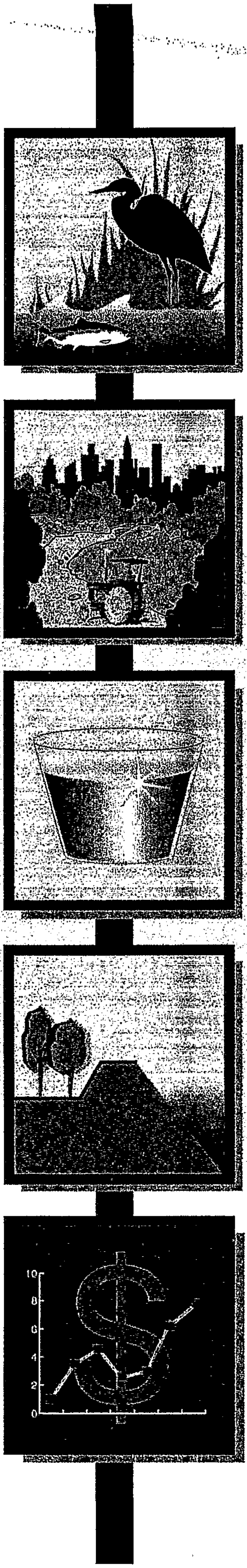

CALFED
BAY-DELTA
PROGRAM

Affected Environment and Environmental Impacts

Groundwater

Draft Technical Report
September 1997

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PRELIMINARY DRAFT REPORT

AFFECTED ENVIRONMENT DRAFT TECHNICAL REPORT GROUNDWATER

Prepared for

CALFED
BAY-DELTA
PROGRAM

July 1, 1997

PREFACE

The intent of this technical appendix is to provide supporting documentation for the CALFED Bay-Delta Program PEIS/EIR. This document is in a preliminary draft form, reflecting work in progress. The contents are subject to change based on public and stakeholder input. During the review of this document questions may be directed to Roger Putty at (916) 921-3540 (voice), (916) 924-9102 (fax), or *roger.putty@us.mw.com* (E-mail). Please direct any formal comments to Stein Buer, Assistant Director, Technical Services Branch, CALFED Bay-Delta Program, 1416 Ninth Street, Suite 1155, Sacramento, California 95814.

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Groundwater is a crucial component of California's water supply, providing about 40 percent of the urban and agricultural water used in California. During drought years groundwater provides up to two-thirds of the water used. The purpose of this appendix is to provide a description of this resource for areas in California that may be affected by implementation of the CALFED Bay-Delta Program.

This technical appendix is organized into five sections. A summary of the groundwater affected environment is presented in Section I. This is a brief overview of the contents presented in the main body of the document. The main body of the document begins with the Section II, Introduction, and is followed by Section III, Sources of Information, Section IV, Environmental Setting, and Section V, References. A companion document titled "Groundwater Technical Appendix: Environmental Impacts" discusses the possible environmental impacts to groundwater in California as a result of CALFED Bay-Delta Program alternatives.

I. SUMMARY

Historical and recent groundwater conditions are summarized below for the study area, consisting of the Sacramento-San Joaquin Delta (Delta) Region, the San Francisco Bay (Bay) Region, the Sacramento River Region, the San Joaquin River Region, and SWP-CVP service areas outside the Central Valley. Additional information and explanation of groundwater conditions is provided in the main body of the document, starting with section II.

Historical information, from approximately the 1920s forward, is based upon numerous regional studies and investigations that have been completed by federal, state, and local agencies. Because groundwater conditions are not consistently recorded and reported on a scheduled basis throughout the study area, recent groundwater conditions are represented by information generally available during the 1990s. In some cases this consisted of 1990 data developed by the California Department of Water Resources (DWR) as part of the most recent California Water Plan Update, Bulletin 160-93. In other cases, the most recent study containing summary information in the form of tables, graphs, maps, and charts was used.

1.1 REGULATORY CONTEXT

California does not have a statewide program for the management of groundwater. Groundwater management is a local responsibility which 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
- AB 3030
- City and county ordinances

1.2 GROUNDWATER MANAGEMENT

The legal and institutional environment governing development of groundwater management projects is an increasingly complex maze that must be negotiated. CALFED is seeking to work cooperatively with local interests as they develop groundwater management plans, contemplate local regulation of water exports, and seek solutions to water and environmental management problems. The implementation of groundwater management programs is dependent on identifying and addressing these complex issues surrounding groundwater management and potential third-party impacts. Appropriate and effective groundwater management will be essential to the success of the CALFED Bay-Delta Program. CALFED has initiated a groundwater outreach component to help identify and address stakeholder concerns about groundwater use and management. This process involves the definition of key terms to facilitate discussions among stakeholders, development of guiding principles for CALFED groundwater management programs to ensure that local concerns and potential impacts are fully addressed prior to implementation, identifying stakeholder concerns, and development of strategies for mitigating the effects of these programs. Details of the CALFED groundwater outreach effort are discussed in the "Groundwater Technical Appendix: Environmental Impacts" companion document.

1.3 DELTA REGION

The Delta Region extends approximately from Sacramento in the north to Tracy in the south, and to Pittsburg to the west.

The groundwater hydrology of the Sacramento-San Joaquin Delta, as with the geology, is contiguous with that of the Sacramento River Basin. Large amounts of water are stored in thick sedimentary deposits in the Sacramento Valley groundwater basin. Groundwater is used intensively in some areas but only slightly in areas where surface water supplies are abundant.

1.4 BAY REGION

Imported surface water from the CVP San Felipe Division is provided to areas in Santa Clara and San Benito Counties. Water conveyed to these areas is intended to supplement available supplies. Historically, these areas 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. In areas of limited groundwater supply, this has resulted in 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.

1.5 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. 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.

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 million acre-feet, and recent groundwater pumping in the Sacramento Valley basin was estimated to be near this perennial yield (California 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. The introduction of a water resources management program different than historical management activities can result in changes in this relationship, which would cause a change in stream accretions and depletions. Historically, the greatest gains to streams from groundwater occurred during the 1940s when groundwater storage was highest in the Sacramento Valley basin (Reclamation, 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, 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).

Land subsidence due to groundwater level declines has been identified in the southwestern part of the Sacramento River Region, near Davis and Zamora. By 1973 land subsidence in this area had exceeded approximately 1 foot, and was reported to be approximately 2.0 feet east of Zamora and west of Arbuckle (Lofgren and Ireland, 1973). Since 1973 limited monitoring of land subsidence has occurred, and some localized land subsidence has been reported in the Davis-Zamora area during the 1988 to 1992 drought period (Dudley, 1995). Groundwater quality is generally excellent, however, areas of local groundwater contamination or pollution exist.

In many reaches of the Sacramento River, flows are confined to a broad shallow man-made channel with stream bottom elevations higher than adjacent ground surface elevations. This condition can cause seepage-induced water logging on adjoining farmlands during extended periods of high streamflows, particularly in areas where local groundwater is in contact with the river. High groundwater tables also contribute to subsurface drainage problems in several areas of the Sacramento Valley Basin.

1.6 SAN JOAQUIN RIVER REGION

The southern two-thirds of the Central Valley regional aquifer system, which extends from just south of the Delta to just south of Bakersfield and covers over 13,500 square-miles, is referred to as the San Joaquin Valley basin. Sub-basins in the northern half of the San Joaquin Valley basin include the Tracy, San Joaquin County, Modesto, Turlock, Merced, Chowchilla, Madera, and Delta-Mendota sub-basins (DWR, 1975). Sub-basins in the southern half of the San Joaquin Valley basin include the Kings, Tulare Lake, Kaweah, Tule, Westside, Pleasant Valley, and Kern sub-basins (DWR, 1975). Much of the western portion of this area is underlain by the Corcoran Clay Member that divides the groundwater system into two major aquifers: a confined aquifer below the clay and a semi-confined aquifer above the clay.

Aquifer recharge to the semi-confined upper aquifer generally occurs from stream seepage, deep percolation of rainfall, and subsurface inflow along basin boundaries. Historically, 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. Historically, the interaction of groundwater and surface water in the San Joaquin River Region has resulted in net gains to the streams. This condition existed on a regional basis until 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 connections have 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 on a regional basis include the eastern San Joaquin and Merced Counties, and western Madera County. Other localized areas have also experienced similar changes.

Annual groundwater pumping in the northern San Joaquin River Region exceeds recent estimates of perennial yield by approximately 200,000 af (DWR, 1994). Historically, land subsidence resulting primarily from groundwater level declines has been a significant problem in the southern half of the San Joaquin River Region. From 1920 to 1970, approximately 5,200 square miles of irrigated land in the valley registered at least 1 foot of land subsidence (Ireland, 1986). Annual groundwater pumping in the basin exceeds DWR's most recent estimate of perennial yield by approximately 630,000 af (DWR, 1994). Historical groundwater level declines that occurred in many areas of the southern San Joaquin River Region have resulted in significant land subsidence over large areas. By the mid 1970s the use of imported surface water in the western and southern portions of San Joaquin Valley essentially halted the progression of land subsidence. During the 1976-1977 and 1987-1992 droughts, however, land subsidence was again observed in areas previously affected due to renewed high groundwater pumping rates.

Groundwater zones commonly used along portions of the western margin of the valley have high concentrations of total dissolved solids (TDS), ranging from 500 mg/l to greater than of 2,000 mg/l (Bertoldi et al., 1991). The concentrations in excess of 2,000 mg/l commonly occur above the Corcoran clay layer. These high levels have impaired groundwater use for irrigation and municipal uses in the western portion of San Joaquin County.

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.

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 water logging to low-lying farmland. In the western portion of the Stanislaus River watershed, groundwater pumping has historically been used for control of high groundwater and seepage conditions. Along the San Joaquin River from the confluence with the Tuolumne River through the South Delta, seepage-induced waterlogging damage to low-lying farmland occurs during periods of high flows, such as during flood control operations in the spring. The seepage-induced waterlogging prevents cultivation of the land until the summer months, and can affect annual crop production levels.

