CALFED

TECHNICAL REPORT
AFFECTED ENVIRONMENT

GROUNDWATER

DRAFT

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CALFED
BAY-DELTA
PROGRAM

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LIST OF ACRONYMS

AB	Assembly Bill
Bay	San Francisco Bay
cfs	cubic feet per second
CVP	Central Valley Project
DBCP	dibromochloropropane
Delta	Sacramento-San Joaquin Delta
DHS	California Department of Health Services
DPR	California Department of Pesticide Regulation
DTSC	California Department of Toxic Substances Control
DWR	California Department of Water Resources
EDB	ethylene dibromide
EPA	U.S. Environmental Protection Agency
FCWCD	Flood Control and Water Conservation District
MAF	million acre-feet
MCL	maximum contaminant level
OEHHA	Office of Environmental Health Hazard Assessment
Reclamation	U.S. Bureau of Reclamation
RWQCB	Regional Water Quality Control Board
SJVDP	San Joaquin Valley Interagency Drain Program
SWP	State Water Project
SWRCB	California State Water Resources Control Board
USGS	U.S. Geological Survey
WUA	Water Users' Association
mg/l	milligram per liter
μg/l	microgram per liter

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GROUNDWATER

INTRODUCTION

This technical report identifies the groundwater resources that could be affected by implementation of the CALFED Bay-Delta Program (CALFED) alternatives and presents general information on the regional groundwater resources directly affected by CALFED actions.

Groundwater resources are described at various levels of detail, with emphasis on the Central Valley. The Sacramento River and San Joaquin River regions have been identified by CALFED as having potential for groundwater storage and management opportunities that could help meet various objectives of the CALFED effort. The discussion of groundwater conditions include hydrogeology, groundwater hydrology, groundwater levels, land subsidence, groundwater quality, seepage-induced waterlogging of farm lands, and agricultural subsurface drainage (only for the San Joaquin River Region).

Groundwater resources of the Delta, Bay, and State Water Project (SWP) and Central Valley Project (CVP) Service Areas Outside the Central Valley regions also are discussed in this report. The discussion of groundwater conditions for these areas is less detailed and addresses hydrogeology, groundwater hydrology, and water quality.

SOURCES OF INFORMATION

Historical information, from approximately the 1920s forward, is based on numerous regional studies and investigations. Because groundwater conditions are not recorded on a regular basis throughout the study area, recent groundwater conditions are represented by information generally available during the 1990s. In some cases, these data were developed by the Department of Water Resources (DWR) as part of the most recent *California Water Plan Update*, Bulletin 160-93 (DWR 1994). In other cases, data from the most recent study for the area were used.

U.S. Geological Survey (USGS) reports were used to describe land subsidence conditions in the Central Valley. Since 1956, USGS has been researching this problem in cooperation with DWR. The discussion of land subsidence in the Santa Clara Valley is based on information provided in the final environmental impact statement prepared by the U.S. Bureau of Reclamation (Reclamation) for the San Felipe Unit of the CVP.

Recent groundwater quality conditions were summarized from the most recent State Water Resources Control Board (SWRCB) Water Quality Assessments; from summary information documented by the USGS; and from various reports published by the California Department of Pesticide Regulation (DPR), DWR, and Reclamation.

ENVIRONMENTAL SETTING

Regulatory Context

Groundwater allocation is a local responsibility that is accomplished under the authority of the California Water Code and a number of court decisions. The following are the six methods for groundwater allocation under present law. Groundwater management can be achieved by a combination of one or more of these methods.

- Overlying property rights
- Local agencies
- Adjudicated basins
- Groundwater management agencies

- Assembly Bill (AB) 3030 (The Groundwater Management Act)

- City and county ordinances

A broad range of groundwater management activities have been undertaken in California. Groundwater management has been an integral part of water use in much of the study area since the early to mid 1990s.

Given the large number of groundwater management efforts in these areas, it is not possible to include all programs.

Additional information on the regulatory context for groundwater management and definitions of common terms used in groundwater management is contained in the Supplement to this report.

California has statewide and local groundwater protection mechanisms that are based primarily on the implementation of data collection and monitoring programs, adopted policy, and regulatory activities that are overseen by various agencies. Various agencies also provide information and guidance to the public in regard to issues that could be threatening to groundwater resources in California.

Additional information on general roles and responsibilities of the agencies involved in groundwater protection is included in the Supplement to this report.

The California Department of Health Services (DHS) has set secondary drinking water standards for TDS at 500 milligrams per liter (mg/l) maximum contaminant level (MCL); however, short-term levels up to 1,500 mg/l are considered acceptable (RWQCB 1993). The DHS primary drinking water standard for nitrates is 45 mg/l MCL as nitrates. The DHS has designated secondary drinking water standards for iron and manganese at 300 micrograms per liter (μg/l) and 50 μg/l MCL, respectively. Agricultural water quality goals are also set at 5,000 μg/l and 200 μg/l for iron and manganese, respectively (Ayers and Westcot 1985).

Arsenic is a naturally occurring trace element in the Central Valley. Arsenic is regulated by the U.S. Environmental Protection Agency (EPA) at a primary drinking water quality standard of 50 μg/l. It can be toxic to plants and animals. For irrigation use, the guidelines recommend that arsenic concentrations not exceed 1,000 μg/l.

Although selenium currently is regulated by federal primary drinking water standards at an MCL of 50 μg/l, EPA recently established chronic and acute toxicity criteria of 5 and 20 μg/l, respectively, for the protection of wildlife and aquatic organisms. The SWRCB, Central Valley Region, has established monthly mean and daily maximum selenium objectives of 5 and 12 μg/l, respectively, for the San Joaquin River from the mouth of the Merced River to Vernalis; and objectives of 10 and 26 μg/l from Sack Dam to the mouth of the Merced River (SWRCB 1992).

Environmental Setting - Delta Region

HISTORICAL PERSPECTIVE

Information on use of groundwater in the Delta Region is limited. Groundwater conditions have not changed considerably from historical conditions. Historically, groundwater use in the Delta primarily occurred on the outermost periphery.

Identification and characterization of groundwater basins is the responsibility of the Department of Water Resources (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 was also 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 1 shows the distribution of geologic materials that have been defined as groundwater basins.

DWR has recently 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.

CURRENT RESOURCE CONDITIONS

HYDROGEOLOGY

The surface of the Delta Region is composed of a variety of soil types, ranging from mineral alluvial fan deposits around the edge to organic peat soil in the center. Soils are dominated by silts, clays, silty clays, and sandy soils. The organic peat soils reach depths of more than 20 feet, a result of thousands of years of deposition of tule marsh vegetative debris (California State Lands Commission 1991). Beneath these organic soils is a thick sequence of sedimentary materials deposited in marine and nonmarine environments. The upper, nonmarine portion attains a maximum thickness of about 3,000 feet.

The principle lithologic unit in which groundwater occurs is the Sacramento-San Joaquin Delta deposits of post-Mehrten to Recent age. These deposits range in thickness, and are in excess of 2,500 feet along the central part of the region (McClure 1956). Other deposits of major importance as a source of groundwater include: the unconsolidated Victor formation and related continental sediments of Recent and Pleistocene age in the eastern portion of the area; the west side alluvial fan deposits and west side older alluvial deposits, all of Pleistocene age; and the semi-consolidated Mehrten formation of Miocene age (McClure 1956).

Groundwater is replenished through deep percolation of streamflow, precipitation, and applied irrigation water. Recharge by subsurface inflow is negligible compared to other sources.

GROUNDWATER HYDROLOGY

Groundwater beneath the Delta Region is not stored in one single mass of homogeneous sediments, but rather in a series of poorly connected sand and gravel lenses that are confined locally by silts and clays. Inadequate yield and poor quality conditions limit the usefulness of groundwater in this area. A majority of groundwater pumping occurs out of necessity because of high groundwater levels affecting agricultural activities.

The outer areas of the region, contiguous with the valley floor areas, contain large quantities of fresh water that are largely unconfined. In these areas, groundwater is relied on as a source for domestic and agricultural purposes. Under recent conditions, estimates of average annual groundwater pumping range between 100,000 and 150,000 acre-feet in the upland areas of the Delta Region (DWR 1994).

One type of land subsidence is associated mainly with loss of peat soils. As water levels decline, oxygen from the atmosphere enters the poor 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.

GROUNDWATER QUALITY

Groundwater of a quality adequate for domestic and agricultural purposes is not prevalent in the central region of the Delta. Rising saline waters unsuitable for most beneficial uses occur at depths less than 100 feet from the surface over 200 square miles of this area (McClure 1956). Groundwater quality found in the valley floor area along the outer edges of the region are generally excellent quality with low mineral content.

Environmental Setting - Bay Region

HISTORICAL PERSPECTIVE

Historically, Santa Clara and San Benito counties have been subject to groundwater mining, which has resulted in a decline in groundwater levels, land subsidence, and seawater intrusion. The delivery of CVP surface water supplies to the San Felipe Division is intended to reduce the use of groundwater, and thereby reduce the extent of these types of problems.

Groundwater resources in parts of Alameda and Contra Costa counties are limited due to availability of supply and poor water quality. These areas experience reliability problems, excessive groundwater level declines and land subsidence, increased pumping costs, and further degradation of water quality conditions. The introduction of imported CVP surface water supplies has supplemented the limited supplies.

Historically, seawater has intruded into most coastal basins in this area.

CURRENT RESOURCE CONDITIONS

HYDROGEOLOGY

San Francisco, San Pablo, and Suisun bays are shallow, with about 85% of the water area less than 30 feet deep. The estuary occupies part of a north-south trending depression that extends from Hollister north to the Petaluma, Sonoma, and Napa valleys. The depression was formed in the late Pliocene, and was repeatedly flooded during the Pleistocence glaciations. The Merced Formation, a Plio-Pleistocence deposit, occurs in the estuary. The lower portion of this formation is marine, but approximately the upper quarter is nonmarine. Above the Merced formation, sediments are derived primarily from the Sierra Nevada and have been transported to the estuary by the Sacramento River (Norris and Webb 1976). The estuary is bordered by various parts of the Coast Ranges, including the Diablo Range, Santa Cruz Mountains, San Francisco Peninsula, and the Mendocino Ranges.

Within the Bay Region estuary, groundwater is found in both the alluvial basins and upland hard rock areas. The alluvial basins range in thickness up to 1,000 feet. Well yields in these basins range from less than 100 to over 3,000 gallons per minute. Yield from wells in the hard rock areas is generally much lower but is usually sufficient for most domestic or livestock purposes. Recharge to the alluvial basins occurs primarily from rainfall and seepage from adjacent streams. A significant percentage or recharge, especially in the South Bay, is through artificial recharge facilities and incidental recharge from irrigation (DWR 1994).

GROUNDWATER HYDROLOGY

Groundwater sub-basins for the Bay Region have been defined by DWR and are summarized in Table 1. From sub-basin to sub-basin, development of groundwater for irrigation, domestic, industrial, and stock uses varies from minor to intensive (DWR 1975).

Table 1 also shows recent estimates of groundwater extraction for 1990 normalized conditions. (1990 normalized conditions represent water demand for a 1990 level of development that has been adjusted to account for unusual events such as dry weather conditions, government interventions for agriculture, rationing programs, or other irregularities.) Under these conditions, total annual 1990 groundwater extractions for the

Basin/Region	Sub-Basin	Extraction[a] (AF/yr)	Management Status of Basin
North Bay Area	Petaluma Valley	3,100	None identified
	Napa-Sonoma Valley	11,000	None identified
	Marin County	2,200	None identified
	Suisun-Fairfield Valley	4,800	None identified
South Bay Area	Santa Clara Valley	150,000	Managed by Santa Clara Valley Water District
	Livermore Valley	5,500	Managed by Alameda County Flood Control and Water Conservation District, Zone 7
	San Mateo County	13,408	None identified

NOTES:

AF/yr = Acre-feet per year.

[a] 1990 normalized conditions represent water demand for 1990 level of development, adjusted to account for unusual events such as dry conditions, government for agriculture, rationing programs, or other irregularities.

SOURCE:
DWR 1994.

Table 1. Bay Region Groundwater Resources

region are estimated to be 190,000 acre-feet. For 1992, drought supplies (including dedicated natural flow) were 28% less than average. Supply reductions occurred in local surface and imported supplies. Groundwater use increased primarily because users in the region often rely more heavily on storage in aquifers in dry years. (DWR 1994).

The condition of groundwater levels in the North Bay indicate that these sub-basins are not currently subject to overdraft. Estimated groundwater storage in these sub-basins is 1.7 million acre-feet (MAF). Total groundwater storage in the South Bay is estimated to be 6.5 MAF. Groundwater sub-basins in the South Bay have been developed intensively for domestic, industrial, and irrigation needs; historical groundwater extraction in excess of groundwater recharge has resulted in groundwater level declines, seawater intrusion, and land subsidence. Artificial recharge programs have resulted in a general recovery of groundwater levels in many of these sub-basins. These efforts have mitigated or eliminated low groundwater level problems (DWR 1994).

GROUNDWATER QUALITY

Groundwater quality varies throughout the Bay Region. Although groundwater quality in the North Bay is generally good, some isolated areas experience elevated levels of TDS, iron, boron, hardness, and chloride. High levels of nitrates occur in Napa and Petaluma valleys as a result of past agricultural practices (DWR 1994). In the southern part of Suisun-Fairfield Valley, heavy pumping may cause brackish water to move inland, degrading groundwater quality (DWR 1975).

Groundwater quality has been poor in the South Bay, where groundwater mining has resulted in seawater intrusion. Quality is still a problem to various degrees in many South Bay locations. The Livermore Valley has elevated levels of TDS, chloride, boron, and hardness. The highly urbanized areas of Santa Clara Valley have experienced groundwater pollution over large areas from organic solvents used in electronic manufacturing. Santa Clara Valley Water District has an extensive groundwater protection program to administer cleanup operations and to prevent degradation of the groundwater basin

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through well sealing and groundwater quality monitoring (DWR 1994).

Groundwater conditions in the Santa Clara County Basin exemplify 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.

Environmental Setting - Sacramento River Region

The northern third of the Central Valley regional aquifer system is located in the Sacramento River Region. This region extends from north of Redding to the Delta in the south (Figure 1). DWR identifies this portion of the Central Valley Aquifer as the Sacramento Valley and Redding basins, which cover over 5,500 square-miles. This discussion refers to these basins collectively as the Sacramento Valley Basin.

HISTORICAL PERSPECTIVE

GROUNDWATER HYDROLOGY

Aquifer recharge to the Sacramento Valley Basin has historically occurred from deep percolation of rainfall, the infiltration from stream beds, and subsurface inflow along basin boundaries. Most of the recharge for the Central Valley occurs in the north and east sides of the valley where the precipitation is the greatest. With the introduction of agriculture to the region, aquifer recharge was augmented by deep percolation of applied agricultural water and seepage from irrigation distribution and drainage canals.

The basin has an estimated perennial yield of 2.4 MAF, and recent groundwater pumping in the Sacramento Valley Basin was estimated to be near this perennial yield (DWR 1994).

In the Sacramento Valley Basin, a long-term dynamic link between the groundwater and surface water system has been maintained on a regional basis. This link results in the movement of water between the two systems. At a particular point in time, the direction of this movement (from the stream to the groundwater, or from the groundwater to the stream) can vary, depending on the location. For example, portions of a stream may lose water to the groundwater system below, while other reaches of the stream may gain water from the groundwater system. In addition, these conditions can change over time as climatic conditions change, and land and water use practices change.

