamination than deep, confined aquifers.

Impacts on groundwater in the upper watershed areas would be similar to those described for the Sacramento River Region.

5.4.6.5 Other SWP and CVP Service Areas

As described for the San Joaquin River Region, reallocation of 800 TAF of water per year for environmental purposes to meet CVPIA requirements could result in a reduction in exports to water contractors outside the Central Valley through the SWP and CVP. This is likely to result in potentially significant adverse impacts on groundwater resources in some areas, including declines in water levels, salt-water intrusion in coastal areas, increased potential for subsidence in severely depleted areas, and degradation of water quality through migration of poor quality water toward pumping centers. Mitigation is available to reduce these impacts to less-than-significant levels.

Reallocation of 800 TAF of water per year for environmental purposes to meet CVPIA requirements could result in a reduction in exports to water contractors outside the Central Valley through the SWP and CVP.

5.4.7 Consequences: Program Elements Common to All Alternatives

For groundwater resources, the environmental consequences of the Ecosystem Restoration, Water Quality, Levee System Integrity, Water Use Efficiency, Water Transfer, and Watershed Programs, and the Storage element are similar under all Program alternatives, as described below. The environmental consequences of the Conveyance element vary among Program alternatives, as described in Section 5.4.8.

5.4.7.1 Delta Region

Ecosystem Restoration Program

Conversion of agricultural lands to wetland or aquatic habitat is a component of the Ecosystem Restoration Program. Groundwater currently needed to grow crops on low-lying lands would no longer be needed on the converted lands. A reduction in groundwater pumping could provide a potential benefit by reducing pumping-induced subsidence. The converted lands also would provide increased infiltration area, thereby improving groundwater recharge.

Water Quality Program

Contaminant concentrations in water and sediment can be expected to decline in the streams immediately downstream of pollutant sources. Because the behavior of these contaminants in natural aquatic systems is complex, it is difficult to predict the consequence downstream. However, it seems probable that these actions could result in minor improvements to the groundwater quality in the Delta Region.

Levee System Integrity Program

Reductions in agricultural acreage would occur in some areas where levee strengthening required setback levees or flooding portions of the interiors of certain Delta islands. Some of this acreage would overlap areas included in Ecosystem Restoration Program actions. Reductions in groundwater pumping to drain agricultural lands could result in similar impacts as those described for the Ecosystem Restoration Program. The amount of land, and therefore the potential impacts, would be less for the Levee System Integrity Program than for the Ecosystem Restoration Program.

The Levee System Integrity Program would not affect groundwater in any Program region other than the Delta; therefore, the program is not discussed under the specific regions below.

Water Use Efficiency Program

Policies designed to increase efficiency of water use would mainly cause reductions in demand, increases in reuse of wastewater, and more effective distribution of water through water transfers. Some opportunities may exist for more efficient use of water in Delta upland areas, which could lead to reduced dependence on groundwater extraction. Since groundwater extraction from deep aquifer zones in excess of recharge can lead to salt-water intrusion, water use efficiency could reduce the potential for future salt-water intrusion. Water use efficiency policies would result in little or no impact on groundwater use in the Delta lowlands, where groundwater pumping primarily is used for draining waterlogged soils.

Policies designed to increase efficiency of water use would mainly cause reductions in demand, increases in reuse of wastewater, and more effective distribution of water through water transfers.

Water Transfer Program

Groundwater is not expected to be transferred from the Delta. Therefore, no impacts on Delta groundwater resources would result from water transfers.

Watershed Program

Elements of the Watershed Program are expected to improve groundwater quality and increase groundwater storage in watershed areas (including the Central Valley floor) tributary to the Delta. These efforts are not expected to measurably affect Delta groundwater resources. Therefore, no impacts on Delta groundwater resources would result from Watershed Program actions.

Storage

Any in-Delta storage that is implemented could increase hydraulic head at the storage site. Currently, groundwater flows from Delta channels toward the interiors of islands that are drained for agricultural production. The difference in hydraulic head across the levees toward the interior of the example storage facility is about 15 feet. After filling, the difference in head across the levees would be about 4 feet, and the direction of the hydraulic potential would be toward the surrounding channels and adjacent land tracts. The increase in the hydraulic head, greater wetted surface area, and larger volume of water in a new reservoir relative to the rivers could cause substantial groundwater underflow toward the tracts on the opposite banks of the Old River and Middle River. This represents a potentially significant impact on groundwater levels in the adjacent tracts that can be mitigated to a less-than-significant level.

The increase in the hydraulic head, greater wetted surface area, and larger volume of water in a new reservoir relative to the rivers could cause substantial ground-water underflow toward the tracts on the opposite banks of the Old River and Middle River.