1.7 SWP-CVP SERVICE AREAS OUTSIDE THE CENTRAL VALLEY

The SWP-CVP service areas outside the Central Valley consist mainly of the Central Coast Service Area and the Southern California Service Area.

The Central Coast service area includes San Luis Obispo, Santa Barbara, Monterey, Santa Cruz, and San Benito counties. SWP service to this area involves completion of the Coastal Branch of the California Aqueduct. Groundwater is the main source of water supply. Overuse of the groundwater resources has led to groundwater level declines and water quality problems in some locations, such as the Santa Maria Valley, southern coastal Santa Barbara County, and Salinas Valley.

The Southern California service area includes Ventura, Los Angeles, and Orange counties and parts of San Diego, Riverside, Imperial, San Bernardino, and Kern counties. Groundwater supplies a significant portion of the water in this service area. Although further development is possible in a few local areas, some of the basins have been over-used.

II. INTRODUCTION

This chapter identifies the groundwater resources that could be affected by implementation of the CALFED alternatives. It has been prepared for use as background and support information for the Program Environmental Impact Statement/Environmental Impact Report (PEIS/EIR). Detailed site-specific information on all groundwater basins and subbasins potentially affected by CALFED is not included in this chapter. Rather, it 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 region. Distinguishing characteristics of this system are discussed for the Sacramento River and San Joaquin River regions. The discussion of groundwater conditions includes hydrogeology, groundwater hydrology, groundwater levels, land subsidence, groundwater quality, seepage-induced waterlogging of farm lands, and agricultural subsurface drainage (San Joaquin River Region only). Groundwater resources of the Delta, Bay, and SWP-CVP Service Areas Outside the Central Valley are also discussed in this chapter. The discussion of groundwater conditions for these areas is less detailed, and addresses hydrogeology, groundwater hydrology, and water quality.

III. SOURCES OF INFORMATION

Historical information, from approximately the 1920s forward, is based upon numerous regional studies and investigations that have been completed by federal, state, and local agencies. 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 this consisted of data developed by the DWR as part of the most recent California Water Plan Update, Bulletin 160-93. In other cases, the most recent study for the area was 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 the DWR. The discussion of land subsidence in the Santa Clara Valley is based on information provided in a 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 various reports published by the California Department of Pesticide Regulation (DPR), DWR, and Reclamation.

IV. ENVIRONMENTAL SETTING

4.1 STUDY AREA

The study area consists of groundwater-bearing regions of the Sacramento and San Joaquin valleys, the Sacramento-San Joaquin Delta (Delta), the San Francisco Bay (Bay), and SWP-CVP service areas outside the Central Valley. Groundwater resources are described at various levels of detail, with more emphasis on the Sacramento and San Joaquin valley regions. Theses 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.

This document is consistent with the goals of CALFED, the California Environmental Quality Act (CEQA), and the National Environmental Policy Act (NEPA), and reflects a level of detail appropriate for a programmatic approach to environmental review.

4.2 REGULATORY CONTEXT

4.2.1 Groundwater Management

California does not have a statewide program for the management of groundwater. Groundwater management is a local responsibility which 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
- AB 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 (e.g., 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.

There are 16 adjudicated groundwater basins in California. In 14 of these basins the court judgment 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.

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.

4.2.2 Groundwater Protection

California has various statewide and local groundwater protection mechanism. These mechanisms are primarily based on the implementation of various 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 regards to issues that could be threatening to groundwater resources in California.

Some of the groundwater quality information presented in this report has been summarized from data maintained by these agencies. Following the PEIS/EIR, the CALFED Bay-Delta Program may require more detailed investigations of groundwater conditions, requiring additional data collection and analysis beyond that conducted for this program document. These agencies would be heavily relied upon for this site-specific information.

The general roles and responsibilities of the agencies are summarized below.

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 (RWQCB) have the primary responsibility to preserve and enhance the quality of California's water resources, and assure their proper allocation

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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 RWQCB 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 Maximum Contaminant Levels (MCLs) for contaminants in drinking water, including pesticides.

Department of Water Resources. The Department of Water Resources (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.

4.3 GROUNDWATER MANAGEMENT PROGRAMS AND DEFINITIONS

The legal and institutional environment governing development of groundwater management projects is an increasingly complex maze that must be negotiated. CALFED is seeking to work cooperatively with local interests as they develop groundwater management plans, contemplate local regulation of water exports, and seek solutions to water and environmental management problems. The implementation of groundwater management programs is dependent on identifying and addressing these complex issues surrounding groundwater management and potential third-party impacts.

4.3.1 Groundwater Outreach Program

Appropriate and effective groundwater management will be essential to the success of the CALFED Bay-Delta Program. CALFED has initiated a groundwater outreach component to help identify and address stakeholder concerns about groundwater use and management. Part of this process involves the development of guiding principles for CALFED groundwater management programs to ensure that local concerns and potential impacts are fully addressed prior to implemention, identifying stakeholder concerns, and development of strategies for mitigating the effects of these programs.

For additional information of the CALFED groundwater outreach effort, refer to the "Groundwater Technical Appendix: Environmental Impacts" companion document.

4.3.2 Definitions of Common Terms

There has been much discussion in recent years about the terms used to describe various aspects of groundwater management in California. To facilitate a dialog among stakeholders, the groundwater outreach program is also in the process of defining key terms to facilitate these discussions. Definitions proposed by CALFED and DWR are presented below:

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

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.

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 since it may result in overdraft conditions as defined above, and also 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 shall be 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.

4.3.3 Examples of Groundwater Management

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.

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 1900s. Table IV-1 lists several examples of on-going programs in the Bay, the Sacramento River, and the San Joaquin River regions, and SWP-CVP Service Areas outside of these regions. Given the large number of groundwater management efforts in these areas, it is not possible to include all programs. The intent of this list is to demonstrate the range of activities and to emphasize the tremendous groundwater management efforts already underway.

Table IV-1 also list 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.

These potential programs share many common goals, and may overlap in various ways. It should be recognized that water supply benefits associated with multiple proposed large-scale programs in a given region are not necessarily additive. As the evaluation of these types of programs continues, additional effort will be required to identify common goals, streamline redundancies, and reconcile discrepancies. This process will require extensive coordinated among parties and stakeholders involved in the programs. Efforts to disseminate information should be made through public forums, and open discussions and exchange of information should be

TABLE IV-1
EXAMPLES OF CURRENT AND POTENTIAL REGIONAL GROUNDWATER MANAGEMENT

Areas with Groundwater Management Activities (1)	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, and water banking
Kern County	Conjunctive use of groundwater and imported/local surface water, and water banking
SWP-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/Richvale Irrigation District	Conjunctive use of groundwater and local surface water
CALFED Potential Sites (2)	Conjunctive use of groundwater and imported/local surface water, and water banking
Urban-Ag (3)	Conjunctive use of groundwater and imported/local surface water, and water banking
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, and water banking
CALFED Potential Sites (2)	Conjunctive use of groundwater and imported/local surface water, and water banking
Urban-Ag (3)	Conjunctive use of groundwater and imported/local surface water, and water banking
SWP-CVP Service Areas Outside the Central Valley	
Metropolitan Water District of Southern California	Expansion of current conjunctive use programs and implementation of additional programs

(1) The Delta Region is not listed separately since many of the present and potential programs listed for other regions require coordinated management of water supplies associated with the Delta region.

(2) 17 conjunctive use sites identified. See Preliminary Working Draft, CALFED Bay-Delta Program Storage and Conveyance Component Inventories, February, 1997. CALFED exploring additional conjunctive use projects.

(3) 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 agree to with upstream water interests. The agreement might or might not involve conjunctive use.

encouraged in order to formulate the most effective and comprehensive programs.

4.4 GROUNDWATER RESOURCES OF THE DELTA REGION

The Delta Region, shown in Figure IV-1, extends approximately from Sacramento in the north to Tracy in the south, and to Pittsburg to the west.

4.4.1 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 both 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; 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.

4.4.2 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 which locally are confined 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 impacting agricultural activities.

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

4.4.3 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.