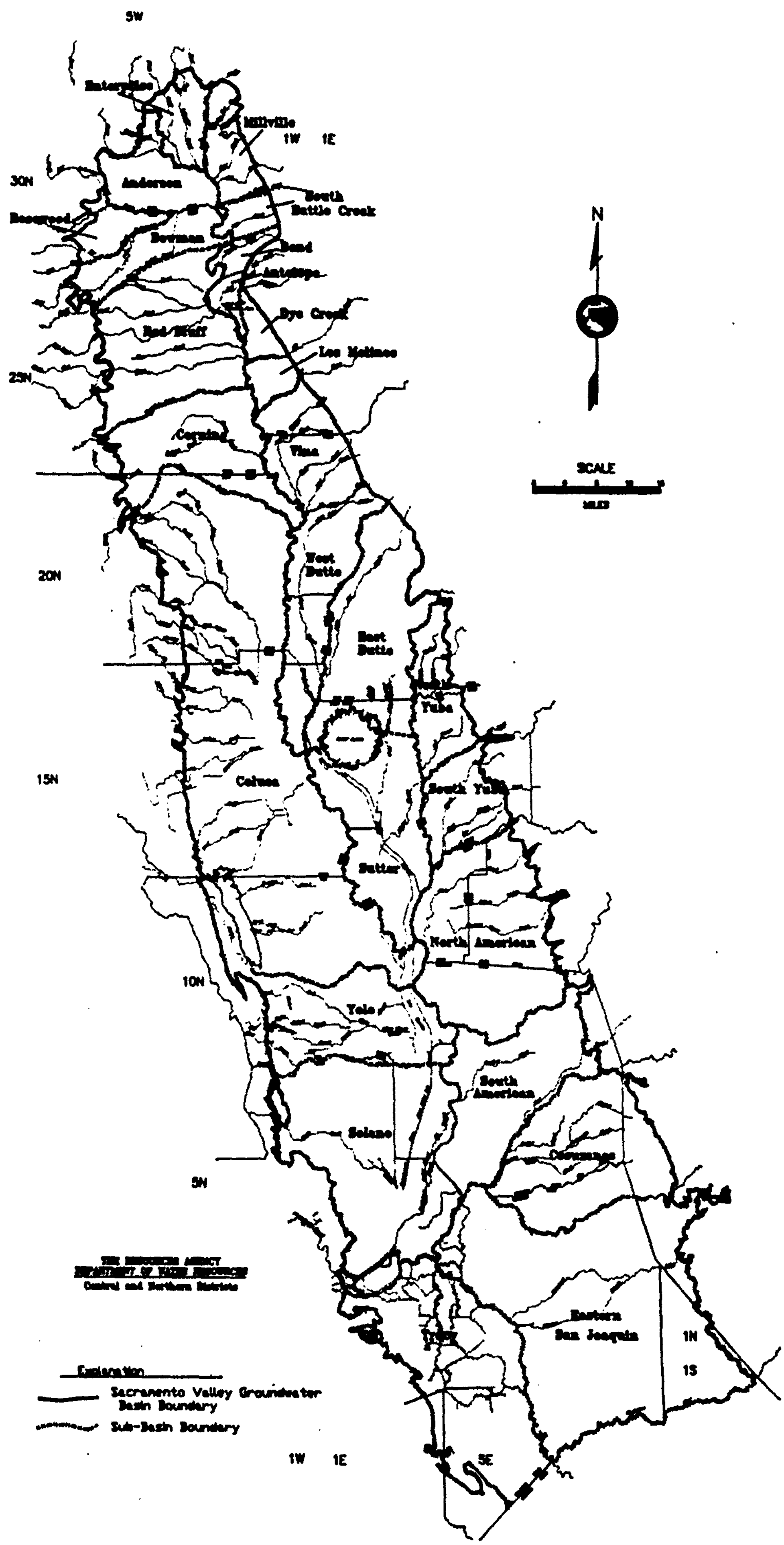

Figure 1. Sacramento Valley Groundwater Sub-Basin Boundaries

Many streams in this region historically have been gaining streams, a condition where groundwater is discharged into the stream. Historically, the greatest gains to streams from groundwater occurred during the 1940s when groundwater storage was highest in the Sacramento Valley Basin (Reclamation et al. 1990). The high groundwater storage condition was primarily a result of an extended wet period that occurred in the Sacramento Valley between 1935 and 1943. Discharge to streams was lowest during and immediately following the 1976 to 1977 drought and the 1987 to 1992 drought (Reclamation et al. 1990, DWR 1994). The USGS conducted an analysis of stream gains and losses for the Central Valley using a water budget approach, and reported that on average over the 1961 to 1977 period streams were generally gaining, with the exception of creeks along the west side of the valley and the American River, which were found to be losing streams on average (Williamson et al. 1989).

During pre-development conditions, the groundwater flow was from the flanks to the valley axis, then south toward the Delta. However, recent development and the associated increased pumping have induced changes in natural groundwater flow patterns. In areas of the region where groundwater pumping has increased more than other areas (such as areas in Sacramento, Yolo, and Solano counties), groundwater movement is now toward areas of groundwater depression.

GROUNDWATER LEVELS

In the Sacramento River Region, groundwater levels associated with the Sacramento Valley Basin historically have declined moderately during extended droughts, generally recovering to pre-drought levels as a result of subsequent wetter periods. This recovery process may span several years or may occur over a single year, depending on the extent of the wet period.

Between the early 1900s and the 1950s, groundwater levels fluctuated in response to varied climatological conditions and increased groundwater development. In fall 1960, regional groundwater levels (reported by DWR) north of the Sutter Buttes were similar to those observed in the early 1900s, suggesting that long-term changes in groundwater conditions in this part of the valley were not occurring. South of the Sutter Buttes, however, groundwater levels in several areas of Yolo, Solano, and Sacramento counties had dropped nearly 50 feet since the early 1900s, indicating a steady decline over this first half of the century.

Groundwater levels in areas north of the Sutter Buttes continued to show little sign of long-term changes through the mid 1970s. South of the Sutter Buttes, groundwater levels in spring 1974 (reported by Reclamation) had increased between 1960 and 1974 in Solano and Yolo counties due in part to several years of above-normal precipitation during the late 1960s and early 1970s and to the introduction of surface water supplies from Reclamation's Solano Project in 1960. However, levels remained below those observed in the early 1900s. Continued groundwater development in Sacramento County resulted in additional groundwater level declines between 1960 and 1974. East of the Sutter Buttes (Marysville area), an increase in ground-water development also resulted in groundwater level declines between 1960 and 1974.

LAND SUBSIDENCE

The water level decline in most parts of the Sacramento Valley was much lower during the past 60 years of agricultural development. However, in a few localities, intensive groundwater pumping, prior to 1969, caused the water levels to decline between 40 and 110 feet (Lofgren and Ireland 1973), resulting in land subsidence in localized areas.

A preliminary investigation of land subsidence in the Sacramento Valley was conducted in 1973 by Lofgren and Ireland. The investigation identified two main areas in the southwestern part of the valley, near Davis and Zamora, where land subsidence had exceeded 1 foot by 1973. Land subsidence in excess of 2 feet was measured by 1973 in the area east of Zamora and west of Arbuckle. The USGS also documented land subsidence in this area in excess of 1 foot by 1970. Since 1973, limited monitoring of land subsidence has occurred; some localized land subsidence has been recorded in the Davis-Zamora area during the 1987 to 1992 drought period (Dudley pers. comm.).

SACRAMENTO RIVER REGION - CURRENT RESOURCE CONDITIONS

HYDROGEOLOGY

During the geologic period of deposition, as much as 10 vertical miles of unconsolidated continental and marine sediment accumulated in the structural trough of the Sacramento Valley Basin. Alluvium deposits can be found throughout the region in the form of alluvial fans, stream channel deposits, and floodplain deposits. These vast deposits are the source of most of the groundwater pumped in the Sacramento Valley. Although the Sacramento Valley Aquifer System is considered unconfined, areas of confinement are present. Depth to the base of freshwater ranges from 1,000 feet in the Orland area to nearly 3,000 feet in the Sacramento area.

Aquifer recharge of the basin historically has occurred from deep percolation of rainfall, the infiltration from stream beds, and subsurface inflow along basin boundaries. Most of the recharge for the Central Valley occurs in the north and east sides of the valley where the precipitation is the greatest. With the introduction of agriculture to the region, aquifer recharge was augmented by deep percolation of applied agricultural water and seepage from irrigation distribution and drainage canals.

Surface water and groundwater resources in this region are interdependent. In general, the relationship between a stream system and an underlying aquifer can be placed into two categories: (1) If the aquifer water levels are below the streambed, the systems are considered to be hydraulically disconnected, and seepage from the stream enters the unsaturated zone between the streambed and the water table; (2) If the streambed and underlying aquifer are in contact with one another, the systems are considered to be hydraulically connected. Under this condition, the relative hydraulic head between the two systems governs whether the movement of water is from the stream to the aquifer, or from the aquifer to the stream. (Further discussion of these complex relationships can be found in a number of groundwater texts (Bear 1972, Todd 1959, and Freeze and Cherry 1979). The latter condition is more prevalent in the Sacramento River Region.

GROUNDWATER HYDROLOGY

Several estimates have been made of the amount of groundwater associated with the Sacramento Valley Basin. The USGS estimated approximately 33.5 MAF of groundwater storage capacity between 20 and 200 feet of the ground surface (Bryan 1923). In DWRs most recent *California Water Plan Update* (Bulletin 160-93), usable storage capacity was estimated at 40 MAF (DWR 1994). The difference between these estimates is a function of the definition of "usable storage capacity." Rather than defining usable storage capacity based on a depth range, DWR's definition is based on aquifer properties (permeability), groundwater quality, and economic considerations such as the cost of well drilling and energy costs (DWR 1994). The USGS estimates are considered conservative because present-day definitions of usable capacity could include groundwater available below 200 feet of the ground surface.

"Safe yield" is a concept commonly used in describing a groundwater basin. The definition of safe yield can include several factors but, in general, it defines the amount of groundwater a basin can produce without promoting an undesirable result. In recent efforts by DWR, groundwater has been characterized by its perennial yield (see definition and assumptions in the Supplement). Perennial yield directly depends on the amount of recharge received by the groundwater basin, which may be different in the future than it has been in the past. There have been numerous attempts to define the amount of safe yield and, more recently,

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perennial yield of the Sacramento Valley Basin. The estimates vary, depending on the methodology used and the assumptions that are made. The most recent estimate, developed by DWR for the *California Water Plan Update* (Bulletin 160-93), is 2.4 MAF (DWR 1994). This perennial yield is directly dependent on the estimate of recharge received by the groundwater basins, which may be different in the future than it has been in the past.

Groundwater elevations for sub-basins defined by DWR for the Sacramento River Region (Figure 2) are summarized in Table 2. Estimates of groundwater extractions by DWR 1990 normalized conditions suggest that 2.6 MAF of groundwater pumping occurred in the region.

GROUNDWATER LEVELS

Groundwater levels for spring 1986 (reported by DWR) indicate little change north and east of the Sutter Buttes since 1974. South of the Sutter Buttes, however, groundwater levels between 1974 and 1986 continued to increase in Solano and Yolo counties.

Groundwater levels observed for spring 1993 (reported by DWR) are shown in Figure 2. The spring 1993 groundwater contours indicate a pumping depression in Sacramento and San Joaquin counties, and that groundwater in much of the western part of these counties is more than 40 feet below sea level. In all other areas of the Sacramento Valley Basin, the above-normal precipitation events during the 1992 to 1993 winter resulted in near full recovery of groundwater levels to pre-drought (1987 to 1992) conditions.

LAND SUBSIDENCE

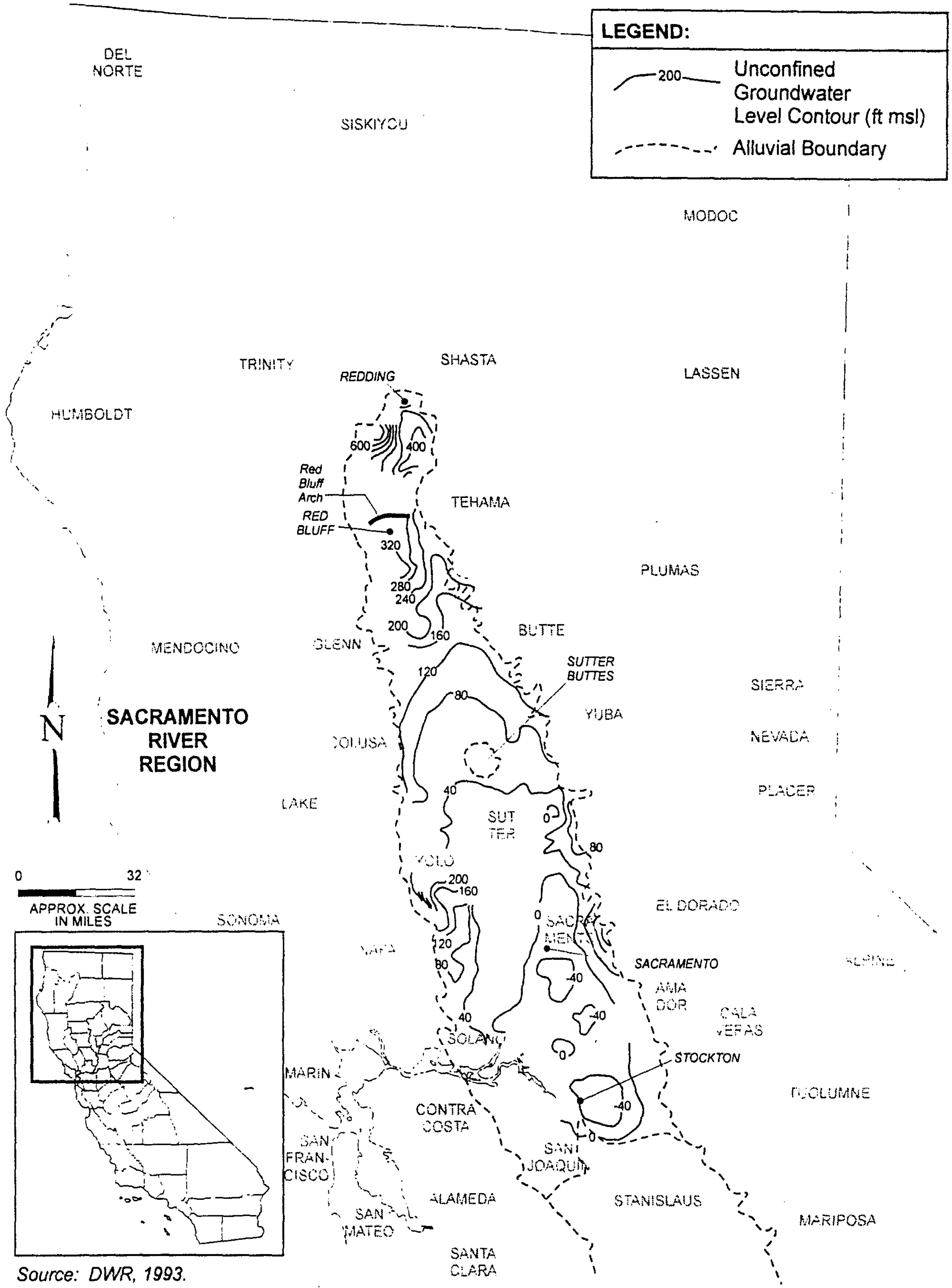
The largest occurrence of land subsidence in the world induced by human activity occurs in California's Central Valley (Bertoldi et al. 1991). The areal extent of this land subsidence is shown in Figure 3. The primary land subsidence occurring in the Central Valley corresponds to areas where groundwater levels have declined significantly due to mining of groundwater.

Areas using groundwater supply for irrigation are much less extensive in the Sacramento Valley than in the San Joaquin Valley because of greater surface water availability. In addition, greater natural recharge in this area relative to the San Joaquin Valley results in less severe groundwater level declines.

GROUNDWATER QUALITY

Groundwater quality generally is excellent throughout the Sacramento Valley and is suitable for most uses. Concentration of TDS is normally less than 300 mg/L, although water in some areas may contain TDS to 1,500 mg/l. Agricultural water quality goals are set at 450 mg/l (Ayers and Westcot 1985).