5.4.7.2 BAY REGION

Ecosystem Restoration Program

The Ecosystem Restoration Program would convert agricultural lands to wetland or other habitat uses. This could result in a reduction in groundwater pumping in shoreline areas. Most pumping in these areas is currently done to depress the water table; therefore, reduced pumping could result in a reduction in pumping-induced subsidence. A reduction in groundwater pumping in submerged lands could locally reduce the potential for salt-water intrusion. These are considered beneficial impacts.

Water Quality Program

Impacts of the Water Quality Program on groundwater quality in the Bay Region are difficult to predict. The impacts are expected to be beneficial but are likely to be negligible because most of the point and nonpoint sources of groundwater contamination in the Bay Region are already subject to regulation.

Most of the point and nonpoint sources of groundwater contamination in the Bay Region are already subject to regulation.

Water Use Efficiency Program

Opportunities exist for more efficient use of water in the Bay Region, which could lead to reduced dependence on groundwater extraction. Benefits of reduced groundwater use could include reduced potential for salt-water intrusion in shoreline areas, reduced potential for subsidence, reduced potential for pumping-induced migration of existing contaminants, and a more dependable long-term supply of groundwater.

Water Transfer Program

Transfers of water to the Bay Region could reduce dependence on groundwater in the Bay Region during low runoff years. This would provide a beneficial impact on groundwater resources relative to the No Action Alternative.

Transfers of water to the Bay Region could reduce dependence on groundwater in the Bay Region during low runoff years.

Watershed Program

Elements of the Watershed Program are expected to improve groundwater quality and increase groundwater storage in watershed areas (including the Central Valley floor) tributary to the Delta. These efforts are not expected to measurably affect groundwater resources in the Bay Region. Therefore, no impacts on groundwater resources in the Bay Region would result from Watershed Program actions.

Storage

Impacts on groundwater resources in the Bay Region are not anticipated from Storage element actions.

5.4.7.3 SACRAMENTO RIVER REGION

Ecosystem Restoration Program

The Ecosystem Restoration Program could convert agricultural lands to riparian habitat. Conversion of agricultural land could result in a reduction in groundwater pumping for drainage or for irrigation. This effect on groundwater resources is expected to be negligible. Groundwater extracted from agricultural lands to depress a high water table may contain farm chemicals, which are pumped with the drain water into the adjacent stream channel. A decrease in pumping for farm drainage could result in a small decrease in loading of these chemicals in the stream waters. This reduction in chemical loading would benefit surface water quality.

Conversion of agricultural land could result in a reduction in groundwater pumping for drainage or for irrigation.

Water Quality Program

The Water Quality Program is expected to focus on reducing contaminant loading to surface waters from point and nonpoint sources. To the extent that Water Quality Program actions improve surface water quality, the dynamic stream-aquifer link that exists between surface water and underlying groundwater resources could result in long-term secondary improvements to groundwater quality conditions in the Sacramento River Region.

Water Use Efficiency Program

Increased water use efficiency could result in beneficial and potentially significant adverse impacts. Reduced demand for water would place less stress on both groundwater and surface water resources. However, inequalities in the distribution and use of groundwater and surface water could lead to local potentially significant adverse impacts on groundwater.

Agricultural water conservation, including a reduction in deep percolation of applied irrigation or reduction in seepage from irrigation conveyance facilities, can result in local reductions in groundwater recharge. In most areas, applied irrigation is managed to minimize the amount of deep percolation and reduce irrigation costs. But in some areas, this seepage is a significant source of recharge and could result in loss of beneficial use to other local groundwater users or reductions in flows of gaining streams dependent on a high water table. The loss of recharge would not necessarily be accompanied by a decrease in loading of salts and agricultural chemicals since irrigation systems generally are operated to ensure that these chemicals are leached through the root zone of plants. However, one of the efficient water management practices (EWMP) in the agricultural water management (AB 3616) process is to optimize conjunctive use of surface water and groundwater resources. If implemented, this process could offset any potentially significant adverse impacts related to improved on-farm water use efficiency. Other

Agricultural water conservation, including a reduction in deep percolation of applied irrigation or reduction in seepage from irrigation conveyance facilities, can result in local reductions in groundwater recharge.

mitigation strategies also are available to reduce these impacts to less-than-significant levels.

As irrigators turn toward some of the more efficient methods, such as drip and micro-irrigation systems, some growers may switch to groundwater as a more reliable source of high-quality water. This could result in groundwater declines and possibly land subsidence. The significance of this impact is not known and would depend on many variables, including the location, groundwater quality, relative cost of pumping groundwater compared to the cost of surface water, and the applicability to crops. Also, the reduction in surface water use could result in indirect groundwater savings elsewhere.

As irrigators turn toward some of the more efficient methods, such as drip and micro-irrigation systems, some growers may switch to groundwater as a more reliable source of high-quality water.