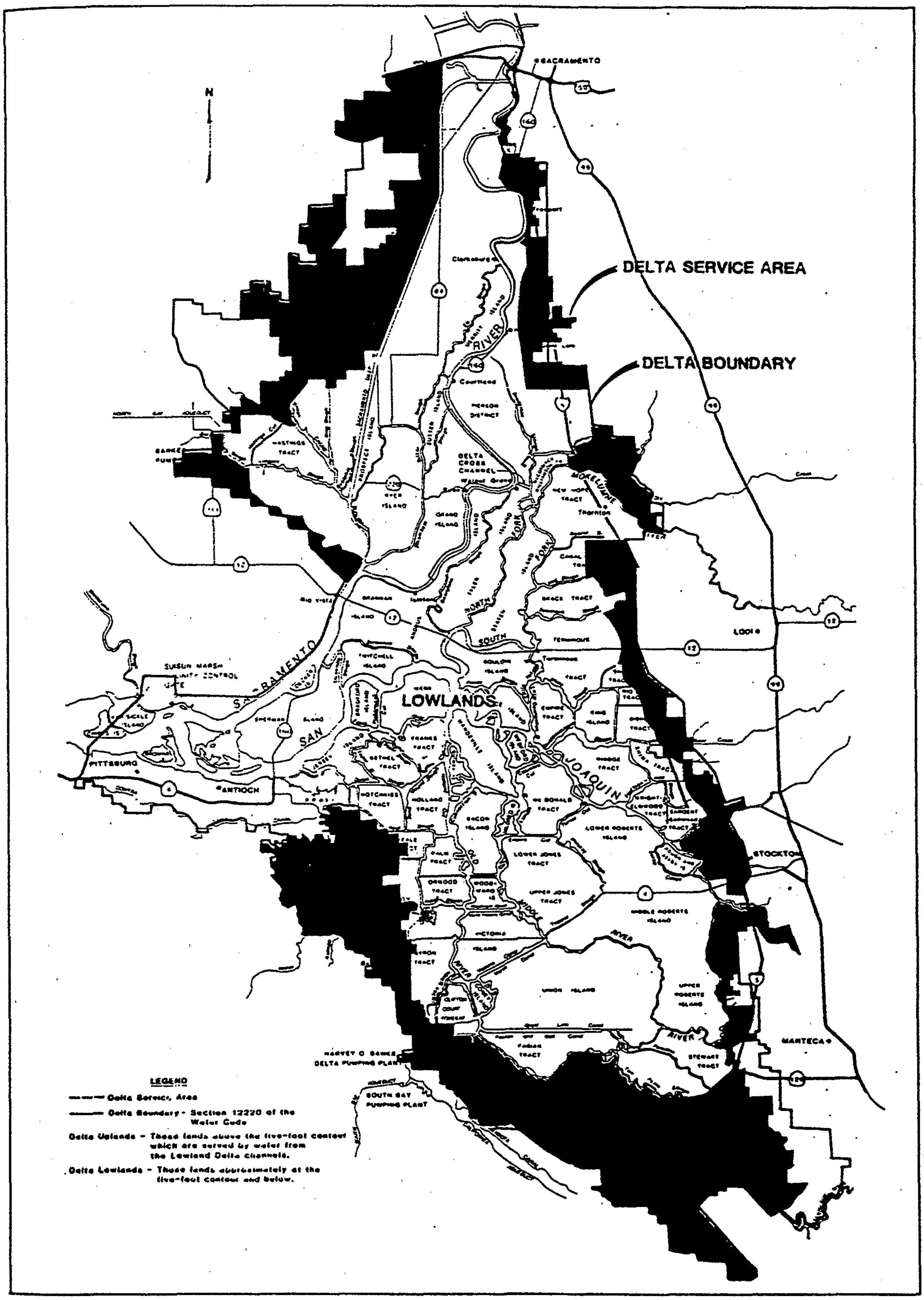

FIGURE IV-1
STATUTORY DELTA SERVICE AREA

4.5 GROUNDWATER RESOURCES OF THE BAY REGION

The Bay Region, shown in Figure IV-2, including Suisun, San Pablo, Central and South bays, extends about 85 miles from the east end of Chipps Island, near the City of Antioch westward and southward to the mouth of Coyote Creek, near the City of San Jose. Nine counties surround the Bay Region: Marin, San Francisco, San Mateo, Santa Clara, Alameda, Contra Costa, Solano, Napa, and Sonoma.

4.5.1 Hydrogeology

San Francisco, San Pablo, and Suisun bays are shallow, with about 85 percent 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 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. However, a significant percentage, especially in the South Bay, is through artificial recharge facilities and incidental recharge from irrigation (DWR, 1994).

4.5.2 Groundwater Hydrology

Groundwater subbasins for the Bay Region have been defined by DWR (subbasin boundary map to be provided in final draft) and are summarized in Table IV-2. From subbasin to subbasin, development of groundwater for irrigation, domestic, industrial, and stock uses varies from minor to intensive (DWR, 1975). Table IV-2 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 region are estimated to be 190,000 acre-feet. For 1992, drought supplies (including dedicated natural flow) were 28 percent 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 present condition of groundwater levels in the North Bay indicate that these subbasins are not currently subject to overdraft. Estimated groundwater storage in these subbasins is 1.7 million acre-feet. Total groundwater storage in the South Bay is estimated to be 6.5 million acre-feet. Groundwater subbasins in the South Bay

TABLE IV - 2
SAN FRANCISCO BAY REGION GROUNDWATER RESOURCES

Basin/Region	Sub-basin	Extraction (1) (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 ACFWCD, Zone 7
	San Mateo County	13,408	None identified.

SOURCES:

California Water Plan Update Bulletin 160-93, October 1994.

LEGEND:

AF/yr = Acre-Feet per year

NOTES:

(1) 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

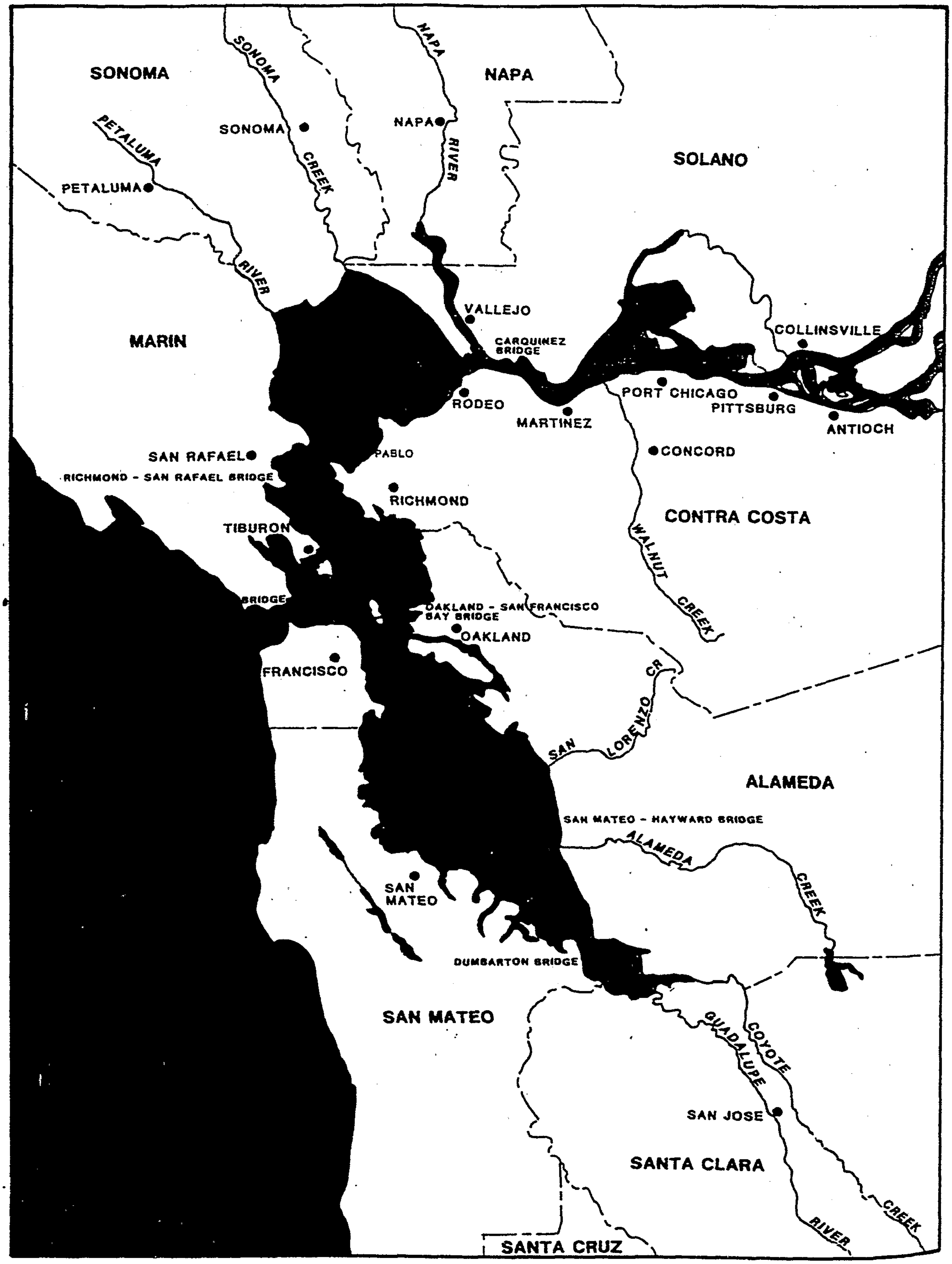

FIGURE IV-2
BAY REGION

have been intensively developed for domestic, industrial, and irrigation needs, and historical groundwater extractions in excess of groundwater recharge has resulting 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 subbasins. These efforts have mitigated or eliminated low groundwater level problems (DWR, 1994).

4.5.3 Groundwater Quality

Groundwater quality varies throughout the Bay Region. 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. However, Santa Clara Valley Water District has an extensive groundwater protection program to administer cleanup operations and to prevent degradation of the groundwater basin through well sealing and groundwater quality monitoring (DWR, 1994).

4.6 GROUNDWATER RESOURCES OF THE SACRAMENTO RIVER REGION

The northern third of the Central Valley regional aquifer system is located in the Sacramento River Region. Referring to Figure IV-3, this region extends from north of Redding to the Sacramento-San Joaquin Delta (Delta) in the south. DWR identifies this area of the aquifer as the Sacramento Valley basin and the Redding basin (California DWR, 1975), together covering over 5,500 square-miles. For the purposes of this technical appendix, references made to the Sacramento Valley basin are assumed to include the Redding basin.

4.6.1 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 flood plain 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 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