TDS concentrations are higher in the south-central part of the Sacramento River Region. This distribution reflects the low concentrations of dissolved solids in recharge water that originates in the Cascade Range and the Sierra Nevada, and the predominant regional groundwater flow pattern. Concentrations of TDS in shallow groundwater have been recorded as high as 1,500 mg/l in areas south of the Sutter Buttes in the Sutter Basin and west of the Sacramento River, extending from West Sacramento on the north to the confluence of the Sacramento and San Joaquin rivers on the south (Bertoldi et al. 1991). Many wells in Butte, Sutter, and Colusa basins have shown an increase in specific conductance over their periods of record. Conductance of Butte Basin wells has not deteriorated to the point of jeopardizing beneficial uses. Some wells in Sutter and Colusa basins are at or near levels that could present problems for irrigation of sensitive crops.



Source: DWR, 1993.

Figure 2. Groundwater Levels in the Sacramento Valley, Spring 1993

Basin/Region	Sub-Basin	Extraction[a] (AF/yr)	Management Status of Basin
Redding Basin	Anderson	29,600	Redding Area Water Committee, Tehama County FCWCD
	Bowman	1,200	Redding Area Water Committee, Tehama County FCWCD
	Enterprise	13,100	Redding Area Water Committee, Tehama County FCWCD
	Millville	7,600	Redding Area Water Committee, Tehama County FCWCD
	South Battle Creek	2,600	Redding Area Water Committee, Tehama County FCWCD
	Rosewood	1,200	Redding Area Water Committee, Tehama County FCWCD
Sacramento Valley Basin	Antelope	14,200	Tehama County FCWCD
	Bend	200	Tehama County FCWCD
	Corning	97,800	Tehama County FCWCD, Orlando Unit WUA
	Dry Creek	14,200	Tehama County FCWCD
	Los Molinas	14,400	Tehama County FCWCD
	Red Bluff	117,100	Tehama County FCWCD
	Vina	145,400	Butte Basin WUA
	Colusa	442,900	Knights Landing WUA, Orland Unit WUA, Cortina Creek FCWCD, Colusa County FCWCD, Yolo County FCWCD
	West Butte	146,000	Butte Basin WUA, Water Code Section 10750
	East Butte	239,200	Butte Basin WUA, Water Code Section 10750
	Palermo	42,500	Butte Basin WUA
	Yolo	144,800	Local planning has begun
	Solano	122,500	City of Vacaville adopted Assembly Bill 3030 plan
	North Yuba	74,800	Planning under Water Code Section 10750 has begun
	South Yuba	99,400	Planning under Water Code Section 10750 has begun
	North American	300,000	Planning under Water Code Section 10750 has begun
	South American	263,000	Planning under Water Code Section 10750 has begun
	Cosumnes	112,400	None identified

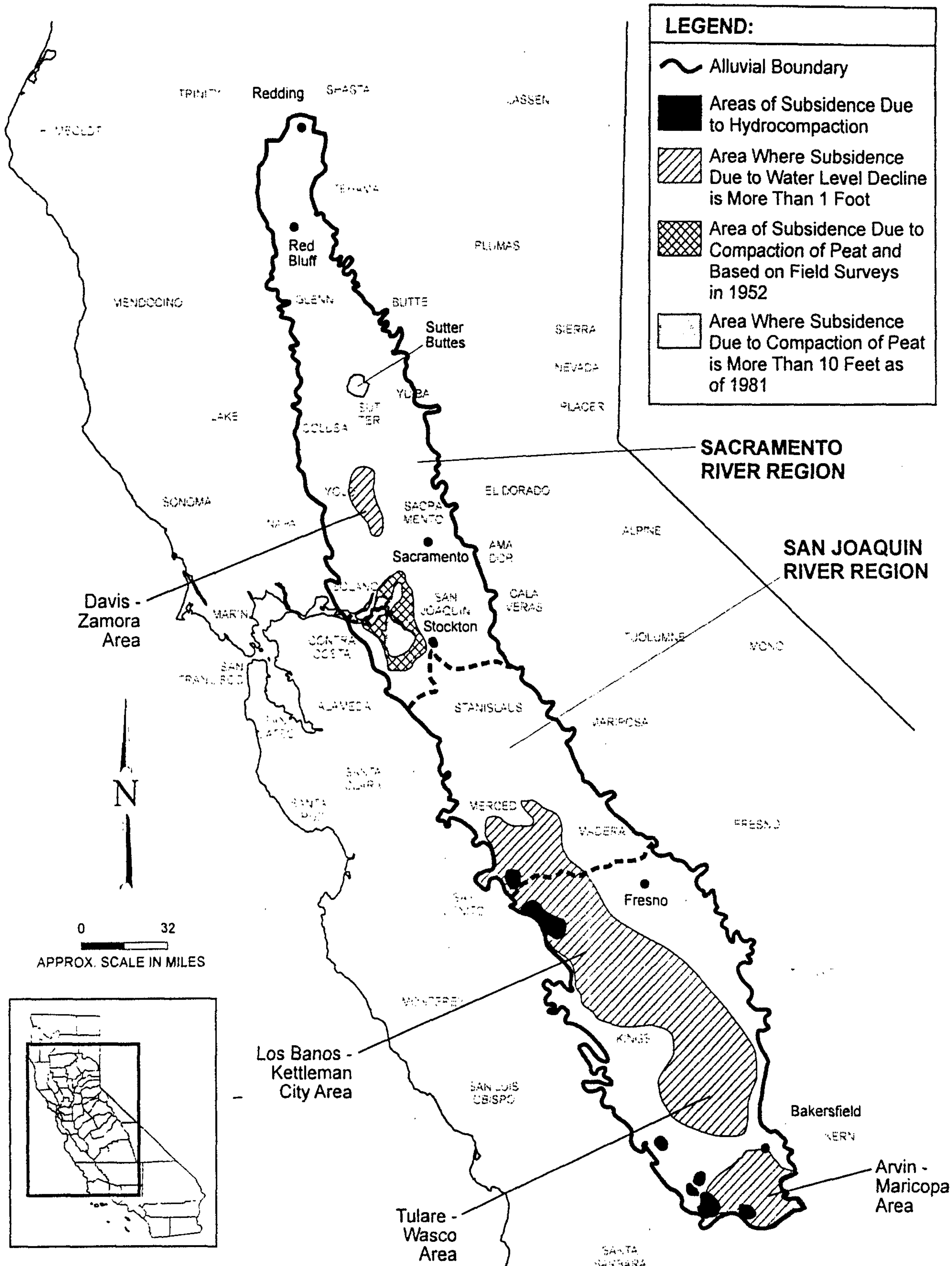
NOTES:

AF/yr = Acre-feet per year.
FCWCD = Flood Control and Water Conservation District.
WUA = Water Users' Association.

[a] 1990 normalized conditions represent water demand for 1990 level of development, adjusted to account for unusual events such as dry conditions, government interventions for agriculture, rationing programs, or other irregularities.

SOURCE:
DWR 1997.

Table 2. Sacramento River Region Groundwater Resources



Source: Adapted from Bertoldi et al., 1991.

Figure 3. Areal Extent of Land Subsidence in the Central Valley

Nitrates can enter the groundwater through the conversion of naturally occurring or introduced organic nitrogen or ammonia. In Butte and Colusa basins, nitrate concentrations have at times exceeded these drinking water standards. Water samples from scattered wells in the southern Sacramento Valley contained concentrations as high as 60 mg/l. Municipal use of groundwater as drinking water supply is impaired due to elevated nitrate concentrations in the Chico area (SWRCB 1991).

In some wells in Butte, Sutter, and Colusa basins, iron and manganese exceed secondary drinking water standards (SWRCB 1991). In the southern Sacramento Valley Basin, iron and manganese have exceeded secondary drinking water limits in some wells (SWRCB 1991).

Boron is not a regulated substance in drinking water, but it is a critical element in irrigation water. In small quantities, boron is essential for plant growth. However, concentrations as low as 0.75 mg/l may be toxic to boron-sensitive plants, and it is toxic to most crops at concentrations above 4 mg/l (Bertoldi et al. 1991). Low levels of boron (below 0.75 mg/l) have been observed in the area extending from Vacaville to West Sacramento, and south to Rio Vista. Boron concentrations greater than 0.75 mg/l have been reported in an area east of Red Bluff, and an area extending from Arbuckle on the north to Davis on the south (Bertoldi et al. 1991).

Pesticides in groundwater have received a great deal of attention in recent years. Contamination of groundwater with organic pesticides is not a widespread problem in Butte Basin, although atrazine, bentazon, 2,4-D, dichloroprop, and DDE all have been detected. In Sutter County, widespread contamination of groundwater was limited to bentazon and dibromochloropropane (DBCP). Pesticide sampling has revealed a widespread problem in Colusa Basin. Pesticides have been found in several wells throughout the basin at levels above water quality standards. Bentazon has been found throughout the Feather River Basin in Butte, Yuba, Placer, and Sutter counties and in isolated wells in the Yuba and American basins. South of Oroville, groundwater contamination has been detected at Koppers and Louisiana Pacific lumber companies. Organic pesticides are not a widespread problem in southern Sacramento Valley Basin groundwater, although contaminated groundwater is present at four locations west of the Yolo Bypass.

Groundwater is not widely used in the upper watershed area due to the availability of surface water. In general, groundwater quality in the upper watersheds of the Sierra Nevada is good; recharge is generally high and groundwater resources are relatively undeveloped. However, in some areas 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 has also caused water levels in the formerly artesian aquifer to drop below the ground surface, complicating the problem of providing winter water for cattle.

SEEPAGE AND WATERLOGGING

In many reaches of the Sacramento River, flows are confined to a broad, shallow human-made channel with stream bottom elevations higher than adjacent ground surface elevations. This condition, combined with areas where local groundwater is in contact with the river, places adjoining farm lands in danger of seepage-induced waterlogging damage during extended periods of high streamflows. This is especially true during spring and summer, when crop roots are susceptible to damage by high groundwater and farmers need to operate equipment on the fields. DWR has conducted an in-depth investigation of the seepage problem, reported in Bulletin 125 (1967). The report contains curves relating crop damage to river flow for three reaches of the Sacramento River. Alternatives for mitigating the seepage problem are presented and evaluated at a reconnaissance level. In 1976 and 1977, Reclamation updated the 1965-level cost estimates presented in Bulletin 125 and conducted a reconnaissance-level evaluation of methods to resolve the problem (Reclamation 1976 and 1977). To date none of these alternatives have been implemented.

Environmental Setting - San Joaquin River Region

The southern two-thirds of the Central Valley regional aquifer system extends from just south of the Delta to just south of Bakersfield, and is referred to as the San Joaquin Valley Basin (DWR 1975), covering over 13,500 square miles (Figure 4).

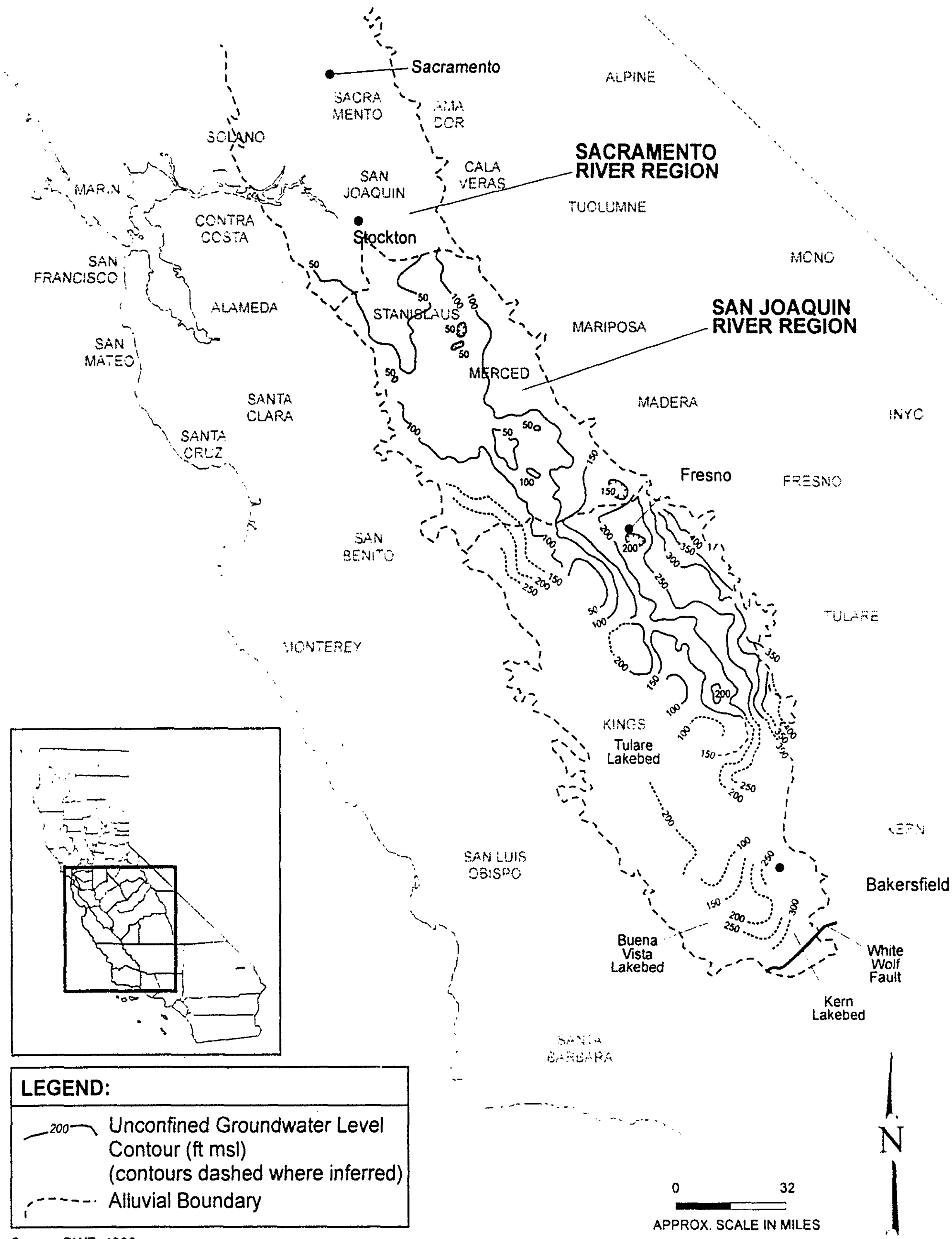
HISTORICAL PERSPECTIVE

HYDROGEOLOGY

Historically, the interaction of groundwater and surface water resulted in net gains to the streams in the northern part of the San Joaquin River Region. This condition existed on a regional basis through about the mid 1950s. Since that time, groundwater level declines have resulted in some stream reaches losing flow through seepage to the groundwater systems below. Where the hydraulic connection has been maintained, the amount of seepage has varied as groundwater levels and streamflows have fluctuated. Areas in the San Joaquin River Region where these dynamics have changed include eastern San Joaquin and Merced counties, western Madera County, and other local areas. Similar to the Sacramento River Region, the largest stream losses have occurred during the drought periods of 1976 to 1977 and 1987 to 1992. Based on the USGS investigation of stream losses and gains for the Central Valley (Williamson et al. 1989), the major east-side San Joaquin River tributaries were found to be gaining streams on average over the 1961 to 1977 period of analysis. The San Joaquin River was determined to be a losing stream above Fremont Ford and a gaining stream from Fremont Ford downstream to Vernalis. Streams along the west side of the San Joaquin River Region are generally ephemeral streams and were not reported in the USGS analysis.

Early agricultural development (pre-1900s) in the southern part of the San Joaquin River Region, together with more arid conditions than in the northern two-thirds of the Central Valley, have resulted in greater groundwater level declines, causing a change in stream-aquifer dynamics. In the period of predevelopment, the interaction was very dynamic, with water exchanged in both directions depending on variations in hydrologic conditions. With the onset and rapid growth of the agricultural sector in the region, groundwater was heavily developed, resulting in regional groundwater level declines. Subsequently, the loss of streamflows to underlying aquifers became the prevailing condition. In some areas, such in Kings and Kern counties, complete disconnection between groundwater and overlying surface water systems has occurred. Many streams and conveyance systems are characterized as "leaky" and, in addition to conveying surface water for irrigation purposes, also are used with the intention of recharging groundwater. The USGS investigation of stream losses and gains of the Central Valley (Williamson et al. 1989) found that major streams south of the San Joaquin River Basin (Kings, Kaweah, Tule, and Kern rivers) all were losing streams on average for the 1961 to 1977 period of analysis.