For some communities, treated wastewater is intentionally applied to spreading basins for recharge of local groundwater resources. To the extent that conservation or recycling reduces the amount of artificial recharge, associated adverse impacts may result to the local aquifer. The significance of the impact is unknown and depends on whether reductions in water use are larger or smaller than reductions in recharge.

Water Transfer Program

Water transfers provide an opportunity to move water from a watershed or basin with surplus water supplies for use in a watershed or basin with inadequate supplies. (The terms "surplus" and "inadequate" are used here in a relative sense. Criteria could include market forces, hydrologic factors, or any criteria that support moving water from one location to another.) The transferred water usually would be surface water with subsequent local groundwater use. In some cases, direct transfers of groundwater would occur.

Promoting development of a state-wide water transfers market probably would cause groundwater use to increase first in basins where groundwater is not yet being withdrawn at rates greater than the perennial yield, where groundwater management programs do not restrict groundwater use, and in basins that have not been adjudicated.

Reducing barriers to water transfers probably would cause groundwater use to increase first in basins where groundwater is not yet being with-drawn at rates greater than the perennial yield, where ground-water management programs do not restrict groundwater use, and in basins that have not been adjudicated.

Potentially significant adverse groundwater impacts could occur if transfers from a basin exceeded inflows. The reasons that this might occur include inadequate planning, low inflow compared to forecast inflow, or intentional overdrafting of a groundwater basin to achieve regional objectives or economic benefits. Mitigation strategies are available to reduce this impact to a less-than-significant level.

Potentially significant adverse impacts also could result if water transfers are based on the conservation of water applied to agricultural lands, some of which percolates below the crop's root zone (deep percolation) and recharges the local aquifer. To the extent that this portion of water is saved or conserved and transferred, less water would recharge the aquifer ,which could result in an adverse effect—depending on the characteristics of the affected aquifer. Water transfers based on land fallowing also could adversely affect deep percolation, thus creating a potentially significant adverse effect on local groundwater conditions.

In general, the Sacramento River Region is expected to be a net exporter to other regions. Cross-Delta transfers from the Sacramento River Region to other regions would be limited by the capability to safely convey water across the Delta under the No Action Alternative. The alternatives would increase this capability.

Increased transfers within the region also could occur. The Program would provide assistance in coordinating these transfers, but the Program does not propose new infrastructure to accommodate intra-regional transfers.

Unless properly regulated, groundwater transfers—or surface water transfers based on groundwater substitution—could result in potentially significant adverse impacts on third-party groundwater users, with potential adverse effects in the source water area. Such impacts might include land subsidence, lower groundwater levels and higher pumping costs, degradation of groundwater quality, impacts on vegetation dependent on groundwater or, in extreme cases, losses of existing wells.

Unless properly regulated, groundwater transfers—or surface water transfers based on groundwater substitution—could result in potentially significant adverse impacts on third-party groundwater users, with potential adverse effects in the source water area.

Prior to implementation of any groundwater transfers, safeguards would need to be implemented to protect third-party users. For example, local groundwater management programs could be used to study the groundwater resources of a particular area and to provide technical review, advice, and guidance regarding transfers involving groundwater.

Watershed Program

Watershed actions could increase net surface water storage, reducing demand for groundwater withdrawals and increasing the amount of water available for recharging groundwater storage facilities. Direct impacts on groundwater recharge in basin areas due to watershed improvements also are important, since the principal basin recharge areas are in the lower watershed.

Storage

The storage components include both surface water and groundwater storage. Both components could affect groundwater resources. The types of impacts on groundwater resources that might occur because of the construction, operation, and maintenance of surface water storage facilities are described below. More detailed impact analysis would be conducted at the project level for specific sites.

The storage components include both surface water and groundwater storage. Both components could affect groundwater resources.

Two example sites were evaluated to study potential groundwater impacts; in both examples, the impacts were similar. Local streamflows could be insufficient to maintain a reservoir, and water would be conveyed to the reservoir via a canal. One example site is underlain by upper Cretaceous marine rocks that typically yield poor-quality water.

Groundwater is present in the shallow alluvial aquifer and in alluvium-filled intermittent stream channels. The site contains several farm wells that draw water from the shallow aquifer. The alluvial aquifer beneath the site is hydraulically isolated from other areas, and withdrawal of water from this aquifer is not expected to affect wells outside the project area. Therefore, construction-related impacts on local groundwater resources are expected to be less than significant.

Surficial deposits beneath the site include Quaternary alluvium underlain by upper Cretaceous marine rocks of low permeability. The reservoir would be contained in the natural basin formed in the Upper Cretaceous rocks. Groundwater flow in the Cretaceous rocks is expected to occur primarily within joints and fractures. Some leakage may be possible along joints and fractures that extend through a ridge that forms one of the sides of the reservoir. Stream channels typically form along pre-existing permeable geological structures, and the intermittent stream channels probably represent preferential groundwater flow pathways. Significant fractures would be investigated and sealed for construction of the dams, but some leakage may still occur, resulting in discharge to springs downslope of the reservoir site; however, subsurface leakage is not expected to result in a potentially significant adverse impact on groundwater.