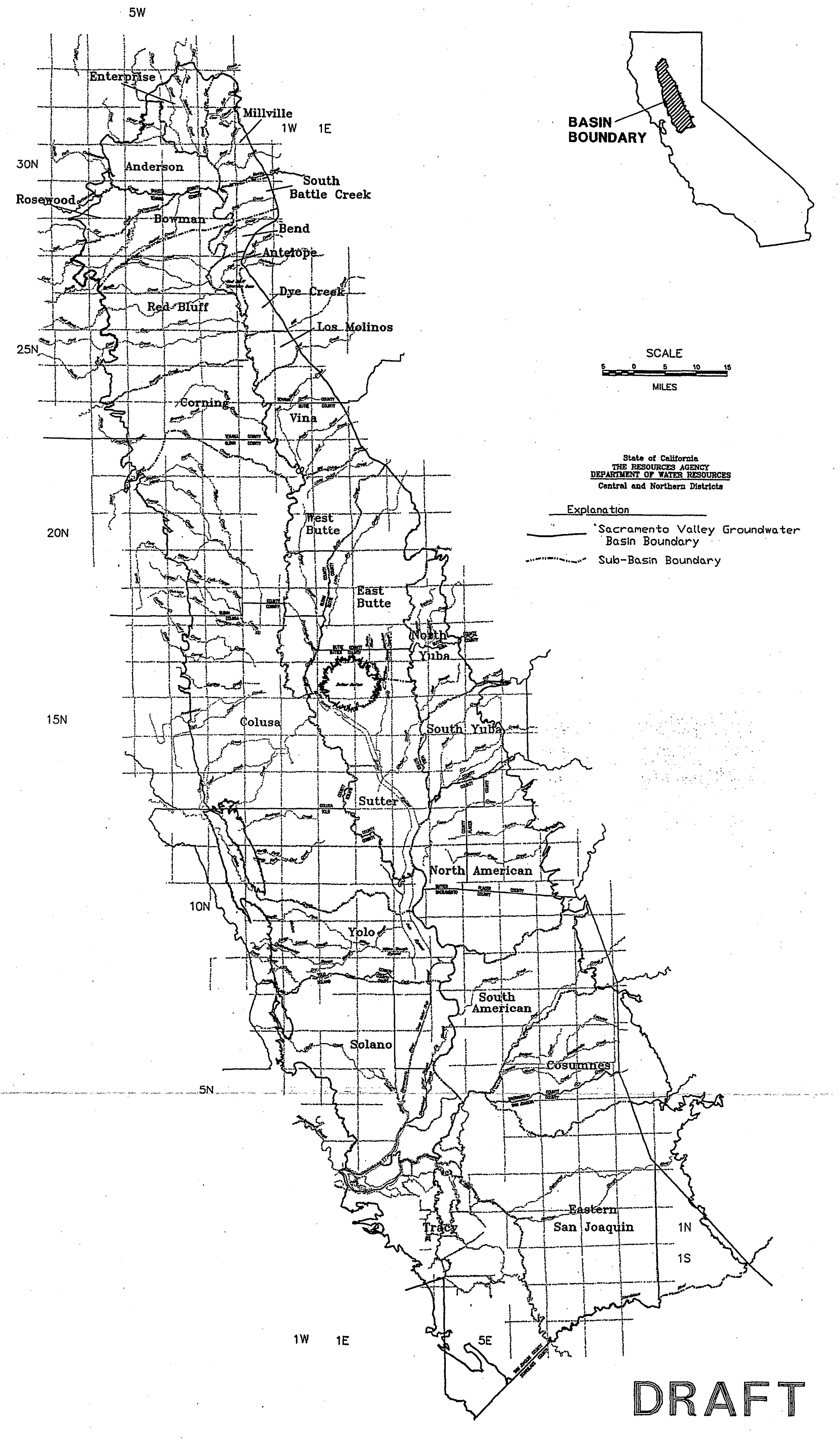

FIGURE IV-3
SACRAMENTO VALLEY
GROUNDWATER SUB-BASIN
BOUNDARIES

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; and (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; Freeze and Cherry, 1979).) This later condition is more prevalent in the Sacramento River Region.

Many streams in this region have historically been gaining streams, a condition where groundwater is discharged into the stream. 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 changes in climatic conditions, and land and water use practices cause groundwater levels to rise and fall.

Historically, the greatest gains to streams from groundwater occurred during the 1940s when groundwater storage was highest in the Sacramento Valley basin (Reclamation, 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, 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 within Sacramento, Yolo, and Solano counties, groundwater movement is now toward areas of groundwater depression.

4.6.2 Groundwater Hydrology

There have been several estimates of the amount of groundwater associated with the Sacramento Valley basin. The USGS estimated approximately 33.5 million af 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 to be 40 million acre-feet (California 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, DWRs definition is based on aquifer properties (i.e. permeability), groundwater quality, and economic considerations such as the cost of well drilling and energy costs (California DWR, 1994). The USGS estimates are considered to be conservative since 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 under Section 4.3.2). Perennial yield is directly dependent upon 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 perennial yield, of the Sacramento Valley basin. The estimates vary depending upon 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 million acre-feet. This perennial yield is directly dependent upon the estimate of recharge received by the groundwater basins, which may be different in the future than it has been in the past.

Groundwater extractions for subbasins defined by DWR for the Sacramento River Region (Figure IV-3) are summarized in Table IV-3. Estimates of groundwater extractions by DWR 1990 normalized conditions suggest that 2.6 million acre-feet of groundwater pumping occurred in the region (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).

4.6.3 Groundwater Levels

In the Sacramento River Region, groundwater levels associated with the Sacramento Valley basin have historically 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 upon the extent of the wet period.

Between the early 1900s and the 1950s groundwater levels fluctuated in response to varied climatological conditions as well as increased groundwater development. In the fall of 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. However, south of the Sutter Buttes groundwater levels in several areas of Yolo, Solano, and Sacramento counties had dropped nearly 50 feet since the early 1900s, 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 the spring of 1974 (reported by Reclamation) had increased between 1960

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TABLE IV-3
SACRAMENTO RIVER REGION GROUNDWATER RESOURCES

Basin/Region	Sub-basin	Extraction (1) (AF/yr)	Management Status of Basin
Redding Basin	Anderson	29,600	Redding Area Water Committee; Tehama County Flood Control and Water Conservation District.
	Bowman	1,200	Redding Area Water Committee; Tehama County Flood Control and Water Conservation District.
	Enterprise	13,100	Redding Area Water Committee; Tehama County Flood Control and Water Conservation District.
	Millville	7,600	Redding Area Water Committee; Tehama County Flood Control and Water Conservation District.
	South Battle Creek	2,600	Redding Area Water Committee; Tehama County Flood Control and Water Conservation District.
	Rosewood	1,200	Redding Area Water Committee; Tehama County Flood Control and Water Conservation District.
Sacramento Valley Basin	Antelope	14,200	Tehama County Flood Control and Water Conservation District.
	Bend	200	Tehama County Flood Control and Water Conservation District.
	Corning	97,800	Tehama County Flood Control and Water Conservation District; Orland Unit Water Users' Association.
	Dye Creek	14,200	Tehama County Flood Control and Water Conservation District.
	Los Molinos	14,400	Tehama County Flood Control and Water Conservation District.
	Red Bluff	117,100	Tehama County Flood Control and Water Conservation District.
	Vina	145,400	Butte Basin Water User Association.
	Colusa	442,900	Knights Landing WUA; Orland Unit WUA; Cortina Creek FC&WCD; Colusa County FC&WCD; Yolo
	West Butte	146,000	Butte Basin Water Users' Association; Water Code Section 10750.
	East Butte	239,200	Butte Basin Water Users' Association; Water Code Section 10750.
	Palermo	42,500	Butte Basin Water User Association.
	Yolo	144,800	Local planning has begun.
	Solano	122,500	City of Vacaville adopted AB3030 plan.
	Sutter	174,900	Planning under Water Code Section 10750 has begun.
	North Yuba	74,800	Planning under Water Code Section 10750 has begun.
	South Yuba	99,400	Planning under Water Code Section 10750 has begun.

TABLE IV - 3 (CONTINUED)
SACRAMENTO RIVER REGION GROUNDWATER RESOURCES

Basin/Region	Sub-basin	Extraction (1) (AF/yr)	Management Status of Basin
Sacramento Valley Basin (continued)	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.

SOURCES:

California Department of Water Resources, Groundwater Basin Inventory, Preliminary Data, May 1997.

LEGEND:

AF/yr = Acre-Feet per year

NOTES:

(1) 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

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 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 groundwater development also resulted in groundwater level declines between 1960 and 1974.

Groundwater levels for spring 1986 (reported by DWR) indicate little change north and east of the Sutter Buttes since 1974. However, south of the Sutter Buttes 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 IV-4. 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 occurring during the 1992-1993 winter months resulted in near full recovery of groundwater levels to pre-drought (1987-92) conditions.

4.6.4 Land Subsidence

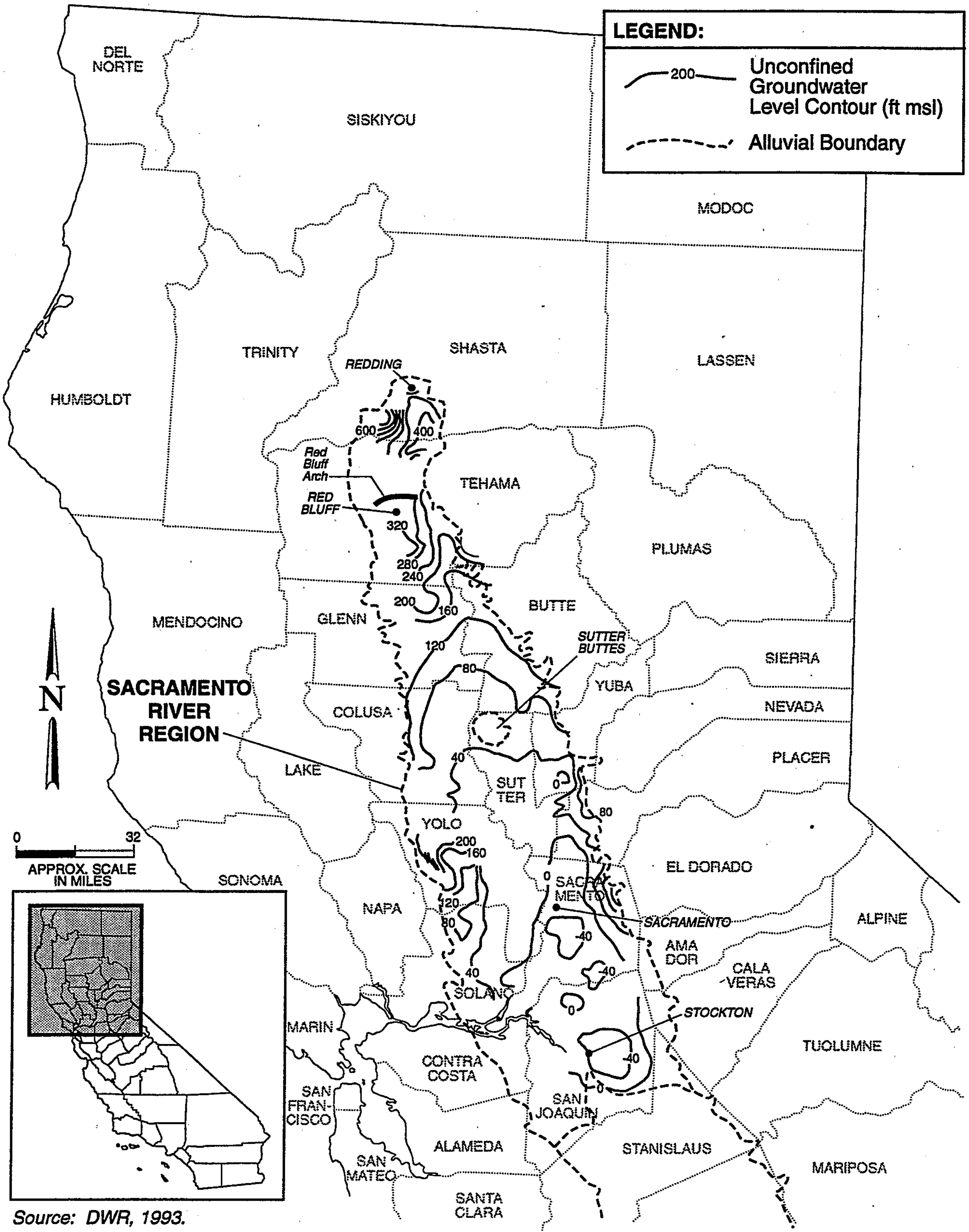
The largest occurrence of land subsidence in the world induced by human activity occurs in California's Central Valley (Bertoldi et al., 1991). The areal extent of this land subsidence is shown in Figure IV-5. The primary land subsidence occurring in the Central Valley corresponds to areas where groundwater levels have declined significantly due to mining of groundwater.