During pre-development conditions, 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, have modified the natural groundwater flow pattern. The groundwater pumping and recharge from imported irrigation water has resulted in a change in regional flow patterns. Flow largely occurs from areas of recharge toward areas of



Source: DWR, 1993.

Figure 4. Groundwater Levels in the San Joaquin Valley, Spring 1993

lower groundwater levels due to groundwater pumping (Bertoldi et al. 1991). The vertical movement of water in the aquifer has been altered in this region as a result of thousands of wells constructed with perforation above and below the confining unit (Corcoran Clay Member), where present, providing a direct hydraulic connection (Bertoldi et al. 1991). This may have been partially offset by a decrease in vertical flow resulting from the inelastic compaction of fine-grained materials within the aquifer system.

GROUNDWATER LEVELS

The expansion of agricultural practices between 1920 and 1950 in the San Joaquin River Region resulted in increased groundwater pumping in order to meet the additional water demand. This increased groundwater pumping caused regional groundwater level declines and related problems, such as land subsidence and saline groundwater intrusion problems for the City of Stockton.

With the introduction of imported surface water supplies, confined groundwater levels reported for spring 1970 (reported by DWR) and spring 1980 (reported by DWR) indicated an increase between these periods of more than 100 to 150 feet in some areas. And by spring 1988, confined groundwater levels (reported by DWR) indicated an additional rise of nearly 100 feet in some areas. Confined groundwater levels south of Tulare Lake bed showed little change between 1970 and 1980.

During the 10-year period from spring 1970 to spring 1980 (reported by DWR), semi-confined groundwater levels generally dropped in the southern half of the San Joaquin River Region, dropping as much as 50 feet in portions of Fresno, Kings, Kern, and Tulare counties. Declines in semi-confined groundwater levels were less severe in the northern half of the region. The 1976 to 1977 drought resulted in additional declines in both the northern and southern areas of the region; however, levels partially recovered by spring 1980 due to above-normal precipitation conditions following the drought.

The 1987 to 1992 drought resulted in substantial deficiencies in surface water deliveries and corresponding increases in groundwater pumping. Water levels declined by 20 to 30 feet throughout most of the central and eastern parts of the San Joaquin Valley (Westlands Water District 1995).

LAND SUBSIDENCE

Beginning in the 1920s, the use of groundwater for irrigation of crops began to increase rapidly until the mid-1960s in the San Joaquin Valley. As a result of this heavy pumping, groundwater level declines have caused land subsidence throughout 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 (Ireland 1986).

Because of the slow drainage of the fine-grained deposits, subsidence at a particular time is more closely related to past water-level change than to current change. For example, in the San Joaquin Valley, groundwater withdrawals increased greatly until large imports of surface water through various canals occurred, but even though water levels in the area started to rise, the rate of subsidence began to decrease 3 years later.

Land subsidence in the San Joaquin Valley has occurred mostly in areas that are confined by the Corcoran Clay, where pressure changes caused by groundwater pumping promote greater compressive stress than in the unconfined zone (DWR 1977). Figure 5 shows 1926 to 1970 land subsidence contours for the 2,600-square-mile Los Banos-Kettleman City area. This area, the largest of the three land subsidence areas in the San Joaquin River Region, extends from Merced County to Kings County but is mostly located within western Fresno County. The maximum land subsidence levels recorded in the Central Valley occurred in this area. In parts of northwestern Fresno County, land subsidence levels of as great as 30 feet have been measured (Ireland et al. 1982).

Tulare-Wasco area land subsidence contours for the period from 1926 through 1970 are also depicted in Figure 5. This 1,200-square-mile area is located between Fresno and Bakersfield, lying mostly in Tulare County. More than half of the area (the area west of Highway 99) is underlain by Corcoran Clay. There are two local areas where land subsidence has exceeded 12 feet (Ireland et al. 1982).

Figure 5 shows land subsidence contours for the Arvin-Maricopa area between 1926 and 1970. This 700-square-mile area is located 20 miles south of Bakersfield, mostly in Kern County. Two confining beds, the A clay and the C clay, underlay the area. The C clay is the more extensive of the two beds. Maximum land subsidence in the Arvin-Maricopa area exceeds 9 feet. Land subsidence in parts of the Arvin-Maricopa area also has been influenced by oil and gas withdrawal and hydrocompaction.

By the mid 1970s, the use of imported surface water in the western and southern portions of San Joaquin Valley essentially eliminated new land subsidence. During the 1976 to 1977 drought, land subsidence was again observed in areas previously affected due to renewed high groundwater pumping rates.

AGRICULTURAL SUBSURFACE DRAINAGE

Inadequate drainage and accumulating salts have been persistent problems for irrigated agriculture along the west side and in parts of the east side of the San Joaquin River Region for more than a century. The most extensive drainage problems exist on the west side of the San Joaquin River Region. A detailed time line for these west side drainage problems is presented in Table 3.

SEEPAGE AND WATERLOGGING

In the western portion of the Stanislaus River watershed, groundwater pumping historically has been used for control of high groundwater levels and seepage-induced waterlogging conditions.

SAN JOAQUIN RIVER REGION - CURRENT RESOURCE CONDITIONS

HYDROGEOLOGY

The San Joaquin River Region has accumulated up to 6 vertical miles of unconsolidated continental and marine sediment in the structural trough. The top 2,000 feet of these sediments consist of continental deposits that generally contain freshwater (Page 1986). As these sediments accumulated over the last 24 million years, large lakes periodically filled and drained, resulting in deposition of laterally extensive clay layers, forming significant barriers to the vertical movement of groundwater in the basin (Westlands Water District 1995). The most extensive of these is the Corcoran Clay (a member of the Tulare Formation, which was deposited about 600,000 years ago), consisting of a clay layer 0 to 160 feet thick, found at depths of 100 to 400 feet below the land surface in the northern part of the San Joaquin River Region. In the southern part of the region, the Corcoran Clay occurs at depths of 300 to 900 feet below the land surface. Other clay layers are present above and below the Corcoran Clay, and may have local impacts on groundwater conditions.

The Corcoran Clay divides the groundwater system into two major aquifers: a confined aquifer below the clay layer and a semi-confined aquifer above the layer (Williamson et al. 1989). Semi-confined conditions are defined by the USGS as:

> "... movement of groundwater is restricted sufficiently to cause differences in head between different depth zones of the aquifer during periods of heavy pumping; but during periods of little draft the water levels recover to a level coincident with the water table."

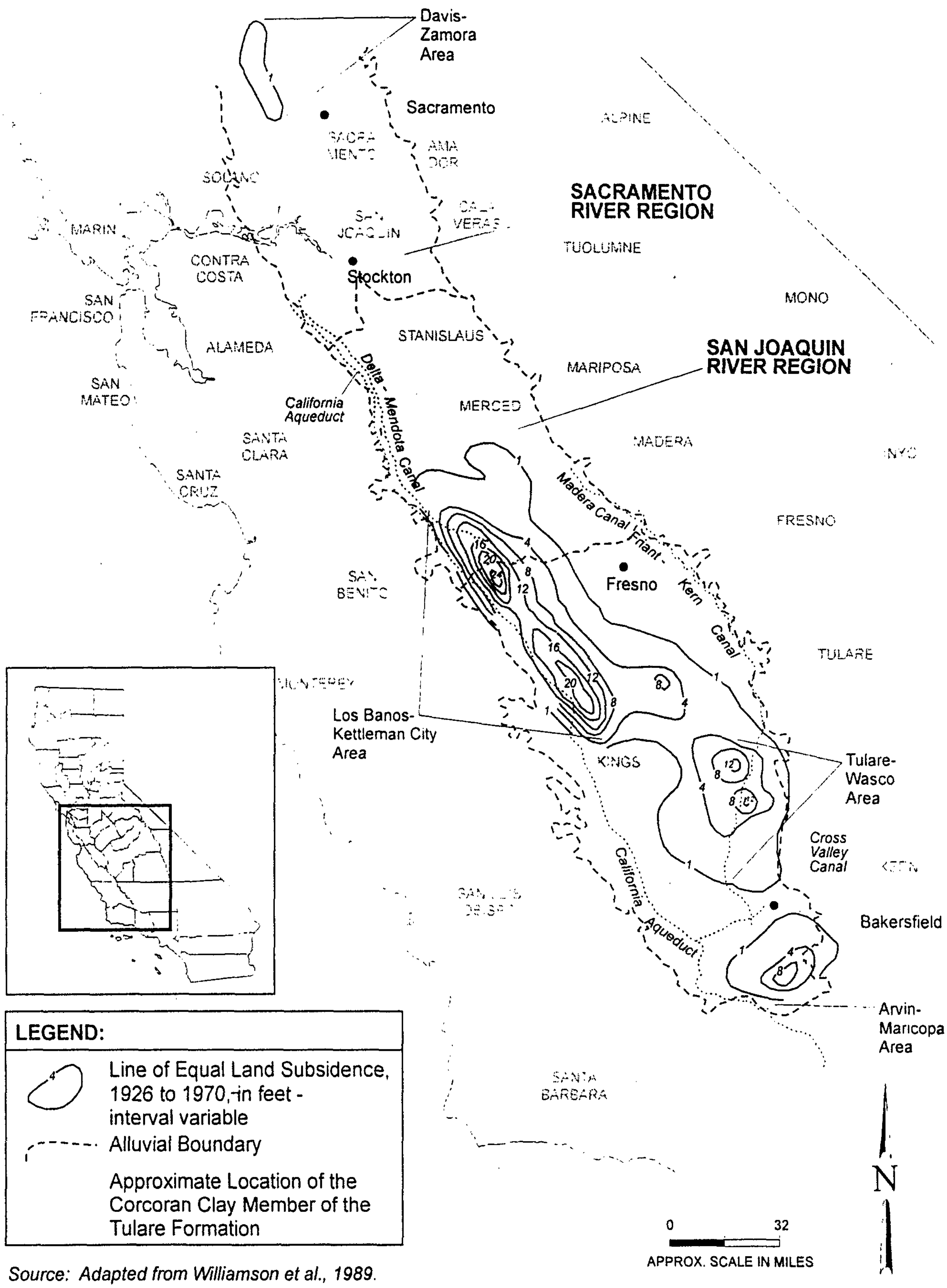


Figure 5. Areal Extent of Land Subsidence in the San Joaquin Valley Due to Groundwater Level Decline

Year	Event
1870s	Widespread planting for grain on the western side of the San Joaquin Valley. Crops were irrigated with water from the San Joaquin and King rivers. Poor natural drainage, rising groundwater, and increasing soil salinity resulted in the removal or abandonment of farm land in production.
1900-1950	Heavy pumping of groundwater resulted in overdrafts and widespread land subsidence.
1951	Central Valley Project (CVP) water transported through the Delta-Mendota Canal to irrigate 600,000 acres of land in the northern San Joaquin Valley. This water primarily replaced and supplemented San Joaquin Valley.
1960	State Water Project (SWP) authorized. San Luis Unit of the CVP authorized which mandated construction of an interceptor drain to collect irrigation drainage water and transport it to the Delta. Reclamation's feasibility report for the San Luis Unit described the drain as an earthen ditch that would drain 96,000 acres.
1962	Reclamation changed plans for the drain to a concrete-lined canal to drain 300,000 acres.
1964	Reclamation added a regulating reservoir to the drain plans to temporarily retain drainage.
1965	Concerns were raised about the potential effects of the discharge of untreated agricultural drainage water into the Delta and San Francisco Bay. A rider was added to CVP appropriation act by Congress in 1965 that required the final point of discharge of the interceptor drain for the San Luis Unit to conform with water quality standards set by California and the U.S. Environmental Protection Agency.
1968	CVP's San Luis Unit and the SWP began delivering water to approximately 1,000,000 acres of agricultural lands in southern San Joaquin Valley.
	Construction of San Luis Drain began.
	Kesterson Reservoir became part of a new national wildlife refuge managed jointly by the U.S. Bureau of Reclamation (Reclamation) and the U.S. Fish and Wildlife Service.
mid 1970	Reclamation decided to use the drainage reservoir to store and evaporate drainage water until the drainage canal to the Delta was completed.
1975	85 miles of the main drain, 120 miles of collector drains, and the first phase of Kesterson Reservoir were completed.
	Budget and environmental concerns halt work on the reservoir and drain.
	Reclamation, DWR, and the State Water Resources Control Board (SWRCB) formed the San Joaquin Valley Interagency Drain Program (SJVDP) to find a solution to valley drainage problems. This group's recommendation was to complete the drain to a discharge point in the Delta near Chipps Island.
1981	Reclamation began a special study to fulfill requirements for a discharge permit from the SWRCB.
1983	Selenium poisoning identified as the probable cause of deformities and mortalities of migratory water fowl at Kesterson Reservoir.
1984	The SJVDP was established as a joint federal and state effort to investigate drainage and related problems, and to identify possible solutions.
1985	The Secretary of the Interior halted the discharge of subsurface drainage water to Kesterson.
1986	The feeder drains to the San Luis Drain and reservoir were plugged.
1988	Kesterson Reservoir was closed. The vegetation was plowed under, and low-lying areas were filled.
	Contamination-related problems similar to Kesterson were appearing in parts of the Tulare Lake Region. Wildlife deformities and mortalities had been observed at several agricultural drainage evaporation ponds.
1990	SJVDP submits final report.

SOURCE:
SJVDP 1990.

Table 3. Events Affecting Drainage Conditions on the West Side of the San Joaquin Valley

The semi-confined aquifer can be divided into four geohydrologic units based on the source of the sediment: Coast Range alluvium, Sierra Nevada sediments, flood basin deposit, and the Tulare Lake sediments in the axis of the valley. The Tulare Lake sediments has similar characteristics to the flood basin deposits. The Coast Range alluvial deposits are derived largely from the erosion of marine rocks from the Coast Range. These deposits are thickest along the western edge of the valley and taper off to the east as they approach the center of the valley floor. These sediments contain a large proportion of silt and clay, are high in salts, and contain elevated concentrations of selenium and other trace elements. The Sierra Nevada sediments on the eastern side of the region are derived primarily from granitic rock. These deposits make up most of the total thickness of sediments along the valley axis and gradually thin to the west until pinching out near the western boundary. These sediments are relatively permeable with hydraulic conductivities three times that of the Coast Range deposits (Belitz et al. 1993). The flood basin deposits are relatively thin and, in geologic terms, have been created in recent time. These deposits occur along the center of the valley floor and are generally only 5 to 35 feet thick (Westlands Water District 1995).

Recharge to the semi-confined upper aquifer generally occurs from stream and canal seepage, deep percolation of rainfall, and subsurface inflow along basin boundaries. As agricultural practices expanded in the region, recharge was augmented with deep percolation of applied agricultural water and seepage from the distribution systems used to convey this water. Recharge of the lower confined aquifer consists of subsurface inflow from the valley floor and foothill areas to the east of the eastern boundary of the Corcoran Clay Member. Present information indicates that the clay layers, including the Corcoran Clay, are not continuous in some areas, and some seepage from the semi-confined aquifer above does occur through the confining layer.

GROUNDWATER HYDROLOGY

In DWR's Bulletin 160-93, usable storage capacity for the San Joaquin River Region was estimated to be approximately 24 MAF in the northern half and 28 MAF in the southern half (DWR 1994). As in the Sacramento River Region, there have been numerous attempts to estimate the safe yield of the San Joaquin River Region. The most recent estimate, made by DWR, is approximately 3.3 MAF of perennial yield in the northern part and 4.6 MAF of perennial yield in the southern part of the region (DWR 1994). These estimates of perennial yield directly depend on the amount of recharge received by the groundwater basins, which may be different in the future than it has been in the past.

Groundwater extractions for sub-basins defined by DWR for the San Joaquin River Region are summarized in Table 4. The DWR estimated recent groundwater extractions for 1990 normalized conditions in the northern half of the San Joaquin River Region to be 3.2 MAF. The DWR estimated 1990 groundwater extractions for 1990 normalized conditions in the southern half of the San Joaquin River Region to be 5.6 MAF.