Inundation of the reservoir would fully saturate the alluvial materials beneath the site to the depth of the underlying bedrock. Therefore, recharge to the shallow aquifer through existing wells in the reservoir inundation area would result in no additional impact on groundwater conditions.

A canal would be constructed to convey reservoir releases to various points in the Sacramento River Region. No potentially significant adverse impacts on local groundwater resources are expected from operation of the canal if the canal is lined and hydraulically isolated from the surrounding environment.

No potentially significant adverse impacts on local groundwater resources are expected from operation of the canal if the canal is lined and hydraulically isolated from the surrounding environment.

The groundwater storage component could consist of various conjunctive use and/or water-banking techniques with the basic objective of improving the reliability of the overall water supply and preserving existing surface water and groundwater resources. Techniques for storing and accounting for the water differ, but they are all designed to manage groundwater storage as a renewable supplement to surface water supplies. Efforts by the Program, DWR, and others are under way to identify and evaluate specific groundwater storage programs in the region. Currently, groundwater storage programs are being explored by the Program through outreach to local communities in order to determine which areas would be interested in participating in a locally controlled program. As part of this effort, information has been gathered from stakeholders. Many communities and individuals with direct experience with past conjunctive use and groundwater banking programs provided historical information concerning local impacts and other concerns. As a result of these efforts, the Program has summarized stakeholder concerns, developed draft guidelines for evaluating groundwater storage development, and identified preliminary mitigation strategies.

Both beneficial and potentially significant adverse impacts on groundwater resources could occur. The potential benefits of an artificial recharge program include increased water supply reliability; reduced long-term lift costs to extract groundwater; and possible reduction or reversal of the adverse effects of past overdrafting of groundwater, such as land subsidence and water quality degradation.

> The potential benefits of an artificial recharge program include increased water supply reliability; reduced long-term lift costs to extract groundwater; and possible reduction or reversal of the adverse effects of past overdrafting of groundwater, such as land subsidence and water quality degradation.

If improperly managed, groundwater storage programs could result in potentially significant adverse impacts associated with overdrafting the aquifer, including land subsidence, water quality degradation, increased pumping costs, reduced well yields, and streamflow depletions.

The nature and magnitude of these impacts would depend on site-specific conditions and the groundwater management program governing groundwater extraction and recharge.

Land subsidence results from compaction of unconsolidated aquifer materials and, more importantly, from compaction of compressible clay layers in multilayered aquifer systems. Sands and gravels are far less compressible than clays and also yield water more easily to wells. But many aquifers consist of a sequence of sands or gravels separated by layers of silts and clays. As groundwater levels decline, the sands compact slightly due to reduction in pore water pressure. But compaction of the clays can be much more significant. Although sandy aquifers tend to rebound when water levels rise again, clay compaction is relatively inelastic. That is, once the clay layers are compacted, they do not recover completely. As a result, most of the subsidence caused by groundwater pumping is not reversible.

These potentially significant adverse impacts could affect the parties directly involved in the groundwater storage project and also could affect neighboring third parties only if the project was mismanaged. During extended drought periods, unforeseen groundwater level declines could occur as a result of over pumping in the storage facility area, and adverse impacts on third-party users could be potentially significant. In extreme cases, third-party users could lose the use of some wells as a result of groundwater quality degradation or lower groundwater levels. Third-party impacts also are discussed in Section 7.2, "Agricultural Economics," and Section 7.14, "Environmental Justice."

Groundwater storage programs typically would be operated to store water before it was extracted. This type of operation would result in a net long-term decrease in storage relative to the No Action Alternative. Consequently, adverse impacts associated with the groundwater storage program could be minimized. In fact, groundwater levels are expected to increase over the long term as a result of increased storage. Some long-term beneficial impacts could result to third-party users, including reduced pumping costs and possibly a reversal of the adverse impacts of past groundwater declines.

> Groundwater storage programs typically would be operated to store water before it was extracted. Groundwater levels are expected to increase over the long term as a result of increased storage.

If mismanaged, groundwater programs could result in groundwater level declines in comparison to the No Action Alternative during dry year periods due to increased groundwater pumping. Most of the remaining potential adverse impacts of operating a groundwater storage project would result from groundwater recharge. The magnitude, extent, and type of impacts would depend on the size, location, and operation of the specific project and would be identified for a particular project in a project-level EIS/EIR. The following impacts refer to artificial recharge systems but also apply to in-lieu recharge.