Areas using groundwater supply for irrigation are much less extensive in 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. Consequently, 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, and some localized land subsidence has been recorded in the Davis-Zamora area during the 1987 to 1992 drought period (Dudley, 1995).

4.6.5 Groundwater Quality

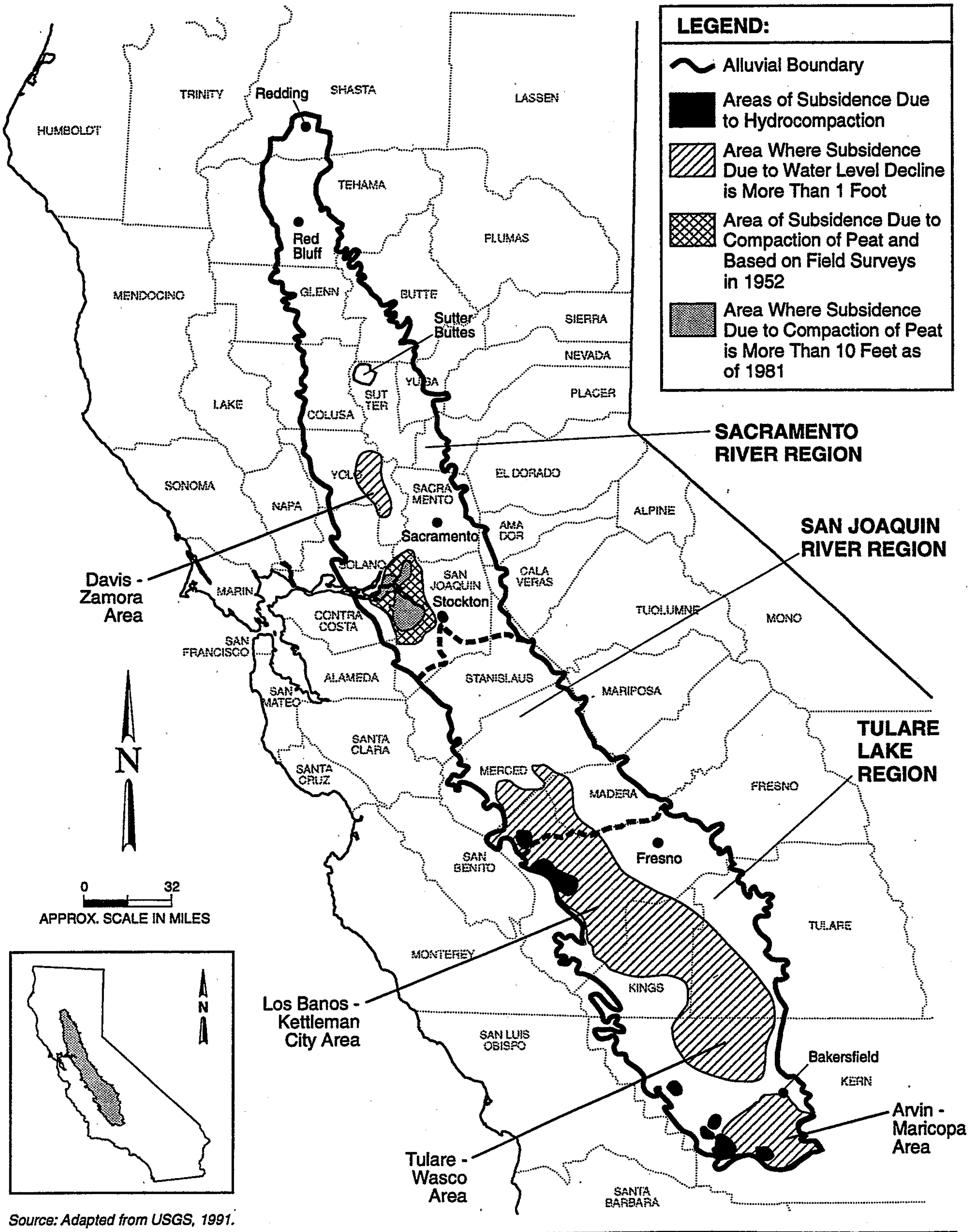
Groundwater quality is generally excellent throughout the Sacramento Valley and is suitable for most uses. Concentration of TDS is normally less than 300 mg/L,



Source: DWR, 1993.

FIGURE IV-4

GROUNDWATER LEVELS IN THE SACRAMENTO VALLEY, SPRING 1993



Source: Adapted from USGS, 1991.

FIGURE IV-5

AREAL EXTENT OF LAND SUBSIDENCE IN THE CENTRAL VALLEY

C—0 0 2 3 9 7

although water in some areas may contain TDS to 1500 mg/l. The California Department of Health Services (DHS) has set secondary drinking water standards for TDS at 500 mg/l (maximum contaminant level, or MCL), however, short-term levels up to 1500 mg/l are considered acceptable (California Regional Water Quality Control Board, 1993). Agricultural water quality goals are set at 450 mg/l (Ayers, R. S., and W. 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 1500 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.

Nitrates can enter the groundwater through the conversion of naturally occurring or introduced organic nitrogen or ammonia. The DHS primary drinking water standard is 45 mg/l (MCL) as nitrates. 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 (California SWRCB, 1991).

The DHS has designated secondary drinking water standards for iron and manganese at 300 µg/l and 50 µg/l (MCL) respectively. Agricultural water quality goals are also set at 5000 µg/l and 200 µg/l for iron and manganese respectively (Ayers, R. S., and W. Westcot, 1985). In some wells in Butte, Sutter, and Colusa basins, iron and manganese do exceed secondary drinking water standards (California SWRCB, 1991). In the southern Sacramento Valley basin, iron and manganese have exceeded secondary drinking water limits in some wells (California, 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 widespread problem in Butte Basin, although atrazine, bentazon, 2,4-D, dichloroprop, and DDE have all been detected. In Sutter County, widespread contamination of groundwater was limited to bentazon and dibromochloropropane. 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 west of the Yolo Bypass, four locations have contaminated groundwater.

4.6.6 Seepage and Waterlogging

In many reaches of the Sacramento River, flows are confined to a broad shallow man-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 months, when crop roots are susceptible to damage by high groundwater and when farmers need to get equipment on the fields. DWR has conducted an in-depth investigation of the seepage problem, reported in Bulletin 125. The report contains curves relating crop damage to river flow for three reaches of the Sacramento River. Alternatives for mitigating the seepage problem were presented and evaluated at a reconnaissance level (California DWR, 1967). In 1976 and 1977 Reclamation updated the 1965-level cost estimates presented in Bulletin 125 and conducted a reconnaissance-level evaluation of methods of resolving the problem (Reclamation, 1976a) (Reclamation, 1977). To date none of these alternatives have been implemented.

4.7 GROUNDWATER RESOURCES OF THE 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 IV-6).

4.7.1 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 zero 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 (Muir, 1977):

> "...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."

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.

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 have 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 the eastern San Joaquin and Merced counties, and western Madera County, as well as 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 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, has resulted in greater groundwater level declines, which has caused a change in stream-aquifer dynamics. In the period of predevelopment, the interaction was very dynamic with water exchanged in both directions depending upon 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 the 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, are also 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) were all 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 towards areas of lower groundwater levels due to groundwater pumping (Bertoldi et at., 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.

4.7.2 Groundwater Hydrology

In DWR's Bulletin 160-93 usable storage capacity for the San Joaquin River Region was estimated to be approximately 24 million acre-feet in the northern half and 28 million acre-feet 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 million acre-feet of perennial yield in the northern part and 4.6 million acre-feet of perennial yield in the southern part of the region (DWR, 1994). These estimates of perennial yield are directly dependent upon 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 subbasins defined by DWR for the San Joaquin River Region (subbasin boundary map to be provided in final draft) are summarized in Table IV-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 million acre-feet (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). The DWR estimated 1990 groundwater extractions for 1990 normalized conditions in the southern half of the San Joaquin River Region to be 5.6 million acre-feet.

4.7.3 Groundwater Levels

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

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). 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 (reported by DWR) 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 1976-1977 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 1987-1992 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).

Recent groundwater conditions, observed following the drought, for spring 1993 are shown in Figure IV-6. 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 also 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 groundwater level high occurs in northern Kings County. These

TABLE IV - 4
SAN JOAQUIN RIVER REGION GROUNDWATER RESOURCES

Basin/Region	Sub-basin	Extraction (1) (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 AB3030 plans.
	Turlock	452,000	Adoption of AB3030 plans.
	Merced	555,000	None identified.
	Chowchilla	255,000	Discussions of AB3030 underway.
	Madera	565,000	Discussions of AB3030 underway.
	Delta-Mendota	511,000	AB3030 pending; Joint plan between local districts to be developed.
Tulare Lake Basin	Kings	1,790,000	Adoption of AB3030 plans.
	Tulare Lake	672,000	Management by local water districts.
	Kaweah	758,000	Implemented AB255 and AB3030 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 AB255 and AB3030 plans .