GROUNDWATER LEVELS

Along the west side of the region, groundwater level declines in the lower confined aquifer of more than 400 feet have been observed (Williamson et al. 1989).

Recent groundwater conditions, observed following the drought, for spring 1993 are shown in Figure 4. Depression areas resulting from groundwater withdrawals are indicated along the east side of the San Joaquin River Region in Merced and Madera counties, and are less than 50 feet above sea level. For areas where groundwater level contours are presented, depression areas resulting from groundwater withdrawals are indicated in the mid-valley area near the center of Fresno County and near the City of Fresno, along the county border between Tulare and Kings counties, in southwestern Kings County, and in parts of Kern County. A

Basin/Region	Sub-Basin	Extraction[a] (AF/yr)	Management Status of Basin
San Joaquin River Basin	East San Joaquin	410,000	Management by local water districts
	Tracy	178,400	None identified
	Modesto	229,000	Development of AB 3030 plans
	Turlock	452,000	Adoption of A Bill 3030 plans
	Merced	555,000	None identified
	Chowchilla	255,000	Discussions of AB 3030 underway
	Madera	565,000	Discussions of AB 3030 underway
	Delta-Mendota	511,000	AB 3030 pending, joint plan between local districts to be developed
Tulare Lake Basin	Kings	1,790,000	Adoption of AB 3030 plans
	Tulare Lake	672,000	Management by local water districts
	Kaweah	758,000	Implemented AB 255 and AB 3030 plans
	Westside	213,000	Groundwater management plans scheduled for adoption
	Pleasant Valley	104,000	None identified
	Tule	660,000	Management by local water districts
	Kern	1,400,000	Implemented AB 255 and AB 3030 plans

NOTES:

AB = Assembly Bill. In 1991, AB255 authorized local agencies in 'critically overdrafted' basins to undertake groundwater management.
AF/yr = Acre-feet per year.

[a] 1990 normalized conditions represent water demand for 1990 level of development, adjusted to account for unusual events such as dry conditions, government interventions for agriculture, rationing programs, or other irregularities.

SOURCE:
DWR 1997.

Table 4. San Joaquin River Region Groundwater Resources

groundwater level high occurs in northern Kings County. These groundwater levels are indicative of depleted conditions due to regional groundwater withdrawals resulting from the 1987 to 1992 drought period. This is consistent with observed storage recovery time, which may span several years. For example, recovery to pre-drought storage conditions took more than 5 years following the 1976 to 1977 drought.

LAND SUBSIDENCE

After nearly two decades of little or no land subsidence, significant land subsidence recently has been detected in the San Joaquin Valley due to increased groundwater pumping during the 1987 to 1992 drought. Land subsidence occurring between 1984 and 1996 was reported along the Delta-Mendota Canal. Two locations of note are: (1) near Mendota Pool, where 1.3 feet of land subsidence was measured; and (2) approximately 25 miles northeast of Mendota Pool, where 2 feet of land subsidence was measured (Central California Irrigation District 1996). Measured land subsidence by DWR between 1990 and 1995 of up to 2 feet was reported along the California Aqueduct in

Westlands Irrigation District (Dudley pers. comm.).

GROUNDWATER QUALITY

Groundwater in the San Joaquin River Region varies widely in type and concentration of chemical constituents. The differences are related to the quality of water that replenishes the groundwater reservoirs and the chemical changes that occur as the water percolates through the soil, including cation exchange, sulfate reduction, mineral matter solution, and precipitation of less soluble compounds (Davis et al. 1959).

TDS concentrations in groundwater along the east side of the San Joaquin Valley are lower in comparison to concentrations in the west side of the San Joaquin River Region. This distribution reflects the low concentrations of dissolved solids in recharge water that originates in the Sierra Nevada, and the predominant regional groundwater flow pattern. In the center and on the east side, TDS concentrations generally do not exceed 500 mg/l. On the west side, TDS concentrations generally are greater than 500 mg/l, and in excess of 2,000 mg/l along portions of the western margin of the valley (Bertoldi et al. 1991). The concentrations in excess of 2,000 mg/l commonly occur above the Corcoran Clay layer. Impaired municipal use of groundwater as drinking water supply due to elevated TDS concentrations occurs at several locations throughout the San Joaquin River Region (SWRCB 1991). Agricultural groundwater use is impaired due to high TDS concentrations above the Corcoran Clay in the western portion of Fresno and Kings counties (SWRCB 1991).

Municipal use of groundwater as a drinking water supply is impaired due to elevated nitrate concentrations in the northern San Joaquin County, Tracy, Modesto-Turlock, Merced, and Madera areas (SWRCB 1991). Several small areas of the Tulare Lake Basin contain elevated nitrate concentrations in groundwater, including areas south and north of Bakersfield, around the Fresno metropolitan area, and scattered areas of the Sierra Nevada foothills in the Hanford-Visalia area (SWRCB 1991).

High boron concentrations occur in the northwestern part of the San Joaquin River Region from the northernmost edge of the region to the southernmost edge of the region (Bertoldi et al. 1991). Agricultural use of groundwater is impaired due to elevated boron concentrations in eastern Stanislaus and Merced counties (SWRCB 1991). In the southern portion of the Tulare Lake Basin, high concentrations of boron are generally found in areas southwest to Bakersfield (greater than 3 mg/l) and southeast of Bakersfield (1 to 4 mg/l) (Bertoldi et al. 1991). Concentrations as high as 4.2 mg/l have been measured near Buttonwillow Ridge and Buena Vista Slough. Agricultural use of groundwater is impaired due to elevated boron concentrations in western Fresno and Kings counties (SWRCB 1991).

Municipal use of groundwater as a drinking water supply is impaired due to elevated arsenic concentrations in eastern Contra Costa, Stanislaus, and Merced counties; western San Joaquin County; and the southwest corner of the Tulare Lake Basin (SWRCB 1991). 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 (SWRCB 1991).

Selenium is a naturally occurring trace element in the Central Valley that is toxic to humans and animals at very low concentrations. The toxicity to fish and wildlife occurs through bioaccumulation. Selenium was found to be responsible for mutations of migratory birds in the Kesterson National Wildlife Refuge. High selenium concentrations in soils of the west side of the San Joaquin River Region have raised considerable concern because of their potential to leach from the soil by subsurface irrigation return flow into the groundwater and into receiving surface waters (Bertoldi et al. 1991). Selenium occurs naturally in soils and groundwater on the west side of the San Joaquin River Region. Selenium concentrations in shallow groundwater along the west side of the region have been highest in the central and southern area south of Los Banos and Mendota

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(median concentrations of 10,000 to 11,000 μg/l) (Bertoldi et al. 1991).

Municipal use of groundwater as a drinking water supply is impaired due to elevated selenium concentrations reported from the northwest and southeast alluvial areas near Bakersfield (SWRCB 1991). Use of groundwater to support aquatic species is impaired due to elevated selenium concentrations in the Tulare Lake Basin near Kettleman City and in western portions of Fresno and Kings counties (SWRCB 1991).

A significant limitation on groundwater use in the Tulare Basin has been the presence of toxins such as DBCP and ethylene dibromide (EDB) exceeding drinking water standards. DBCP levels resulting from historical agricultural use exceed the maximum standard in large areas of eastern Fresno County and Tulare County, and limit groundwater use in Fresno and other urban areas. EDB contamination, also resulting from historical agricultural use, limits groundwater use in many areas of Kern County. In addition to DBCP and EDB, several other toxic compounds limit the use of water for municipal purposes in parts of the Tulare Basin.

AGRICULTURAL SUBSURFACE DRAINAGE

The soils on the west side of the region are derived from marine sediments and are high in salts and trace elements. Irrigation of these soils has mobilized these compounds and facilitated their movement into the shallow groundwater. Much of this irrigation has been with imported water, resulting in rising groundwater and increasing soil salinity. Where agricultural drains have been installed to control rising water tables, drainage water frequently contains high concentrations of salts and trace elements (SJVDP 1990). The area of subsurface drainage problems extends along the western side of the San Joaquin River Region from the Delta on the north to the Tehachapi Mountains south of Bakersfield. In some portions of the San Joaquin River Region, natural drainage conditions are inadequate to remove the quantities of deep percolation that accrue to the water table. Therefore, groundwater levels often encroach on the root zone of agricultural crops, and subsurface drainage must be supplemented by constructed facilities for irrigation to be sustained.

Toxic and potentially toxic trace elements in some soil and shallow groundwater on the western side of the San Joaquin River Region are also of concern. These trace elements greatly complicate the disposal of subsurface drainage waters. Elements of primary concern are selenium, boron, molybdenum, and arsenic. Selenium is of greatest concern due to the wide distribution and known toxicity of selenium to aquatic animals and water fowl.

SEEPAGE AND WATERLOGGING

In the lower reaches of the San Joaquin River and in the vicinity of its confluence with major tributaries, high periodic streamflows and local flooding combined with high groundwater levels have resulted in seepage-induced waterlogging damage to low-lying farmland. 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 have recently contributed to seepage-induced waterlogging damage to low-lying farm land, a result of streamflow seepage into adjacent shallow groundwater aquifers. The seepage-induced waterlogging places neighboring crops and farm land at risk. It prevents cultivation of the land until the summer months, placing the annual crop production at risk. Concern has been raised that San Joaquin River flows in excess of 16,000 cubic feet per second (cfs) at Vernalis can result in seepage-induced waterlogging damage of adjacent low-lying farm land in the south Sacramento-San Joaquin Delta area (Hildebrand pers. comm.).

SWP and CVP Service Areas Outside the Central Valley

HISTORICAL PERSPECTIVE

Historical groundwater extractions in excess of groundwater recharge in the Salinas Basin area has resulted in groundwater level declines and seawater intrusion.

However, a long history of largely uncontrolled groundwater use in this area resulted in a serious over-exploitation of many basins, with resultant seawater intrusion and declining water levels. Historically, seawater has intruded into most coastal basins in this area.

CURRENT RESOURCE CONDITIONS

CENTRAL COAST SERVICE AREA

The Central Coast Service Area consists only of San Luis Obispo and Santa Barbara counties. Groundwater of the area is often discussed in the context of the Central Coastal Hydrologic Study Area (DWR 1994), which also includes Santa Cruz and Monterey counties and portions of Santa Clara and San Benito counties. Groundwater is the main source (90%) of water supply in the Central Coastal Hydrologic Study Area. Overuse of groundwater resources in some locations has led to groundwater level declines and water quality problems from seawater intrusion.

Groundwater sub-basins for the Central Coast have been defined by DWR and are summarized in Table 5. Recent estimates of groundwater extractions are also shown in Table 5 for 1990 normalized conditions. Under these conditions, total annual 1990 groundwater extractions for the Central Coast area are estimated to be 1.1 MAF.

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. The rate of seawater intrusion has increased rapidly because of increased agricultural production, urban development, and the effects of the recent drought.

Basins in the southern Central Coast are small but important to their local communities. These shallow basins underlie seasonal coastal streams. During years with normal or above-normal rainfall, aquifers in the basins are continuously replenished by creek flows. In years of below-normal precipitation, the creek flows are intermittent, flow is insufficient for both agriculture and municipal uses, wells become dry, and seawater intrudes into some coastal groundwater basins (DWR 1994).

Groundwater quality in the Central Coast Service Area generally is quite good. TDS content of the water is generally less than 800 mg/l, but locally it can be more than 11,000 mg/l.

SOUTHERN CALIFORNIA SERVICE AREA

The Southern California Service Area can be divided into three hydrologic areas: South Coast, South Lahontan, and Colorado Desert. In the inland desert areas, groundwater is the principal source of supply. Groundwater commonly occurs in alluvial basins that vary greatly in size and storage capacity. Typically, the basins contain a complex interfingering of coarse-grained aquifer and fine-grained material that limits water movement between aquifers. Many basins contain fine-grained material at or near the surface, which limits the area through which groundwater recharge can be accomplished. The relatively low recharge rates in comparison to storage capacity in many basins have resulted in a tendency toward over-exploitation. Recent estimates of groundwater extractions are shown in Table 5 for groundwater sub-basins associated with the three hydrologic study areas (sub-basin boundary map to be provided in final draft).

Basin/Region	Sub-Basin	Extraction[a] (AF/yr)	Management Status of Basin
Central Coast Region	Soquel-Aptos	9,000	Monitoring program
	Pajaro Valley	64,000	Managed by Pajaro Valley Water Management Agency; Basin Management Plan completed
	Salinas Valley	550,000	Managed by Monterey County Water Resources Agency; Basin Management Plan being developed
	South Santa Clara-Hollister	75,000	Monitoring program
	Carmel Valley-Seaside	14,000	None identified
	Arroyo Grande Nipomo Mesa	14,000	None identified
	Santa Maria Valley	129,000	Management plan being developed
	Cuyama Valley	28,000	None identified
	San Antonio	16,400	None identified
	Santa Ynez Valley	67,000	Management plan being developed
	South Central Coast	31,400	None identified
	Carrizo Plan	510	None identified
	Upper Salinas	64,000	None identified
	San Luis Obispo	13,000	None identified
South Coast Region			
	Orange County	208,000	Managed by Orange County Water District
	Chino	145,000	Adjudicated
	San Bernardino Basin Area	232,090	Adjudicated
	Riverside Basin Area in San Bernardino County	20,390	Part of San Bernardino adjudication
	Riverside Basin Area in Riverside County	28,550	Part of San Bernardino adjudication
	Colton Basin	9,150	Part of San Bernardino adjudication
	Central Basin	180,000	Adjudicated
	West Coast Basin	60,000	Adjudicated
	San Fernando Valley	96,000	Adjudicated
	Raymond Basin	30,000	Adjudicated
	San Gabriel	148,000	Adjudicated
	Upper Ojai Valley	6,000	Managed by Ojai Groundwater Management Agency; considering formal groundwater plan
	Fox Canyon Groundwater Management Area	143,000	Managed by Fox Canyon Groundwater Management Agency; ordinance prohibits export of groundwater; ordinance reduces seawater intrusion
	Temecula Valley	25,000	Adjudicated
	San Juan Valley	5,000	None identified (limited groundwater use)

Table 5. Groundwater Resources of SWP and CVP Service Areas Outside the Central Valley

Basin/Region	Sub-Basin	Extraction[a] (AF/yr)	Management Status of Basin
South Coast Region (Cont'd)	El Cajon Valley	500	None identified (limited groundwater use)
	Warner Valley	Unknown	None identified
	San Luis Rey	Unknown	None identified
	Sweetwater Valley	2,500	None identified
	Otay Valley	1,000	None identified
South Lahontan Region	Owens Valley	103,000	Cooperative agreement between Los Angeles Department of Water and Power and Inyo County
	Death Valley	12,000	None identified
	Mojave River Valley	129,000	Adjudicated
	Antelope Valley	26,000	Management is voluntary with incentives
Colorado Desert Region	Warren Valley	2,740	Adjudicated
	Coachella Valley	85,000	Management by local water districts
	Chuckwalla	27,000	None identified

NOTES:

AF/yr = Acre-feet per year.

[a] 1990 normalized conditions represent water demand for 1990 level of development, adjusted to account for unusual events such as dry conditions, government interventions for agriculture, rationing programs, or other irregularities.

SOURCES:
DWR 1994, 1996a, and 1996b.

Table 5. Groundwater Resources of SWP and CVP Service Areas Outside the Central Valley (Continued)

Potential adverse impacts of continued overdraft (land subsidence, increased pumping cost, water quality degradation) have resulted in adjudication of the Mojave groundwater basin and sporadic efforts to either adjudicate or develop groundwater management plans for the Antelope Valley Basin. These efforts could restrict the use of groundwater and give impetus to developing more active conjunctive use programs. Such programs would rely on imported water supplies to a considerable extent.

In the heavily urbanized Coastal Plain area extending into Ventura County and eastward into San Bernardino and Riverside counties, reliance on groundwater is less because more surface water is available. As a result of litigation springing from these problems, most of the major groundwater basins have been adjudicated or have had active groundwater management programs developed. In the adjudicated basins, the rights to pump groundwater have been quantified and assigned. The nature of the adjudication process makes it somewhat difficult to modify basin operations significantly to alleviate short-term water shortages, particularly under drought concerns. Managed basins often have similar restrictions but tend to be more flexible in their ability to respond to changing conditions.