Artificial recharge systems are designed to speed up natural recharge rates, either by enhancing the rate of percolation to the water table or bypassing natural barriers to recharge. Percolation ponds speed up groundwater percolation by providing constant downward water pressure (in-lieu recharge does this through deep percolation of applied irrigation water). Percolation ponds usually are used to recharge shallow, unconfined water table aquifers. Injection wells are designed to conduct recharge water past fine-grained soil layers that otherwise would impede the downward flow of water. Injection wells can be used to place surface water into a targeted aquifer unit at a selected depth.

Percolation ponds speed up groundwater percolation by providing constant downward water pressure (in-lieu recharge does this through deep percolation of applied irrigation water).

Differences in the chemical or biological properties of the recharge water relative to the water in the targeted aquifer (such as the dissolved oxygen concentration, pH, mineral content, temperature, microbial population, and other parameters) could result in potentially significant adverse impacts. For example, introduction of nutrients can cause existing dormant microbial populations to bloom. New, undesirable microbial populations may be introduced. Changes in water chemistry can cause precipitation or solution of minerals. In addition, in some locations, recovery of water levels could remobilize residual chemical contaminants that have been left behind by falling water levels.

Other potentially significant adverse impacts include:

- Increased movement of contaminants due to changes in groundwater levels
- Impacts on groundwater quality due to poor-quality recharge waters

In most locations, the adverse impacts would be less than significant; however, potentially significant adverse impacts can be mitigated to less-than-significant levels.

5.4.7.4 SAN JOAQUIN RIVER REGION

Ecosystem Restoration Program

The Ecosystem Restoration Program would convert agricultural lands to riparian or aquatic habitat. The impacts would be the same as those described for the Sacramento River Region, except that a smaller amount of acreage would be affected. Increased streamflows during low runoff periods and restoration of natural stream meanders could increase groundwater recharge along the San Joaquin River. This increase is considered a beneficial impact on groundwater resources.

Increased streamflows during low runoff periods and restoration of natural stream meanders could increase groundwater recharge along the San Joaquin River. This increase is considered a beneficial impact on groundwater resources.

Additional in-streamflow requirements may result in reduced frequency of meeting agricultural (and to some extent) municipal and industrial demands in the San Joaquin River Region relative to the No Action Alternative. This would put increased pressure on groundwater resources to supply the unmet demand and could result in potentially significant adverse impacts on groundwater resources in some basins during low runoff years. These impacts can be mitigated to less-than-significant levels.

Water Quality Program

The impacts on groundwater quality in the San Joaquin River Region would be the same as those described for the Sacramento River Region.

Water Use Efficiency Program

Opportunities exist for more efficient use of water in the San Joaquin River Region. If implemented, water use efficiency measures could lead to reduced dependence on groundwater. This would result in beneficial impacts in areas currently subject to groundwater overdraft. Agricultural and landscape water use efficiency could cause reductions in recharge to the water table aquifer. These reductions would probably not be significant compared to the amount of recharge that occurs along stream channels during high-flow periods but, if not replaced, the loss of recharge could result in declines in the shallow water table.

Opportunities exist for more efficient use of water in the San Joaquin River Region. If implemented, water use efficiency measures could lead to reduced dependence on groundwater.

Many water districts use delivery canals as recharge basins. During wet years, these canals are purposely filled with water during winter to recharge the underlying aquifer. Recharge also occurs during normal periods of operation. Canal lining would reduce this source of groundwater recharge. This is not considered a potentially significant adverse impact, however.

Many water districts use delivery canals as recharge basins.

The most important recharge zone for the deep, confined aquifer is along the margin of the valley, on alluvial fans of large streams at the base of the Sierra Nevada foothills. The Water Use Efficiency Program is unlikely to significantly affect recharge of the confined aquifer, unless water savings from water use efficiency programs are transferred to a program to artificially recharge the deep aquifer. The Program provides a possible institutional format in which to transfer water savings from one sector to another sector in order to achieve desired regional objectives.

Water Transfer Program

The Water Transfer Program could result in similar beneficial and adverse impacts to those described for the Sacramento River Region. As recipients of cross-Delta transfers, basins in the San Joaquin River Region would receive immediate benefits from water transfers that alleviate pressure on the groundwater resources in the region. However, in the long term, increased reliance on inter-basin transfers could result in potentially significant adverse impacts if the reliability of transferred water is reduced.

Storage

Operation of the groundwater storage component could result in groundwater impacts similar to those described for the Sacramento River Region. The potential for subsidence is of considerable concern in the San Joaquin River Region, given the large regional occurrence of land subsidence in the western and southern portions of the San Joaquin Valley.

> The potential for subsidence is of considerable concern in the San Joaquin River Region, given the large regional occurrence of land subsidence in the western and southern portions of the San Joaquin Valley.