SOURCES:

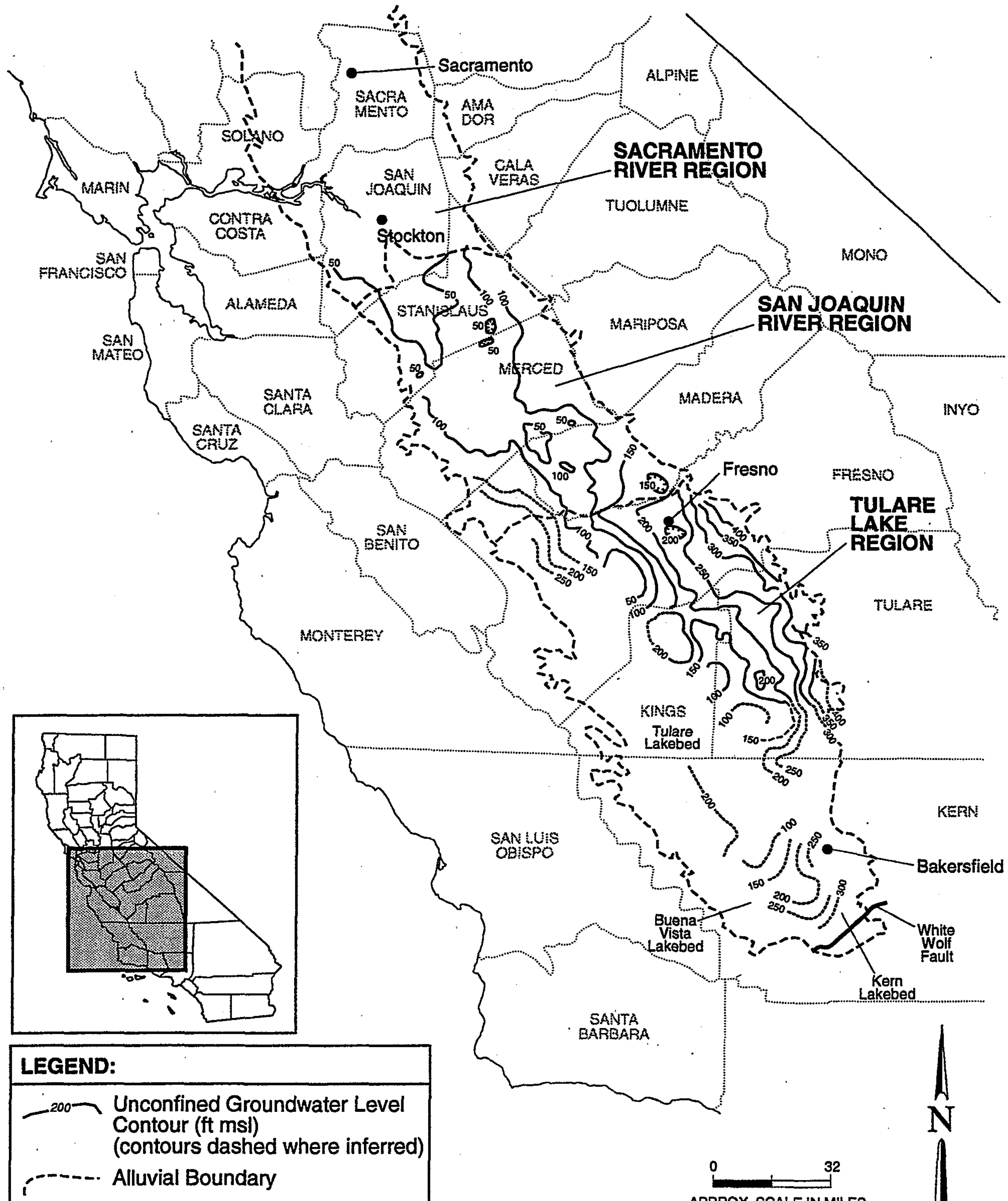
California Department of Water Resources, Groundwater Basin Inventory, Preliminary Data, May 1997.

LEGEND:

AF/yr = Acre-Feet per year

NOTES:

(1) 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, 1993.

FIGURE IV-6

GROUNDWATER LEVELS IN THE SAN JOAQUIN VALLEY, SPRING 1993

groundwater levels are indicative of depleted conditions due to regional groundwater withdrawals resulting from the 1987-1992 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 five years following the 1976-1977 drought.

4.7.4 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).

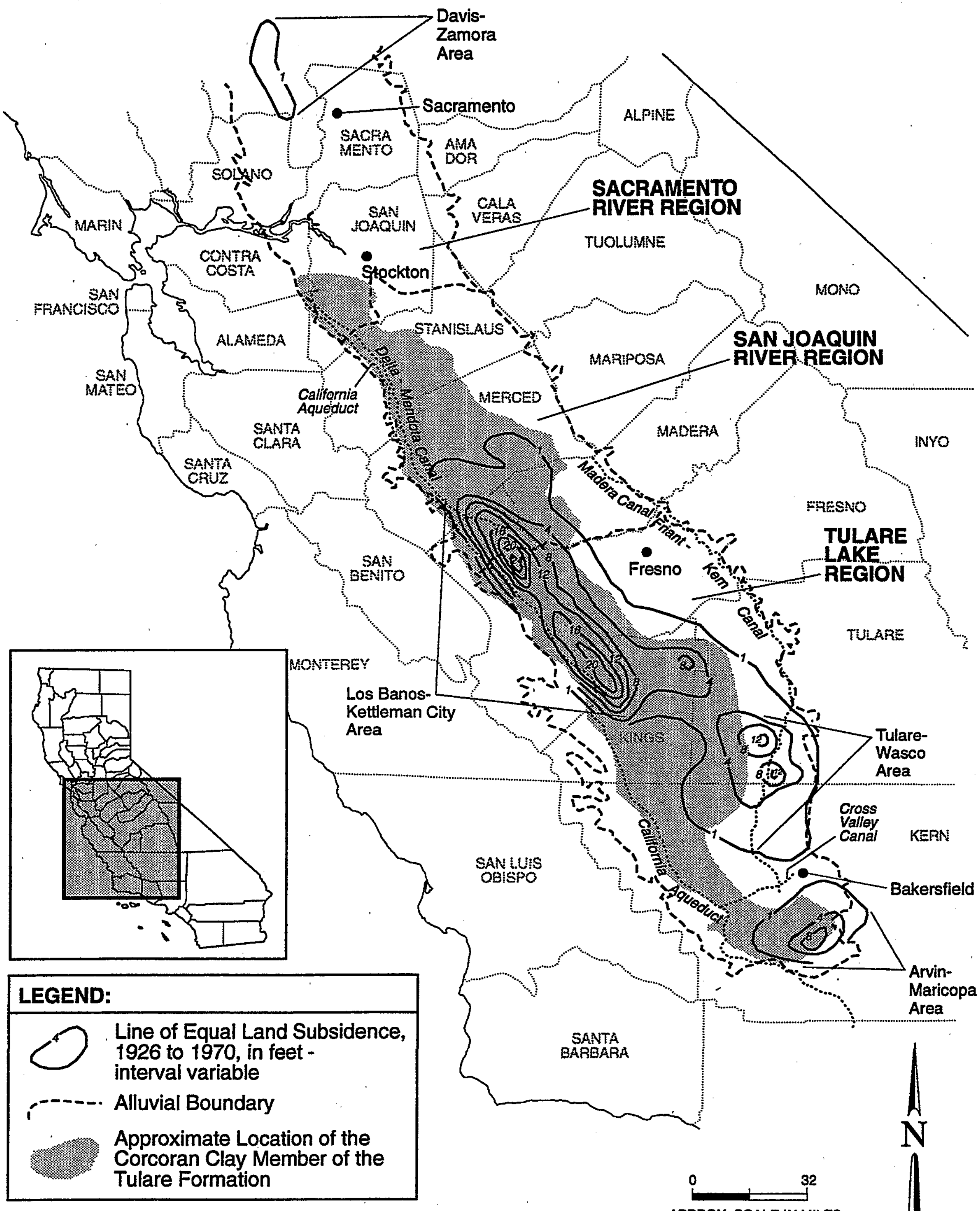
Because of the slow drainage of the fine-grained deposits, subsidence at a particular time is more closely related to past water-level change than to current change. For example, in the San Joaquin Valley, groundwater withdrawals increased greatly until large imports of surface water through various canals occurred, but even though water levels in the area started to rise, the rate of subsidence began to decrease three 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 IV-7 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 IV-7. 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 IV-7 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 has also 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. After nearly two decades of little or no land subsidence, significant land subsidence has been recently detected in the San Joaquin Valley due to increased groundwater pumping during the 1987-1992



Source: Adapted from USGS, 1989.

FIGURE IV-7

AREAL EXTENT OF LAND SUBSIDENCE IN THE CENTRAL VALLEY DUE TO GROUNDWATER LEVEL DECLINE

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 2.0 feet of land subsidence was measured (Central California Irrigation District, 1996). Measured land subsidence by DWR between 1990 and 1995 of up to 2.0 feet was reported along the California Aqueduct in Westlands Irrigation District (Dudley, 1995).

4.7.5 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 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 are generally 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).

Arsenic is a naturally occurring trace element in the Central Valley. Arsenic is regulated by the USEPA at a primary drinking water quality standard of 50 µg/l.

It can be toxic to both plants and animals. For irrigation use, the guidelines recommend that arsenic concentrations not exceed 1,000 μg/l. 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). Although selenium is currently regulated by federal primary drinking water standards at an MCL of 50 μg/l, USEPA 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 10 and 26 μg/l from Sack Dam to the mouth of the Merced River (SWRCB, Central Valley Region, 1992). 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 (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 dibromochloropropane (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.