In San Diego County, the groundwater basins tend to be much smaller. Although they constitute an important part of the water supply system, these basins have little potential for more use in the short term.

Although much of the groundwater in Southern California is suitable for municipal and

Although much of the groundwater in Southern California is suitable for municipal and agricultural supplies, substantial degradation in some areas, such as San Diego County, limits groundwater use. Loss of production capability, while of concern, has been relatively small. Given the heavily urban character of the area and the former widespread citrus orchards, elevated levels of nitrate and TDS, as well as contamination by synthetic organics, are a fairly common problem in some basins. In particular, the San Fernando and San Gabriel basins have widespread synthetic organics contamination, which constrains basin operations in order to limit the spread of contamination. Similar but less severe limitations on operations exist in many other basins.

Seawater intrusion can be a significant water quality problem in coastal groundwater basins. Injection wells are used to create intrusion barriers along the coast in Orange and Los Angeles counties. The barriers use imported surface water and reclaimed wastewater for injection and increase the extent to which inland groundwater levels can be drawn down. However, the barriers are not entirely effective (or even present in some basins), thus limiting the availability of groundwater for use during extended dry periods.

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CALFED

TECHNICAL REPORT
AFFECTED ENVIRONMENT

SUPPLEMENT TO GROUNDWATER

DRAFT

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SUPPLEMENT TO GROUNDWATER

The following information supplements the environmental setting for the Affected Environment Technical Report for Groundwater.

Regulatory Context

GROUNDWATER MANAGEMENT

California does not have a statewide program for the management of groundwater. Groundwater management is a local responsibility that is accomplished under the authority of the California Water Code and a number of court decisions. The following are the six possible methods for groundwater management under present law. Groundwater management can be achieved by a combination of one or more of these methods.

- Overlying property rights
- Local agencies
- Adjudicated basins
- Groundwater management agencies
- Assembly Bill 3030
- City and county ordinances

Overlying Property Rights. Overlying property rights allow anyone in California to build a well and extract their correlative share of groundwater. All property owners above a common aquifer possess a right to use a groundwater resource on their land. This mutual right is the only limit set on groundwater use, if the basin is not adjudicated. The availability and use of groundwater has increased local prosperity in various areas. In some cases, it has provided enough money to construct a water project that can convey surface water into the local area. Even though the management of groundwater may not have been closely coordinated under the overlying property right, it has been considered a form of management.

Local Management Agencies. Twenty-two kinds of districts or local agencies are identified in the California Water Code with specific statutory provisions to manage surface water. Some of these agencies also have statutory authority to impose some form of groundwater management, which several have done. Various local agencies have implemented conjunctive use programs as a form of groundwater management. This form of management involves the operation of a groundwater basin in coordination with a surface water system.

Adjudicated Basins. In basins where a suit is brought to adjudicate the basin (for example, *Alhambra vs. Pasadena*) the groundwater rights of all the overliers and appropriators are determined by the court. This type of management guarantees each party to the decision a proportionate share of the groundwater that is available. The court decides: (1) who the extractors are, (2) how much groundwater those well owners can extract, and (3) where the boundaries of the basin are. The court also appoints a Watermaster to ensure that the basin is managed in accordance with the court judgement. The Watermaster must report periodically to the court.

In 14 of the 16 adjudicated groundwater basins in California, the court judgement limits the amount of groundwater that can be extracted by all parties to the judgement.

Groundwater Management Agencies. In some parts of California, special legislation has been enacted to form groundwater management districts, or water management agencies. This legislation allows such districts to enact ordinances to manage groundwater use within their boundaries. There are twelve of these water management agencies in California which can pass ordinances to regulate the amount of groundwater extraction and limit its place of use within the district. Only a few have been effective in groundwater management, however.

Assembly Bill (AB) 3030. Section 10750 et seq. of the California Water Code (AB 3030) provides a systematic procedure for an existing local agency to develop a groundwater management plan. This section of the code provides such an agency with the powers of a water replenishment district to raise revenue. This revenue is used to pay for extraction, recharge, conveyance, quality, and other facilities to manage the basin. Thirty agencies have adopted groundwater management plans in accordance with AB 3030. Ninety-eight more agencies have begun the process.

City and County Ordinances. In 1995, the California Supreme Court declined to review a lower court decision (*Baldwin vs. Tehama County*) that holds that state law does not occupy the field of groundwater management. Therefore, state law does not prevent cities and counties from adopting ordinances to manage groundwater. Tehama County retains its ordinance and Imperial, San Benito, San Diego, and San Joaquin counties have adopted ordinances. The nature and extent of the police power of cities and counties to regulate groundwater is presently uncertain.

GROUNDWATER PROTECTION

California has statewide and local groundwater protection mechanisms that are based primarily on the implementation of data collection and monitoring programs, adopted policy, and regulatory activities that are overseen by various agencies. Various agencies also provide information and guidance to the public in regard to issues that could be threatening to groundwater resources in California.

Department of Pesticide Regulation. DPR is the agency responsible for regulating the sale and use of pesticides and safety of the pesticide work place. DPR has primary responsibility of evaluating and mitigating environmental and human impacts of pesticide use and for promoting the development and use of alternative pest control agencies.

State Water Resources Control Board. The State Water Resources Control Board (SWRCB) and the nine Regional Water Quality Control Boards (RWQCBs) have the primary responsibility to preserve and enhance the quality of California's water resources, and assure their proper allocation and efficient use. In carrying out this responsibility, the SWRCB formulates and adopts plans and policies for water quality control statewide. However, the SWRCB has not adopted a statewide groundwater plan. The RWQCBs formulate, adopt, and implement water quality control plans for all waters within their jurisdiction.

Department of Toxic Substances Control. The Department of Toxic Substances Control (DTSC) regulates the management of hazardous waste and promotes the reduction of such waste. DTSC has no requirements specific to the protection of groundwater resources from the legal use of pesticides on the farm site.

Office of Environmental Health Hazard Assessment. The Office of Environmental Health Hazard Assessment (OEHHA) identifies environmental health hazards, develops risk assessment guidelines, and provides scientific and technical expertise and public health oversight in assessing the human health risks posed by hazardous substances in the environment.

Department of Health Services. The Department of Health Services (DHS) has been vested with the jurisdiction of regulating all public water systems in California. It establishes the maximum contaminant level (MCL) for contaminants in drinking water, including pesticides.

Department of Water Resources. The DWR is the agency responsible for management of state water supplies, including groundwater. DWR assigns state well numbers and maintains well records, including drilling logs. In addition, DWR conducts an extensive program of groundwater level measurement, along with collection of groundwater quality data. Information from these activities is furnished to other agencies throughout the state.

ONGOING GROUNDWATER MANAGEMENT ACTIVITIES

Management of groundwater in California generally involves the conjunctive use of both groundwater and surface water resources, wherein, in accordance with locally prevailing physical and economic conditions, water supplies from the two sources are integrated to accomplish the optimum utilization of each. Individual management concepts differ, depending on the physical area, the water sources and their relative costs, available infrastructure for distributing the water, and the public and private management entities involved.

Table S-1 lists several examples of ongoing programs in the Bay, Sacramento River, and San Joaquin River regions, and the SWP and CVP Service Areas Outside the Central Valley. The intent of this list is to demonstrate the range of activities and to emphasize the tremendous efforts already under way for the conjunctive management of groundwater and surface water.

Table S-1 also lists several groundwater management opportunities being considered. These potential programs share a common goal of improving the ability to provide surface water and groundwater for increasing demands, and include the ultimate objective of long-term preservation of both resources. Once again, it was not possible to list all the vast number of potential programs. However, it is important to recognize that this list suggests there are a range of programs being considered for the conjunctive management of groundwater and surface water.

DEFINITIONS OF COMMON TERMS USED IN GROUNDWATER MANAGEMENT

Conjunctive Use. The operation of a groundwater basin in combination with a surface water storage and conveyance system to maximize water supply. The three common forms of conjunctive use are as follows:

> ***Incidental Conjunctive Use.*** Incidental conjunctive use occurs when an area relies on surface water when it is available, and on groundwater when surface water is not available. This is the basic level of conjunctive use. Management techniques may be used to define the timing and location of surface water deliveries and groundwater pumping to maximize water supply reliability.

C-008380

Areas with Groundwater Management Activities[a]	General Description
Bay Region	
Alameda County Water District	Aquifer reclamation to mitigate seawater intrusion
Santa Clara Valley Water District	Groundwater replenishment; mitigate seawater intrusion/land subsidence; extensive recharge basins
Sacramento River Region	
Yolo County Flood Control/Water Conservation District	Conjunctive use of groundwater and local surface water
South Sutter Water District	Conjunctive use of groundwater and local surface water
San Joaquin River Region	
Westlands Water District	Management of imported supplies to minimize groundwater use and land subsidence
Consolidated Irrigation District	Conjunctive use of groundwater and imported/local surface water; extensive recharge basins
Fresno Irrigation District, et al.	Conjunctive use of groundwater and imported/local surface water; extensive recharge basins
Semitropic Water Storage District	Conjunctive use of groundwater and imported/local surface water; water banking
Kern County	Conjunctive use of groundwater and imported/local surface water; water banking
SWP and CVP Service Areas Outside the Central Valley	
Orange County Water District	Groundwater replenishment; mitigate seawater intrusion; recharge of imported/local/reclaimed supplies
Fox Canyon Groundwater Management Agency	Conjunctive use of groundwater and surface water; recharge basins
Metropolitan Water District of Southern California	Conjunctive use of groundwater and imported water
Groundwater Management Efforts under Study	**General Description**
Bay Region	
East Bay Municipal Utility District	Conjunctive use for supply augmentation and mitigation of saline intrusion
Sacramento River Region	
American Basin	Conjunctive use of groundwater and local surface water
Lower Colusa Basin	Conjunctive use of groundwater and local surface water
Los Rios Farms	Conjunctive use of groundwater and local surface water
Provident Irrigation District	Conjunctive use of groundwater and local surface water
Chico M&T Ranch	Conjunctive use of groundwater and local surface water
Western Canal Water District/Eastside Water District	Conjunctive use of groundwater and local surface water
CALFED Potential Sites[b]	Conjunctive use of groundwater and imported/local surface water; water banking
Urban-Ag[c]	Conjunctive use of groundwater and imported/local surface water; water banking

Table S-1. Examples of Current and Potential Regional Groundwater Management

Groundwater Management Efforts under Study	General Description
San Joaquin River Region	
Turlock Irrigation District/Eastside Water District	Conjunctive use of groundwater and local surface water
Madera Ranch	Conjunctive use of groundwater and imported/local surface water; water banking
CALFED Potential Sites[b]	Conjunctive use of groundwater and imported/local surface water; water banking
Urban-Ag[c]	Conjunctive use of groundwater and imported/local surface water; water banking
SWP and CVP Service Areas Outside the Central Valley	
Metropolitan Water District of Southern California	Expansion of current conjunctive use programs and implementation of additional programs

NOTES:

[a] The Delta Region is not listed separately because many of the present and potential programs listed for other regions require coordinated management of water supplies associated with the Delta Region.

[b] Seventeen conjunctive use sites have been identified. See Preliminary Working Draft, CALFED Bay-Delta Program Storage and Conveyance Component Inventories, February 1997. CALFED is exploring additional conjunctive use projects.

[c] Common name for negotiations between exporters (generally SWP and CVP export contractors) and upstream water interests; exporters would assume responsibility assigned by SWRCB to meet Bay-Delta water quality standards pursuant to whatever settlement is agreed to with upstream water interests. The agreement may or may not involve conjunctive use.

Table S-1. Examples of Current and Potential Regional Groundwater Management (Continued)

In-Lieu Recharge. In-lieu recharge brings additional surface water into an area using groundwater or both surface water and groundwater. The additional surface water is used to irrigate in lieu of groundwater, thereby allowing groundwater levels to recover. The replenished groundwater supply can then be retrieved during dry years, easing the burden on surface water supplies.

Direct Recharge. Conjunctive use programs incorporating artificial recharge methods require a source of surface water that is not needed for immediate use. The surface water is placed directly into the ground by various means, including spreading basins and injection wells. The water stored in the aquifer is then available for use in dry years.

Groundwater Overdraft (Synonym: Groundwater Mining). The intentional or inadvertent withdrawal of water from an aquifer in excess of the amount of water that recharges the basin over a period of years during which water supply conditions approximate average, which, if continued over time, could eventually cause the underground supply to be exhausted, cause subsidence, cause the water table to drop below economically feasible pumping lifts, or cause a detrimental change in water quality.

Perennial Yield. The maximum quantity of water that can be annually withdrawn from a groundwater basin over a long period of time without developing an overdraft condition (sometimes referred to as sustained yield). Perennial yield is based on the assumption that there are no long-term changes in water management. For example, some groundwater systems receive recharge from deep percolation of irrigation applied water. Certain agricultural and urban conservation practices could decrease the amount of this deep percolation, thereby changing perennial yield estimates. Another important distinction affecting recharge of the groundwater system is associated with areas where there is hydraulic continuity between surface water and groundwater. In this case, perennial yield depends in part on the amount of extraction that occurs. Increases in groundwater extractions can increase groundwater gradients and induce additional recharge from hydraulically connected streambeds, resulting in increased perennial yield. This may not be acceptable because it may result in overdraft conditions, as defined above, and also may result in excessive depletions from streams.

Water Banking. A water conservation and use optimization system whereby water is allocated for current use or stored in surface water reservoirs or in aquifers for later use. Water banking is a means of handling surplus water resources.

Water Marketing. The selling or leasing of water rights in an open market.

Long-Term Contract. A long-term contract is for any period in excess of 1 year (California Water Code Section 1735).

Water Transfer. Conveyance of groundwater or surface water from one area to another that involves crossing a political or hydrologic boundary. A voluntary change in a point of diversion, place of use, or purpose of use that may involve a change in water rights.

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CALFED

TECHNICAL REPORT
ENVIRONMENTAL CONSEQUENCES

GROUNDWATER RESOURCES

DRAFT

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CALFED
BAY-DELTA
PROGRAM

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LIST OF ACRONYMS

CALFED	CALFED Bay-Delta Program
CVP	Central Valley Project
DWR	California Department of Water Resources
EIS/EIR	Environmental Impact Statement/Environmental Impact Report
SWP	State Water Project
SWRCB	State Water Resources Control Board
TDS	total dissolved solids
WQCP	Water Quality Control Plan

GROUNDWATER RESOURCES

INTRODUCTION

This technical report describes impacts on groundwater resources associated with implementation of the CALFED Bay-Delta Program (CALFED).

Numerous activities could result in potentially significant impacts, including:

- Construction of new storage and conveyance facilities;
- Changes in surface water supplies and streamflows, both of which can influence long-term groundwater conditions;
- Conjunctive management of groundwater and surface water; and
- Changes in urban and agricultural land uses.

Impacts on groundwater resources are described at various levels of detail, with more emphasis on the Sacramento River and San Joaquin River regions because groundwater storage and management opportunities in these regions could help to meet various objectives of the CALFED effort.

ASSESSMENT METHODS

Impacts on groundwater resources were assessed qualitatively. Groundwater modeling studies were not conducted for the alternatives. Descriptive information for each alternative was used together with State Water Project (SWP) and Central Valley Project (CVP) surface water simulation studies and professional judgement to determine whether potential changes in groundwater conditions could occur under Alternatives 1, 2, or 3 as compared to the No Action Alternative. In addition, specific consideration was given to stakeholder concerns that have been identified as part of CALFED's ongoing Groundwater Outreach Program.

Groundwater impacts for each alternative were summarized as potential changes to groundwater levels, groundwater quality, land subsidence, and streamflow impacts as compared to the No Action Alternative. Changes in groundwater levels provide a measure of associated groundwater impacts such as pumping costs, costs for lowering pumps or deepening wells, and reduced well yields. Groundwater levels also could be indicative of potential land subsidence in areas where clay and silt lenses susceptible to compaction were prevalent. Land subsidence could damage water conveyance facilities, flood control and drainage levee systems, groundwater well casings, and other infrastructure.