5.4.7.5 OTHER SWP AND CVP SERVICE AREAS

Ecosystem Restoration Program

The Ecosystem Restoration Program would not directly affect groundwater resources in the Other SWP and CVP Service Areas. However, to the extent that the amount of water available for export to the service areas was reduced the program at certain times, water supply contractors could increase their dependence on groundwater at these times. The impacts probably would be less than significant.

Water Quality Program

In some areas, groundwater contamination has reduced the beneficial uses of large amounts of groundwater. It is possible that additional efforts to reduce point and nonpoint sources of contamination could lead to an increase in the amount of high-quality groundwater resources available to supplement surface water sources. Without these efforts, additional groundwater resources may be rendered unusable in the future.

Water Use Efficiency Program

More efficient use of water in the Other SWP and CVP Service Areas would result in the same impacts on groundwater resources as described for the Sacramento River Region. Reducing demand or increasing supply through recycling waste water would decrease dependence on groundwater.

Water Transfer Program

The Other SWP and CVP Service Areas could receive additional water from transfers from the Central Valley or from other basins outside the Central Valley. This water could partially offset groundwater overdrafts in the service areas, thereby resulting in a beneficial impact on groundwater resources outside the Central Valley. As described in the previous sections, increased reliance on imported water could result in potentially significant adverse impacts if the reliability of the transferred water is reduced.

Watershed Program and Storage

Impacts on groundwater resources in the Other SWP and CVP Service Areas are not expected from Watershed Program or Storage element actions.

5.4.8 CONSEQUENCES: PROGRAM ELEMENTS THAT DIFFER AMONG ALTERNATIVES

For groundwater resources, the Conveyance element results in environmental consequences that differ among the alternatives, as described below.

5.4.8.1 PREFERRED PROGRAM ALTERNATIVE

This section includes a description of the consequences of a pilot diversion project. If the pilot project is not built, these consequences would not be associated with the Preferred Program Alternative.

With the pilot diversion facility near Hood, leakage could occur through the unlined canal transferring water from the diversion facility to the Mokelumne River. The amount of leakage would depend on the permeability of the bottom of the canal, the permeability of the soils underlying the canal, and the difference between the elevation of water in the canal and the elevation of the water table beneath the canal. Leakage could cause waterlogging of soils along the alignment of the canal. The rate of leakage also would depend on the width of the canal. Leakage could result in a potentially significant adverse impact on water levels in soils adjacent to the canal.

Leakage could cause waterlogging of soils along the alignment of the canal.

Changes in project operations would not significantly affect water quantities potentially available for beneficial use in the channels and open waterbodies of the Delta Region. Proposed flow changes would not be sufficiently large or prolonged to cause significant changes in groundwater resources. Since no change in groundwater pumping or recharge is expected, no impacts on groundwater are anticipated in the Delta Region from the changes in operations.

Changes in project operations could affect groundwater resources in the Bay Region. Potential short- and long-term changes in the amounts of water available for export could cause significant increases or decreases in water supply and water management in the Bay Region. This could lead to small losses or benefits in opportunities to use and recharge groundwater resources and to implement conjunctive use programs.

In the Sacramento River Region, changes in project operations would not significantly affect groundwater resources. Water supply and water management in the region could be affected by changes in reservoir operation and river flows to meet new Delta operational requirements. These changes would not be sufficiently large or prolonged to cause significant changes in groundwater resources.

Changes in project operations could result in potentially significant impacts on groundwater resources in the San Joaquin River Region and in the Other SWP and CVP Service Areas. The impact would depend on the magnitude of change in recharge rates and pumping that could result due to the reduction or increase in export water resulting from operation changes. The potential range of changes in supply for SWP and CVP service areas south of the Delta could vary from increases of up to about 800 TAF to losses of as much as 500 TAF. Changes in project operations also could adversely affect water supply and water management in the San Joaquin River Region; changes in groundwater use could be adverse or beneficial, depending on the magnitude of the change.

Changes in project operations could result in potentially significant impacts on groundwater resources in the San Joaquin River Region and in the Other SWP and CVP Service Areas. The impact would depend on the magnitude of change in recharge rates and pumping that could result due to the reduction or increase in export water resulting from operation changes.

CVGSM modeling indicated that with increased SWP and CVP deliveries, groundwater levels could remain higher than under the No Action Alternative. Changes in groundwater use could change subsidence rates, which could affect land use and water demands. Groundwater effects could extend outside service areas if water resources are managed to make up or redirect the effects of changing the amount of export water deliveries. Changes in beneficial uses of the groundwater resource would depend on the magnitude of the variations in supply and usage.

5.4.8.2 ALTERNATIVE 1

Under Alternative 1, the Conveyance element is not expected to affect groundwater resources in any Program region. Changes in project operations would cause effects similar to those described for the Preferred Program Alternative.