4.7.6 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 Regions. A detailed time line for these west side drainage problems is presented in

Table IV-5.

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.

4.7.7 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 farm land. In the western portion of the Stanislaus River watershed, groundwater pumping has historically been used for control of high groundwater levels and seepage-induced waterlogging conditions. 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 has 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 and 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 fee 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, 1996).

4.8 GROUNDWATER RESOURCES OF THE SWP-CVP SERVICE AREAS OUTSIDE THE CENTRAL VALLEY

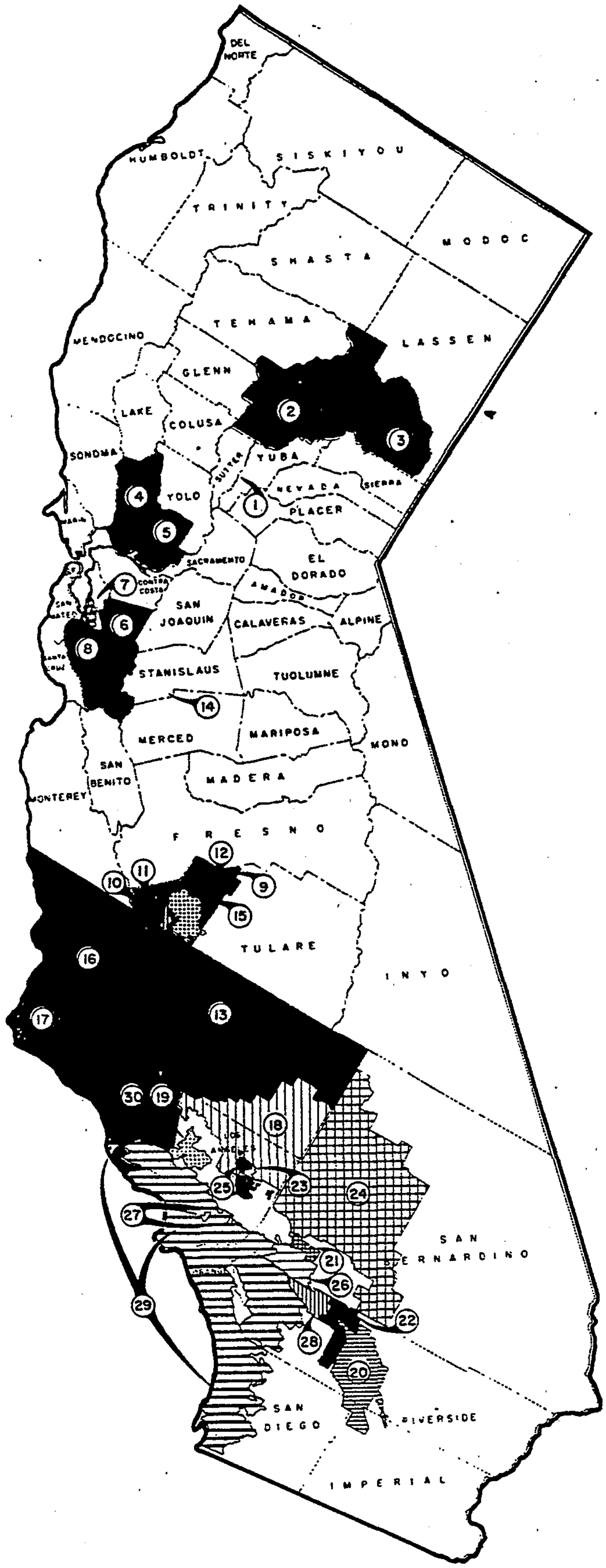
The 30 long-term water supply contractors of the SWP are organized into six service areas: Feather River, North Bay, South Bay, Central Coast, San Joaquin Valley, and Southern California, and are shown in Figure IV-8. The CVP service areas are shown in Figure IV-9. The groundwater resources of the Central Coast and Southern California service areas are discussed below.

TABLE IV-5

EVENTS AFFECTING DRAINAGE CONDITIONS ON THE WEST SIDE OF THE SAN JOAQUIN VALLEY

Year	Event
1870s	Widespread planting of 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	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 River water that was diverted at Friant Dam to the southern 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 in the Delta and San Francisco Bay. A rider was added to CVP appropriations 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 USEPA.
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 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 completed.
	Budget and environmental concerns halt work on the reservoir and drain.
	Reclamation, DWR, and SWRCB formed the San Joaquin Valley Interagency Drain Program 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 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 has been 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.



Location No.	Contracting Agency	Maximum Annual Entitlement (acre-feet)
	UPPER FEATHER AREA	
1	City of Yuba City	9,600
2	County of Butte	27,500
3	Plumas County Flood Control and Water Conservation District	2,700
	Subtotal	39,800
	NORTH BAY AREA	
4	Napa County Flood Control and Water Conservation District	25,000
5	Solano County Flood Control and Water Conservation District	42,000
	Subtotal	67,000
	SOUTH BAY AREA	
6	Alameda County Flood Control and Water Conservation District, Zone 7	46,000
7	Alameda County Water District	42,000
8	Santa Clara Valley Water District	100,000
	Subtotal	188,000
	SAN JOAQUIN VALLEY AREA	
9	County of Kings	4,000
10	Devil's Den Water District	12,700
11	Dudley Ridge Water District	57,700
12	Empire West Side Irrigation District	3,000
13	Kern County Water Agency	1,153,400
14	Oak Flat Water District	5,700
15	Tulare Lake Basin Water Storage District	118,500
	Subtotal	1,355,000
	CENTRAL COASTAL AREA	
16	San Luis Obispo County Flood Control and Water Conservation District	25,000
17	Santa Barbara County Flood Control and and Water Conservation District	45,486
	Subtotal	70,486
	SOUTHERN CALIFORNIA AREA	
18	Antelope Valley-East Kern Water Agency	138,400
19	Castaic Lake Water Agency	41,500
20	Coachella Valley Water District	23,100
21	Crestline-Lake Arrowhead Water Agency	5,800
22	Desert Water Agency	38,100
23	Littlerock Creek Irrigation District	2,300
24	Mojave Water Agency	50,800
25	Palmdale Water District	17,300
26	San Bernardino Valley Municipal Water District	102,600
27	San Gabriel Valley Municipal Water District	28,800
28	San Gorgonio Pass Water Agency	17,300
29	The Metropolitan Water District of Southern California	2,011,500
30	Ventura County Flood Control District	20,000
	Subtotal	2,497,500
	TOTAL STATE WATER PROJECT	4,217,786

FIGURE IV-8
SWP SERVICE AREAS AND CONTRACTING AGENCIES

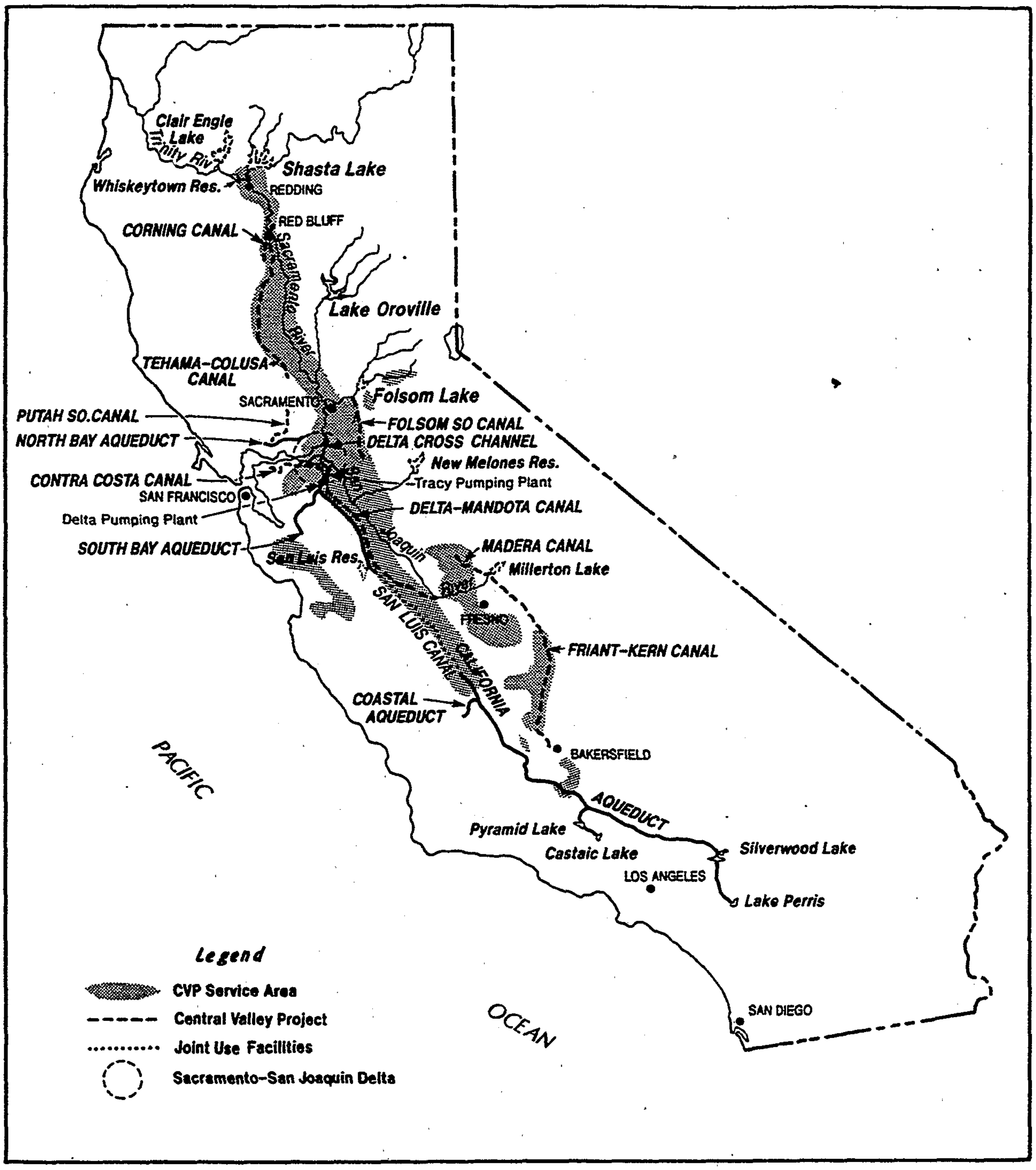


FIGURE IV-9
CVP AND ITS SERVICE AREAS

4.8.1 Groundwater Resources in the Central Coast Service Area

Although 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 subbasins for the Central Coast have been defined by DWR (subbasin boundary map to be provided in final draft) and are summarized in Table IV-6. Recent estimates of groundwater extractions are al:o shown in Table IV-6 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 Central Coast area are estimated to be 1.1 million acre-feet.