DWRSIM simulation studies conducted for the Programmatic Environmental Impact Statement/ Environmental Impact Report (EIS/EIR) for CALFED were designed to approximate conditions under one or more of the CALFED actions. These studies indicated changes in surface water supplies and streamflows, both of which can influence long-term groundwater conditions. It was assumed that variations in surface water deliveries to SWP and CVP service areas would be compensated for by reductions or increases in the amount of groundwater pumping occurring in these areas.

The influence of new storage and conveyance facilities on water supply conditions also was provided by these studies. Ideally, individual CVP and SWP operations would be optimized to provide the best integrated operations, including sharing of new storage and conveyance facilities. Since modeling optimized CVP and SWP operations is not possible with the current tools available, SWP operations must serve as a surrogate for combined SWP and CVP operation of new facilities in DWRSIM.

The potential for conjunctive management of groundwater and surface water identified in certain CALFED alternatives also may contribute to long-term changes in regional groundwater pumping. Regional groundwater impacts associated with these management concepts were inferred from previous and ongoing conjunctive use studies and investigations, and from information gathered by the CALFED Groundwater Outreach Program.

Changes in land use could result in significant long-term impacts on groundwater conditions. It is possible that changes in urban and agricultural land use could occur as a result of selecting a CALFED alternative. Important factors in assessing the response of groundwater to changes in land use include the magnitude, type, and geographic extent of the change.

Possible groundwater impacts resulting from changes associated with CALFED actions were assessed based on the magnitude (acres) and type (agricultural lands to native vegetation) of change. The geographic extent of these changes was not determined for this programmatic document.

SIGNIFICANCE CRITERIA

Impacts were considered significant if implementation of a CALFED action would result in:

- Substantial long-term declines in groundwater levels resulting in third-party effects,
- Detectable degradation of groundwater quality, or
- Detectable land subsidence caused by water level declines.

ENVIRONMENTAL CONSEQUENCES

Comparison of No Action Alternative to Existing Conditions

DWRSIM model output data were used on a limited basis to assess possible changes in surface water and groundwater use, and in streamflows. The DWRSIM run representing the No Action Alternative is the CALFED Benchmark Study. The DWRSIM run representing existing conditions was based on the State Water Resources Control Board (SWRCB) simulation reflecting the 1995 Water Quality Control Plan (WQCP), referred to as the SWRCB 1995 WQCP Study.

DELTA REGION

Agricultural demands in the Delta Region are expected to decrease slightly by year 2020. Any reduction in water use associated with reduced agricultural demands could be offset by expected small increases in urban demands. Because groundwater plays only a small role in satisfying local demands, it is not expected that long-term regional groundwater conditions under the No Action Alternative would change significantly from existing conditions.

BAY REGION

With increasing populations and the resulting increase in water demand, water agencies in the Bay Region are considering a number of options to increase supplies and to ensure the reliability of their existing water sources. As part of these efforts, coordinated use of groundwater and surface water through various types of water resources programs would continue to be initiated or enhanced where already in place.

To what degree future supply shortages would be met by increased groundwater overdraft is unknown. In some areas of California, the historical response to increasing water demands has been to overdraft groundwater basins to meet these shortages. Based on this observation, regional groundwater resources in the Bay Region under the No Action Alternative could experience groundwater level declines, degradation of water quality, or possible land subsidence as compared to existing conditions.

SACRAMENTO RIVER REGION

The northern third of the Central Valley regional aquifer system is located in the Sacramento River Region. The California Department of Water Resources (DWR) identifies this area of the aquifer as the Sacramento Valley Basin and the Redding Basin (DWR 1975), together covering over 5,500 square miles. For this technical report, references to the Sacramento River Region include the Sacramento Valley Basin and the Redding Basin.

Under the No Action Alternative, long-term groundwater conditions would remain similar to existing conditions in the northern half and west side of the Sacramento River Region, except for a groundwater depression in the Yolo County area. Groundwater levels along the east side of the Sacramento River Region would be similar to existing conditions, except in the Sacramento County area. Continued groundwater level declines could occur in the Sacramento County area as a result of groundwater use in excess of groundwater recharge.

Compared to existing conditions, areas of possible groundwater level declines could experience increased pumping costs due to added lift and additional costs for lowering pumps or deepening wells. Additional stream depletions also could occur in response to these lower groundwater levels.

Land subsidence is known to occur only in the southwestern part of the Sacramento Valley basin, in central Yolo County. Land subsidence in Sacramento County area is not likely to occur. Under the No Action Alternative, possible long-term declines in groundwater levels in the Yolo County area could result in additional land subsidence, compared to existing conditions.

Groundwater quality under the No Action Alternative could be degraded compared to existing conditions from induced migration of groundwater high in total dissolved solids (TDS), known to exist south of the Sutter Buttes and southern Yolo County, toward depressed groundwater levels south and east of these areas. Potential boron problems in central Yolo County also could contribute to groundwater quality degradation from this potentially induced migration.

Ongoing groundwater management planning efforts in some parts of the Sacramento River Region could prevent or minimize the negative impacts summarized above; however, formal programs have not been adopted.

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 impact groundwater levels in the Sacramento River Region, but could have significant local impacts in the upper watershed. For example, a reduction in the groundwater underflow component of stream flow could cause a decline in stream flows.

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 will occur with the No Action Alternative will continue to result in deterioration of groundwater quality, with potential for poor quality water to be drawn into basin pumping centers.

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 are 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 may accelerate the shift from agriculture to more intensive land uses (homesite development), resulting in increased demands on water resources. This would be a significant but mitigable impact in areas with limited groundwater resources.

SAN JOAQUIN RIVER REGION

The southern two-thirds of the Central Valley regional aquifer system is located in the San Joaquin River Region. DWR identifies this area of the regional aquifer as the San Joaquin Valley basin (DWR 1975), covering over 13,500 square miles.

Population projections indicate that more than twice as many people would reside in the San Joaquin River Region by year 2020 (DWR 1994). Such growth is expected to drive the conversion of some agricultural lands to urban development. This may further stretch water supplies in some areas or simply shift water use from agricultural to urban uses.

Changes in imported surface water supplies likely would result in negative impacts on groundwater resources in some areas of this region. Areas that rely on Delta exports for all or a portion of their supplies would face uncertainty in terms of water supply reliability due to the unknown outcome of a number of actions that would be undertaken to protect aquatic species in the Delta. Because groundwater historically has been used to replace much of the shortfall in surface water supplies, limitations on Delta exports could increase the possibility of additional groundwater overdraft in the San Joaquin River Region.

Land subsidence is known to occur along the west side of the San Joaquin River Region, as well as in the southwestern portion of Tulare County and the southern end of Kern County. For the No Action Alternative, increased land subsidence in this region could occur relative to existing conditions.

Under the No Action Alternative, groundwater quality for the San Joaquin River Region could be further impaired, compared to existing conditions, in areas that experienced additional declines in groundwater levels. The additional degradation could occur as a result of induced migration of poor-quality groundwater into areas of superior quality groundwater. Because mineral concentrations usually are higher in groundwater than in surface water, increased use of groundwater for irrigation could increase salt loading to soils, groundwater, and surface water.

Existing and planned groundwater management programs in the San Joaquin River Region could prevent or minimize the occurrence of these types of negative impacts on a local scale; nevertheless, potentially significant impacts in unmanaged areas could occur.

SWP AND CVP SERVICE AREAS OUTSIDE THE CENTRAL VALLEY

Numerous groundwater basins are located along the coast and inland valleys in the SWP and CVP Service Areas Outside the Central Valley. Many of the basins are adjudicated or managed by a public agency. Additional imported supplies from the SWP Coastal Branch of the California

Aqueduct could reduce future groundwater overdraft in the coastal areas. Areas that rely on Delta exports for all or a portion of their supplies, however, face uncertainty in terms of water supply reliability due to the unknown outcome of a number of actions undertaken to protect aquatic species in the Delta. This uncertainty could increase the possibility of additional groundwater overdraft under the No Action Alternative in groundwater basins that are not closely managed.

Comparison of CALFED Alternatives to No Action Alternative

DELTA REGION

ALL ALTERNATIVES

Ecosystem Restoration Program

A series of programmatic actions are proposed for the Delta as part of the Ecosystem Restoration Program. With regard to groundwater conditions, substantial changes in agricultural land use could result in reduced deep percolation from the applied water. An overall reduction in recharge of Delta groundwater resources could result from these actions. However, the extent of wetlands and the net amount of net recharge are uncertain relative to the No Action Alternative.

Groundwater pumping, currently needed to grow crops on low-lying lands, would no longer be needed on these lands. A reduction in groundwater pumping would provide a potentially significant benefit from reduction in pumping-induced subsidence, and an unknown but potentially significant reduction in loading of farm chemicals (such as nitrates, phosphates, and pesticides) discharged with the drain water to the Delta.

In some parts of the Delta, for example in the Delta portion of the Cosumnes River, setback levees are expected to result in more groundwater recharge because the bottom area of the stream will be increased.

Water Quality Program and Coordinated Watershed Management

With the Water Quality Program and Coordinated Watershed Management, contaminant concentrations in water and sediment quality are expected to decline in streams immediately downstream of pollutant sources. Because the behavior of these contaminants in natural aquatic systems is complex, it is difficult to predict the consequences downstream. It is probable that these actions could result in minor improvements to groundwater quality in the Delta Region.

The Water Quality Program and Watershed Management for the Bay Region includes actions similar to Actions 2 and 3 previously described. These actions probably would result in minor improvements to groundwater quality.

Actions 1 through 4 also are proposed for the Sacramento River and San Joaquin River regions. To the extent that these actions benefit surface water quality conditions, the stream-aquifer relationship that exists between surface water and underlying groundwater resources could result in long-term secondary improvements in groundwater quality conditions.

Water Use Efficiency Program and Water Transfers

This program does not address specific geographic regions but focuses on the five elements listed in Table 1. On a qualitative basis, the discussion of groundwater impacts for the Delta Region applies to all regions. Water use efficiency is not discussed for the Bay Region and SWP and CVP Service Areas Outside the Central Valley. The Sacramento River and San

Programmatic Action	Potentially Significant Impacts on Groundwater Resources
1. Agricultural water use efficiency approach	Yes
2. Urban water use efficiency approach	Yes
3. Approach to effective use of diverted environmental water	No
4. Water recycling approach	Yes
5. Water transfers	Yes

Table 1. Water Use Efficiency Program Programmatic Actions for the Delta Region

Joaquin River regions are discussed because of the significant link between groundwater resources and recharge from applied irrigation water.

Agricultural water use efficiency could result in beneficial and potentially significant impacts on groundwater conditions, as noted below.

- Agricultural water conservation resulting in reductions in deep percolation from applied water or seepage from conveyance facilities could result in reduced groundwater recharge. This reduction in turn could result in declines in long-term groundwater storage and levels in adjacent areas, causing third party negative impacts in the form of increased energy costs, and costs to lower pumps or deepen wells. In addition, where groundwater and surface water are in hydraulic continuity, decreasing groundwater levels would lead to increasing recharge of surface water back into aquifers. In such cases, instream flows could be decreased, possibly requiring release of additional water from upstream storage sources.

- Increased reliance on groundwater as a water supply may occur for current agricultural surface users who may lose their surface supply as a result of upstream efficiency improvements (resulting in less surface runoff used to supply downstream users).

- As irrigators turn towards more efficient methods, such as drip and micro-irrigation systems, some growers may switch to groundwater as a more reliable, cleaner source as compared to surface water sources.

- The impact of water transfers on groundwater conditions depends largely to what extent the transfer may involve groundwater substitution and/or land fallowing. If groundwater substitution occurred, groundwater level declines could be expected on a local basis, affecting pump-lift requirements for those relying on groundwater in the area. It is likely that this substitution would be discouraged in areas of critical overdraft or areas subject to land subsidence. Water transfers that involve land fallowing would have similar impacts on groundwater resources as conservation measures. If irrigation was not applied to a field, deep percolation would be reduced, possibly affecting the underlying groundwater levels that previously partially depended on such recharge.

- Demand for groundwater could decline as agricultural water use becomes more efficient, resulting in a positive impact on groundwater conditions. For example, water recycling generally is expected to result in a beneficial impact on groundwater conditions because future water supplies would be augmented by the availability of recycled water, thus reducing the dependence on groundwater as a supplemental supply.

Urban water use efficiency could have effects similar to agricultural water use efficiency, as noted below.

- Groundwater use may increase if, during drought periods, an urban supplier who relies heavily on surface water has limited options for further conservation.
- For some communities, treated wastewater is applied to spreading basins for recharge of local groundwater resources. To the extent that conservation or recycling reduces the amount of artificial recharge, the local aquifer may experience potentially significant impacts.

Levee System Integrity Program

Concerning potential impacts on groundwater conditions, the Levee System Integrity Program affects only areas in the Delta Region and therefore is not discussed for any other CALFED region.

Thousands of acres of agricultural land could be affected by actions associated with the Levee System Integrity Program. The conversion of land from agricultural cropland to levee potentially could reduce the deep percolation of applied water, potentially resulting in a negative impact on long-term groundwater storage conditions as compared to existing conditions. Reductions in groundwater pumping (required to drain these low-lying agricultural lands) could result in a potentially beneficial impact from reduction in subsidence (subsidence associated with the loss of peat soils) and an unknown but potentially significant reduction in loading of farm chemicals (such as nitrates, phosphates, and pesticides) discharged with the drain water to the Delta. Because of the complex relationship occurring between the surface and subsurface systems in the vicinity of these levees, it is difficult to assess the significance of this potential impact at a programmatic level.

Storage and Conveyance

Alternative 1

Alternative 1 has three possible configurations (1A, 1B, and 1C), each of which include various CALFED actions. The program actions associated with Configurations 1A and 1B involve operational elements and do not include any storage elements. Configuration 1C includes new storage (surface water and groundwater) north and south of the Delta, and south Delta improvements. It is not likely that any action in these configurations would significantly change groundwater use in the Delta Region. From a regional perspective, groundwater conditions in the Delta Region for Configurations 1A, 1B, and 1C would be similar to No Action Alternative groundwater conditions.

Alternative 2

Alternative 2 includes four configurations: 2A, 2B, and 2E. Configurations 2B, 2D, and 2E include new storage (surface water and groundwater) north and south of the Delta. Configuration 2A does not include any new storage.

On a long-term average annual basis, surface water hydrology in the Delta Region under Configuration 2A would be similar to the No Action Alternative, resulting in little change in flow and surface water supplies in the Delta. Flows into and out of the Delta under Configurations 2B and 2E would change as a result of the new storage, primarily affecting the monthly distribution of flow. Long-term annual conditions, however, would not be expected to change significantly relative to the total flow through the Delta. Groundwater conditions in the Delta Region for Configurations 2A and 2E would be similar to No Action Alternative groundwater conditions.

Alternative 3

The five possible configurations for Alternative 3 were organized into two groups to discuss groundwater impacts. Configuration 3A includes south Delta improvements and a 5,000-cfs isolated facility. This combination would provide the potential to deliver water more efficiently for Delta outflow and Delta export. It also could make additional water available that was previously used to offset the inefficiency associated with moving water through the Delta. As a result, inflows to the

Delta would be reduced in comparison to the No Action Alternative on a long-term average annual basis; however, changes in inflows would be small relative to total inflow. Surface water supplies to the Delta Region would be similar to the No Action Alternative. No potentially significant impacts on groundwater conditions in the Delta Region are anticipated as a result of Configuration 3A in comparison to the No Action Alternative.

The second group, Configurations 3B, 3E, 3H, and 3I, includes south Delta improvements, a 5,000-cfs isolated facility, and north of Delta and south of Delta storage (both surface water and groundwater). Configurations 3B, 3E, and 3I also include in-Delta surface storage. The Delta surface storage component could increase groundwater levels in the vicinity of the storage facility, possibly waterlogging adjacent low-lying farmlands.