5.4.8.3 ALTERNATIVE 2

Under Alternative 2, the impacts associated with conveyance facilities would be similar to those described for the Preferred Program Alternative but with greater water diversion capacity. Changes in project operations also would cause effects similar to those described for the Preferred Program Alternative.

5.4.8.4 ALTERNATIVE 3

With the isolated facility water conveyance in Alternative 3, leakage could occur through the unlined canal of the isolated facility. The amount of leakage would depend on the permeability of the bottom of the canal, the permeability of the soils underlying the canal, and the difference between the elevation of water in the canal and the elevation of the water table beneath the canal. Leakage could cause waterlogging of soils along the alignment of the canal. The rate of leakage also would depend on the width of the canal. Leakage could result in a potentially significant adverse impact on water levels in soils adjacent to the canal.

With the isolated facility water conveyance in Alternative 3, leakage could occur through the unlined canal of the isolated facility.

Changes in project operations would cause effects similar to those described for the Preferred Program Alternative.

5.4.9 PROGRAM ALTERNATIVES COMPARED TO EXISTING CONDITIONS

This section presents the comparison of existing conditions to the Preferred Program Alternative and Alternatives 1, 2, and 3. This programmatic analysis found that the potentially beneficial and adverse impacts from implementing any of the Program alternatives when compared to existing conditions were the same impacts as those identified in Sections 5.4.7 and 5.4.8, which compare the Program Alternatives to the No Action Alternative.

Some actions that are beneficial when compared to the No Action Alternative could result in a potentially significant adverse impact when compared to existing conditions. While the Program is expecting an overall improvement in groundwater resources relative to the No Action Alternative, the potential remains that groundwater conditions could be worse than those currently existing. This potential primarily is possible because of changes in population levels and demand that would occur under the No Action Alternative but are not considered under existing conditions. Implementation of the Program likely would result in groundwater resources being better than without the Program but degraded relative to existing conditions.

Implementation of the Program likely would result in groundwater resources being better than without the Program but degraded relative to existing conditions.

For some actions, the beneficial impacts of Program actions would be greater when compared to existing conditions. Under existing conditions, clean-up of existing point and nonpoint pollution sources would not occur. The beneficial impacts of Program actions on groundwater resources therefore would be incrementally higher compared to existing conditions than under the No Action Alternative scenario. Subsequent environmental documentation for specific projects will better identify the type and extent of the improvements in relation to existing conditions.

At the programmatic level, the comparison of the Program alternatives to existing conditions did not identify any additional significant environmental consequences than were identified in the comparison of Program alternatives to the No Action Alternative. All potentially significant adverse impacts identified when compared to the No Action Alternative are still significant when compared to existing conditions. However, the extent of the potentially significant adverse impacts could be greater under some actions when compared to existing conditions.

The following potentially significant impacts are associated with the Preferred Program Alternative:

- Changes in groundwater levels.
- Increased demand for groundwater supplies.
- Increased groundwater overdraft.
- Increased land subsidence.
- Increased degradation of groundwater quality from contaminant movement, salt-water intrusion, or naturally poor-quality water drawn into the aquifer.
- Impacts from groundwater recharge and storage system operations.

No potentially significant unavoidable impacts on groundwater resources are associated with the Preferred Program Alternative.

5.4.10 ADDITIONAL IMPACT ANALYSIS

Cumulative Impacts. For a summary of cumulative impacts for all resource categories, please refer to Chapter 3. For the list and a description of the projects and programs considered in this analysis of cumulative impacts, please see Attachment A.

In all regions, Program actions and the projects listed in Attachment A would result in cumulative changes in groundwater levels due to increased demand for groundwater supplies, increased groundwater overdraft, and groundwater recharge and storage system operations. Cumulative changes in groundwater levels could either directly or indirectly lead to a cumulative increase in land subsidence and increased degradation of groundwater quality from contaminant movement, salt-water intrusion, or naturally poor-quality water being drawn in the aquifer.

In all regions, Program actions and the projects listed in Attachment A would result in cumulative changes in ground-water levels due to increased demand for groundwater supplies, increased ground-water overdraft, and groundwater recharge and storage system operations.

Mitigation strategies have been identified that may reduce the impacts associated with Program actions and for the projects described in Attachment A. Nevertheless, cumulative impacts on groundwater resources are considered potentially significant.

Growth-Inducing Impacts. The Program is expected to improve groundwater resources relative to the No Action Alternative. However, the potential remains that groundwater conditions could be worse than those currently existing. Improvements to groundwater resources could increase water supply reliability and thus increase the attractiveness for land development within the study area.

If improvements in water supply are caused by the Preferred Program Alternative, the Preferred Program Alternative could induce growth, depending on how the additional water supply was used. If the additional water was used to expand agricultural production or urban housing development, the proposed action would foster economic and population growth. Expansion of agricultural production and population could affect groundwater resources, but the significance of the impact on groundwater would depend on where agricultural or population growth occurred and how it was managed.