Leakage would occur through the unlined canals of the isolated facilities. The amount of leakage would depend upon 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 would also depend on the width of the canal. The leakage rate would be highest for a 15,000-cfs capacity canal (Configurations 3E and 3I) and lowest for a 5,000-cfs canal (Configurations 3A, 3B, and 3H). Leakage could have a significant adverse impact on water levels in soils adjacent to the canal.

BAY REGION

ALL ALTERNATIVES

Ecosystem Restoration Program

A series of programmatic actions are proposed for the Bay Region as part of the Ecosystem Restoration Program. Some actions would result in a reduction of agricultural lands. Some of this acreage would overlap acreage in the Levee System Integrity Program actions. This reduction could cause a reduction in deep percolation from applied water. Uncertainty is associated with the extent of the wetlands and net amount of recharge relative to the No Action Alternative. Reductions in groundwater pumping, as discussed previously for the Levee System Integrity Program, could result in a potentially significant benefit from reductions in subsidence (subsidence associated with the loss of peat soils) and a reduction in loading of farm chemicals discharged with the drain water to the Delta.

Storage and Conveyance

Alternative 1

Water supplies exported from the Delta to the Bay Region could decrease slightly as a result of Configurations 1A and 1B in comparison to the No Action Alternative. Increases in groundwater use could occur but likely would be minimal. From a regional perspective, groundwater conditions in the Bay Region for Configurations 1A and 1B would be similar to No Action Alternative groundwater conditions. Local declines in groundwater levels could occur relative to the No Action Alternative, however, and could result in increased pumping costs and costs to lower pumps or deepen wells, degradation of water quality, and land subsidence.

Configuration 1C would result in a beneficial impact in terms of surface water supply exported from the Delta to the Bay Region. This could result in additional recharge available to conjunctive use management programs and less pumping in areas relying on groundwater as a supplemental supply. In summary, Bay Region groundwater conditions associated with Configuration 1C would be similar to the No Action Alternative groundwater conditions, with the possibility of slightly improved conditions.

The Configurations 2B, 2E, and 3A indicate that small increases in water supply to the Bay Region would occur, like those observed for Configuration 1C.

Alternative 2

A decrease in water supplies exported from the Delta to the Bay Region could occur under Configuration 2A, similar to those observed for Configurations 1A and 1B. However, the decrease would be much smaller and would result in very small increases in groundwater pumping in comparison to the No Action Alternative. Regional groundwater conditions would most likely remain similar to the No Action Alternative. No potentially significant impacts are anticipated on groundwater resources in the Bay Region under Alternative 2 compared to the No Action Alternative.

Alternative 3

Configurations 3B, 3E, 3H, and 3I provide a larger positive water supply benefit than any other configuration. Groundwater conditions in the Bay Region as a result of Configurations 3B, 3E, 3H, and 3I would be similar to No Action Alternative groundwater conditions, with the possibility of improved conditions.

SACRAMENTO RIVER REGION

ALL ALTERNATIVES

Ecosystem Restoration Program

A series of programmatic actions are proposed for the Sacramento River Region as part of the Ecosystem Restoration Program. An overall reduction in recharge of the Sacramento River Region groundwater resources could occur as a result of the restoration of riparian habitat.

Water Use Efficiency Program and Water Transfers

Improved on-farm and district efficiency would result in decreased deep percolation of applied water. Although this savings may result in other benefits, deep percolation plays a vital role in recharging underlying aquifers in many areas of the Sacramento River and San Joaquin River regions. Many farms in these regions serve as vast, effective, economical groundwater recharge basins. Given the potential of increased groundwater pumping, decreases in recharge could further adversely affect groundwater levels and aquifer capacities.

Storage and Conveyance

Several configurations of Alternatives 1, 2, and 3 include groundwater storage components north and south of the Delta, the most important feature with regard to assessing potential impacts on groundwater resources in the Sacramento River Region. This feature would consist of conjunctive use or groundwater banking concepts, and would operate with the basic objective of maximizing overall water supply and preserving existing surface water and groundwater resources.

Efforts by CALFED, DWR, and others are underway to identify and evaluate specific groundwater storage programs in the Sacramento River Region. Currently, groundwater storage programs are being explored by CALFED through outreach to local communities 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 in the region. Many communities and individuals who have had direct experience with past conjunctive use and groundwater banking programs provided historical information with regards to local impacts and other concerns. As a result of these efforts CALFED has summarized stakeholder concerns, developed draft guidelines for evaluating groundwater storage development, and identified preliminary mitigation strategies.

Groundwater storage components for the Sacramento River Region are included in Configurations 1C; 2B and 2E; and 3B, 3E, 3H, and 3I. At this programmatic level of analysis, groundwater impacts resulting from components other than the groundwater storage feature were not distinguishable among these configurations; therefore, impacts are discussed only once under Configuration 1C. Configurations 1A, 1B, 2A, and 3A would affect groundwater similarly and are discussed only under Configurations 1A and 1B.

In general, these programs would rely on groundwater supplies during dry years, when surface water supplies generally are less likely to be available. Under more favorable hydrologic conditions, surface water supplies would then be used to directly recharge groundwater basins or to irrigate in lieu of pumping groundwater, allowing groundwater levels to recover. The available surface water would be provided by existing storage and conveyance facilities or obtained from new surface storage and conveyance facilities.

Configurations 1A and 1B

Configurations 1A and 1B (and Configurations 2A and 3A) consist of various surface water-related actions. No groundwater storage components are included in either configuration. In comparison to the No Action Alternative, surface water supply conditions in the Sacramento River Region would be similar under Configurations 1A and 1B. Little change in groundwater use would be expected as a result of these configurations in comparison to the No Action Alternative. From a regional perspective, groundwater conditions in the Sacramento River Region for Configurations 1A and 1B would be similar to No Action Alternative groundwater conditions.

Configuration 1C

The storage components of Configuration 1C include both tributary storage and groundwater storage. Both could have an effect on groundwater resources. Examples of the types of impacts on groundwater resources that might occur because of the construction, and operation and maintenance of surface water storage facilities are described below to illustrate some of the common types of impacts that might occur. More detailed impact analysis would be conducted at the project level for specific sites.

The groundwater impacts at both example sites which were evaluated are similar. Local stream flows are insufficient to maintain the 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 expected to have no impact on 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

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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. Subsurface leakage is not expected to result in a substantial adverse groundwater impact, however, subsurface leakage is not expected to result in a substantial adverse groundwater impact.

Inundation of the reservoir will 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 will have no additional impact on groundwater conditions.

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

A 250,000 acre-foot groundwater storage component would be implemented in the Sacramento River Region under Configuration 1C (and Configurations 2B, 2E, 3B, 3E, 3H, and 3I). Operation of this component could result in groundwater level declines in comparison to the No Action Alternative. These declines would be greatest during dry year periods due to increased groundwater pumping. Since mineral concentrations usually are higher in groundwater than in surface water, increased use of groundwater for irrigation could increase salt loading to soils, groundwater, and surface water.

Potential negative impacts related to groundwater level declines could include land subsidence, increased pumping costs, costs for lowering pumps or deepening wells, reduced well yields, water quality degradation, increased streamflow depletions, loss of native vegetation, and wetlands impacts. These negative impacts could affect parties directly involved in the groundwater storage program, and neighboring third party communities and individuals.

The occurrence of these negative impacts depends on many factors. For example, land subsidence caused by groundwater level declines has been observed only in the Davis-Zamora area of the region. However, it is possible that additional groundwater development in other areas of the Sacramento River Region also could result in land subsidence.

In general, fewer construction-related impacts are associated with groundwater storage programs than developing or expanding surface storage facilities because of fewer land use changes. No potentially significant construction-related impacts on groundwater storage, flow, or quality are anticipated from development of this type of project (Configuration 1C).

Streamflows (simulated by DWRSIM) would be altered in the Sacramento River Region from CALFED storage and conveyance components in Configuration 1C. Streamflow conditions would tend to be lower in winter months and higher in summer months in comparison to the No Action Alternative, primarily as a result of operations associated with additional storage facilities. The hydraulic connection between the stream and aquifer system in the Sacramento River Region could be influenced by these changes, resulting in lowered groundwater levels entering the summer season. This condition could negatively affect agricultural and municipal wells in the vicinity of the streams affected (primarily the SWP- and CVP-controlled streams), resulting in increased pumping costs and, in some cases, additional costs for lowering pumps or deepening wells. Loss of native vegetation also may occur when groundwater levels are lowered and less water is available in root zones. In addition, lowered groundwater levels could affect wetlands.

SAN JOAQUIN RIVER REGION

ALL ALTERNATIVES

Ecosystem Restoration Program

A series of programmatic actions are proposed for the San Joaquin River Region as part of the Ecosystem Restoration Program. Because reductions in agricultural lands as a result of these actions would be minimal, potentially significant impacts are not anticipated for the region.

Water Use Efficiency Program and Water Transfers

Groundwater conditions in the San Joaquin River Region are particularly sensitive to the issues of agricultural and urban water use efficiency, specifically those actions involving agricultural water conservation and urban landscape conservation. Implementation of these types of water conservation programs would decrease deep percolation and reduce future groundwater recharge, thus reducing future long-term groundwater yield available from the groundwater basin. This reduction in turn could result in declines in long-term groundwater storage and levels in adjacent areas, causing third party negative impacts in the form of increased energy costs, modifications to well pump bowls to keep them below the groundwater level, and/or abandonment of wells. Many water districts depend on their delivery canals as recharge basins. During wet years, these canals purposefully are filled with water during winter to recharge the underlying aquifer. This operation acts as a method of water storage for use later in the season or during drier years. Lining canals could affect their ability to conjunctively use groundwater and surface water supplies.

Storage and Conveyance

The configurations of Alternatives 1, 2, and 3 with a groundwater storage component for the Sacramento River Region include a similar component for the San Joaquin River Region. Most groundwater storage options in this area overlie groundwater basins that are presently dewatered. The existence of dewatered aquifer space provides an opportunity to store surplus flows diverted from the Delta, from the San Joaquin River or its tributaries, or from existing or new south of Delta storage and conveyance facilities. Water stored in these dewatered aquifers could be extracted to meet demands during dry periods. Groundwater extractions could be made for in-lieu uses or to reduce demands for water diversions from the Delta or the San Joaquin River. Banked groundwater also could be extracted for use in the California Aqueduct, which could reduce the demand for Delta diversions during critical periods.

For this programmatic level of analysis, groundwater impacts resulting from components other than the groundwater storage feature are not distinguishable among configurations; therefore, impacts for Configurations 2B, 2E, 3B, 3E, 3H, and 3I are discussed under Configuration 1C. Configurations 1A, 1B, 2A, and 3A would result in similar effects on groundwater and are discussed only once under Configurations 1A and 1B.

Configurations 1A and 1B

Water supply exports from the Delta to the San Joaquin River Region could decrease as a result of Configurations 1A and 1B (and Configurations 2A and 3A) in comparison to the No Action Alternative. Increases in the amount of groundwater pumping in response to these changes could occur, resulting in negative groundwater impacts on areas receiving Delta export water. Negative impacts could include declines in groundwater levels, resulting in increasing pumping costs and costs to lower pumps or deepen wells, potential degradation of water quality, and possible land subsidence.

Configuration 1C

A groundwater storage component would be implemented in the San Joaquin River Region under Configuration 1C (and Configurations 2B, 2E, 3B, 3E, 3H, and 3I), which could result in negative groundwater impacts similar to those discussed for the Sacramento River Region under Configuration 1C. The potential for land subsidence is of considerable concern in this region given the extensive regional occurrence of subsidence along the west side and in the southern San Joaquin Valley.

Groundwater management operations in the southern portion of the San Joaquin River Region would likely have little effect on stream accretions and depletions, since rivers in the area are generally hydraulically disconnected from underlying groundwater basins. In addition, the loss of native vegetation and wetlands habitat would be negligible since groundwater levels historically have been too low to support such habitat.

Streamflows would not be altered in the San Joaquin River Region as a result of CALFED storage components represented in this configuration. No direct impacts from these conditions on groundwater-surface water interaction would occur.

SWP AND CVP SERVICE AREAS OUTSIDE THE CENTRAL VALLEY

<u>ALL ALTERNATIVES</u>

Ecosystem Restoration Program

The Ecosystem Restoration Program would not directly impact groundwater resources in the SWP and CVP Service Areas Outside the Central Valley. However, to the extent that it reduced the amount of water available for export to the service areas at certain times, it could have the indirect effect of requiring water supply contractors to increase their dependence on groundwater at these times. The impacts would probably be less than significant.

Water Quality Program and Coordinated Watershed Management

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 non-point 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 SWP and CVP Service Areas Outside the Central Valley would have the same impacts on groundwater resources as described for the Sacramento River Region. Reducing demand and/or increasing supply through recycling waste water would decrease dependence on groundwater.

Water Transfers

The SWP and CVP Service Areas Outside the Central Valley could receive additional water from transfers from the Central Valley, or from transfers 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 significant adverse impacts if the availability of the imported water changes.

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Comparison of CALFED Alternatives to Existing Conditions

Comparison of Program alternatives to existing conditions indicates that:

- All significant adverse impacts of Program Alternatives identified when comparing the No Action Alternative are still significant when comparing to existing conditions.

- Some actions which are beneficial when compared to the No Action Alternative could result in a significant adverse effect when compared to existing conditions. While CALFED is expecting an overall improvement in groundwater resources relative to the No Action Alternative, there is still the potential that groundwater conditions could be worse than those that currently exist. Implementation of the CALFED program will likely result in groundwater resources being better than they would be in absence of the program, but that groundwater resources could still be degraded relative to existing conditions.

MITIGATION STRATEGIES

Groundwater management programs, including conjunctive use projects, should monitor and evaluate the following for changes:

- **Groundwater levels.** The conjunctive use program should develop a network of monitoring wells, a monitoring schedule, and procedures for periodic evaluation of the data. Such efforts would provide the information necessary to determine whether storage capacity was available in the aquifer for recharge, or conversely, that the aquifer was full. In addition, such measurements would show when groundwater levels reach or exceed established thresholds.

- **Land surface elevation (for potential subsidence).** Extensometers could be installed to monitor vertical movement of the land surface, or such movement of the land surface could be monitored by global positioning system surveying.

- **Groundwater quality.** The same wells that would be used to monitor groundwater levels could be used for water quality sampling; in some cases, however, additional wells may be required to effectively monitor water quality. Background levels should be established before a conjunctive use project begins. A program then should be designed to sample for appropriate mineral and chemical constituents at appropriate time intervals.

- **Stream flow.** Stream gauges should be established on watercourses in the area. The data collected would not be immediately useful in determining adequate stream flow but over the operation of the conjunctive use project, the data may begin to provide information about the effect of aquifer recharge and discharge on streamflow. These data eventually could play an important role in maintaining surface water rights.

Conjunctive use projects should be thoroughly monitored, so that any detrimental impacts could be identified quickly. The monitoring program for each conjunctive use project must be tailored to fit the requirements and thresholds of that particular program. In some areas, groundwater extraction over time may not cause subsidence, and the monitoring program could be reduced. The same might be true regarding groundwater quality. The threshold values in each conjunctive use project should be reviewed periodically after evaluation of the data obtained from the monitoring program.

Appropriate mitigation measures, ranging from reduction in pumping to cessation of the project, could then be effectively implemented.

POTENTIALLY SIGNIFICANT UNAVOIDABLE IMPACTS

No potentially significant unavoidable impacts on groundwater resources are associated with CALFED actions.

REFERENCES - ENVIRONMENTAL CONSEQUENCES

Printed References

CALFED Bay-Delta Program. 1997. Phase II - Draft Alternatives Descriptions (includes: Appendix A - Ecosystem Restoration Program Programmatic Actions; Appendix B - Water Quality Program Programmatic Actions; Appendix C - Water Use Efficiency Program Programmatic Actions; Appendix D - Levee System Integrity Program Programmatic Actions; Appendix E - Operation Assumptions for No Action Alternative Modeling; Appendix F - Operation Assumptions for Existing Conditions Modeling). May. Sacramento, CA.

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