Short- and Long-Term Relationships. This section assesses the balance between short-term uses of groundwater resources throughout the study areas and the maintenance and enhancement of the long-term productivity of those resources in those areas.

Development and associated activities would cause some unavoidable short-term adverse impacts on groundwater in local areas. However, these impacts can be mitigated as described previously, to the maximum extent possible. Mitigation would be accomplished through minimization of adverse effects, containment of impacts, and application of sound groundwater management practices. The overall benefits to long-term productivity of any facilities, changes in land forms, and resultant or independent changes in groundwater resource management that are selected for implementation generally would outweigh any short-term adverse impacts. If the reverse were true, the proposed actions would be eliminated from consideration during screening.

Changes in the following specific resource categories also could affect groundwater resources: surface water, geomorphologic forms, soils, regional economics, agricultural production, land use, urbanization, flooding and flood control actions, power production and energy, and environmental hazards and their control or remediation. Where possible, avoidance of adverse impacts and implementation of mitigation measures would be used as standard procedures to lessen impacts on these resources that would cause long-term adverse impacts on groundwater resources.

Irreversible and Irretrievable Commitments. Implementation of the Program could result in some irreversible and irretrievable commitments of existing groundwater resources. In addition to short-term direct groundwater deficiencies due to water supply demands, land subsidence due to adverse groundwater conditions and diminished groundwater quality would be difficult, if not impossible, to fully reverse once these conditions occurred. Adaptive management would be used during the course of the Program to identify situations that could lead to undesirable or less-than-optimum results. In this way, potential mistakes could be identified early, and plans could be altered to minimize any unintentional adverse results.

Land subsidence results from compaction of unconsolidated aquifer materials and, more importantly, from compaction of compressible clay layers in multi-layered aquifer system. Compaction of clays can be significant and irreversible. Once the clay layers are compacted, they do not recover completely. As a result, in certain areas of the study region, most of the subsidence caused by groundwater pumping is not reversible.

Compaction of clays can be significant and irreversible.

In some areas, groundwater contamination has reduced the beneficial uses of large amounts of groundwater. Once the quality of groundwater is diminished, this condition is nearly irreversible. In addition, differences in the chemical and biological properties of recharge water relative to the water in a targeted aquifer (such as the dissolved oxygen concentration, pH, mineral content, temperature, microbial population, and other parameters) could result in potentially significant adverse and irreversible impacts.

In some areas, groundwater contamination has reduced the beneficial uses of large amounts of groundwater. Once the quality of groundwater is diminished, this condition is nearly irreversible.

5.4.11 MITIGATION STRATEGIES

These mitigation strategies will be considered during project planning and development. Specific mitigation measures will be adopted, consistent with the Program goals and objectives and the purposes of site-specific projects. Not all mitigation strategies will be applicable to all projects because site-specific projects will vary in purpose, location, and timing.

Mitigations are proposed as strategies in this programmatic document and are conceptual in nature. Final mitigations would need to be approved by responsible agencies as specific projects are approved by subsequent environmental review.

The following mitigation strategies could reduce impacts on groundwater resources from Program actions:

- Creating additional groundwater or surface water storage facilities to meet demand without resorting to overdraft.
- Importing water from other basins.
- Purchasing water rights from willing sellers (including transferring water rights between sectors—for example, from agriculture to municipal uses).
- Regulating groundwater withdrawals to avoid overdraft.
- Implementing conservation measures to reduce demand.
- Integrating Ecosystem Restoration Program floodplain restoration efforts with setback levees.
- Increasing water supplies from recycling.

- Increasing regulations regarding new and existing domestic wells and septic systems.
- Developing alternative water supplies.
- Monitoring and testing groundwater wells and aquifers.
- Limiting new septic tank systems in vulnerable areas.
- Allowing water levels to increase periodically.
- Importing new soil (including dredged spoil) to raise land surface.
- Reducing or discontinuing groundwater pumping.
- Recharging vulnerable aquifers through injection wells (confined aquifers) or percolation ponds (unconfined aquifers).
- Distributing groundwater pumping over a wide region rather than to a concentrated area to minimize drawdown of the aquifer.
- Treating extracted groundwater at the well head.
- Diluting poor-quality groundwater with higher quality water.
- Developing groundwater basin management plans, including defining objectives, project boundaries, responsibilities, operations and maintenance specifications and procedures, and conditions under which corrective action must be taken.
- Temporarily removing the recharge system from service.

5.4.12 POTENTIALLY SIGNIFICANT UNAVOIDABLE IMPACTS

None of the potentially significant adverse impacts on groundwater resources that are associated with the Preferred Program Alternative are unavoidable.

None of the potentially significant adverse impacts on groundwater resources that are associated with the Preferred Program Alternative are unavoidable.