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

4.8.2 Groundwater Resources of the Southern California Service Area

The Southern California 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 IV-6 for groundwater subbasins associated

TABEL IV - 6

GROUNDWATER RESOURCES OF SWP-CVP SERVICE AREAS OUTSIDE CENTRAL VALLEY

Basin/Region	Sub-basin	Extraction (1) (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	Monitoring program.
	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 Plain	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 management plan.
	Fox Canyon Groundwater Management Area	143,000	Managed by Fox Canyon Groundwater Management Agency; Ordinance prohibits export of groundwater; Ordinance reduces sea water intrusion.

TABEL IV - 6 (CONTINUED)
GROUNDWATER RESOURCES OF SWP-CVP SERVICE AREAS OUTSIDE CENTRAL VALLEY

Basin/Region	Sub-basin	Extraction (1) (AF/yr)	Management Status of Basin
South Coast Region (continued)	Temecula Valley	25,000	Adjudicated.
	San Juan Valley	5,000	None identified (limited groundwater use)
	El Cajon Valley	500	None identified (limited groundwater use)
	Warner Valley	Unknown	None identified.
	San Luis Ray	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	Magement 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.

SOURCES:

California Water Plan Update Bulletin 160-93, October 1994.

California Department of Water Resources. Water Facts 3: Adjudicated Groundwater Basins in California, Jan 1996.

California Department of Water Resources. Water Facts 4: Groundwater Management Districts or Agencies in California, Jan 1996.

LEGEND:

AF/yr = Acre-Feet per year

NOTES:

(1) 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

with the three hydrologic study areas (subbasin boundary map to be provided in final draft).

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 have to 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. 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. 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 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. Historically, seawater has intruded into most coastal basins in this area. 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 waste water 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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PRELIMINARY DRAFT REPORT

ENVIRONMENTAL IMPACTS/CONSEQUENCES DRAFT TECHNICAL REPORT GROUNDWATER

Prepared for

CALFED
BAY-DELTA
PROGRAM

September 5, 1997

PREFACE

This intent of this technical appendix is to provide supporting documentation for the CALFED Bay-Delta Program PEIR/EIS. The document is in a preliminary draft form, reflecting work in progress. The contents are subject to change based on public and stakeholder input. During the review of this document questions may be directed to Roger Putty at (916) 921-3540 (voice), (916) 924-9102 (fax), or *roger.putty@us.mw.com* (E-mail). Please direct any formal comments to Stein Buer, Assistant Director, Technical Services Branch, CALFED Bay-Delta Program, 1416 Ninth Street, Suite 1155, Sacramento, California 95814. For general information regarding the CALFED Bay-Delta Program, or to request additional information or documentation, please call (916) 657-2666.

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***To be completed.**

****Partially completed.**

CALFED Bay-Delta Program
Environmental Impacts/Consequences
Groundwater

Groundwater is a crucial component of California's water supply, providing about 40 percent of the urban and agricultural water used in California. During drought years groundwater provides up to two-thirds of the water used. The purpose of this technical report is to provide a description of environmental impacts and consequences to groundwater as a result of CALFED Bay-Delta Program alternatives. This report is intended to provide additional information in support of the Programmatic Environmental Impact Report/Environmental Impact Statement (PEIR/EIS). A companion document titled "Draft Affected Environment Technical Report: Groundwater" discusses the environmental setting of groundwater in California for areas that may be affected by CALFED Bay-Delta Program alternatives.

I. SUMMARY

A summary of the environmental impact analysis of groundwater, resulting from proposed CALFED Bay-Delta Program actions, is summarized below for the study area. The study area consists of the Sacramento-San Joaquin Delta (Delta) Region, the San Francisco Bay (Bay) Region, the Sacramento River Region, the San Joaquin River Region, and SWP-CVP service areas outside the Central Valley.

1.1 SUMMARY OF GROUNDWATER OUTREACH PROGRAM

CALFED has initiated a groundwater outreach component to help identify and address stakeholder concerns about groundwater use and management with special emphasis on conjunctive use projects. Progress to date on the outreach program has included:

- Defining common terms to facilitate discussions among stakeholders
- Developing a better awareness of stakeholder concerns regarding potential impacts resulting from conjunctive use programs, and identifying critical questions regarding the implementation of these programs
- The development of draft guiding principles for conjunctive use programs to ensure that local concerns and potential impacts are fully addressed prior to implementing a conjunctive use operation
- Formulation of a committee to develop operating guidelines and principles for conjunctive use projects, consisting of representatives from the groups proposing to implement the projects, as well as members representing Sacramento and San Joaquin valley concerns
- The development of an approach that will be required to implement a CALFED-supported conjunctive use program

The CALFED Bay-Delta Program will continue to evaluate and modify its conjunctive use program with stakeholder contributions as the groundwater outreach program progresses.

CALFED will look for opportunities to help communities maximize their water supplies through voluntary conjunctive use programs that are operated at the local level. CALFED will also continue to refine the guiding principles by working with the conjunctive use committee to address and mitigate potential impacts prior to implementing a conjunctive use program.

1.2 SUMMARY OF PRELIMINARY MITIGATION STRATEGIES

Strategies for mitigating the effects of the CALFED Bay-Delta Program can be incorporated within the contract between the buying and selling parties. Such strategies should be aimed at detecting changes that are undesirable or unallowable and taking the appropriate steps to reduce their effects to acceptable levels or stopping the project. Groundwater management programs, including conjunctive use projects, should monitor and evaluate the following for changes:

- groundwater levels
- land surface elevation for potential subsidence
- groundwater quality
- streamflow

Threshold values for each of these parameters would be established by committee. The threshold values in each conjunctive use project should be reviewed periodically after evaluation of the data obtained from the monitoring program.

It is CALFED's position that conjunctive use projects should be thoroughly monitored, so that any detrimental impacts can be identified quickly, preferably during the pilot testing. The monitoring program would be tailored to fit the requirements and thresholds established by the local committee overseeing the project. Appropriate mitigation measures, ranging from reduction in pumping to cessation of the project, could then be implemented by the local committee.

1.3 SUMMARY OF NO ACTION GROUNDWATER CONDITIONS

The No Action Alternative represents conditions in the future assuming a projected 2020 level of development without implementation of CALFED actions, and provides a base condition for comparison with each of the CALFED alternatives. A summary of potential groundwater conditions under the No Action Alternative, as compared to existing conditions, is presented below for each region of the study area:

- Groundwater conditions in the Delta Region would be similar under the No Action Alternative conditions as compared to existing conditions.
- Under the No Action Alternative, increased demands in the Bay Region and SWP-CVP service areas outside of the Central Valley could result in increased pumping, depending upon the future availability of imported surface water supplies. This increased groundwater pumping could result in additional groundwater level declines, degradation of water quality, and possible land subsidence as compared to existing conditions. Because many of the groundwater basins in the SWP-CVP service areas outside the Central Valley are closely managed, it is likely that most groundwater impacts would

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occur in non-managed areas.

- Groundwater conditions in the Sacramento River Region under the No Action Alternative would be similar to existing conditions except for groundwater depressions in the Yolo and Sacramento county areas. In these areas, continued groundwater level declines, possible degradation of water quality, and possible land subsidence (Yolo County only) could occur.
- Groundwater conditions in the San Joaquin River Region could be impacted under the No Action Alternative, in comparison to existing conditions, as a result of increased pumping in response to greater demands on water supplies and uncertainty in terms of imported water supply. In areas where these surface water supplies become more limiting, groundwater pumping could increase above existing levels, resulting in additional groundwater level declines, degradation of water quality, and possible land subsidence.

1.4 SUMMARY OF GROUNDWATER IMPACTS OF CALFED COMMON PROGRAMS

The common programs include actions to restore the Delta ecosystem, improve water quality, improve the efficiency of water use, and restore the structural integrity of the levees. The common elements of the CALFED program could influence groundwater conditions through changes in streamflow, water and land use practices, and water quality.

Loss of agricultural land as a result of the levee system integrity program and the ecosystem restoration program could result in a reduction of deep percolation from the applied water used to irrigate these lands. The levee system integrity program would only impact the Delta Region. However, the ecosystem restoration program could impact all regions except for the SWP-CVP service areas outside the Central Valley.

The water use efficiency program includes several actions that could impact groundwater conditions. The program does not designate specific actions by region, but instead identifies policies that could lead to improvements to Bay-Delta water supplies:

- Agricultural water use efficiency can result in both beneficial and adverse impacts to groundwater conditions. Demand for groundwater can decline as agricultural water use becomes more efficient, having a positive impact on groundwater conditions. However, agricultural water conservation resulting in either reductions in deep percolation from applied water or seepage from conveyance facilities results in reduced groundwater recharge, thereby reducing long-term yields expected from the groundwater basin. This in turn can result in declines in long-term groundwater storage and levels in adjacent areas, causing third party impacts in the form of increased energy costs, and costs to lower pumps or deepen wells. Urban water use efficiency can have the same affect as agricultural water use, when the actions involve more efficient use of urban water for outdoor purposes.
- Water recycling generally would be expected to have a beneficial impact on groundwater conditions since in this case, future water supplies would be augmented by the availability of recycled water, thus reducing the dependence on groundwater as a supplemental supply.

- The impact of water transfers on groundwater conditions depends largely to what extent the transfer may involve groundwater substitution. In the event groundwater substitution occurs, groundwater level declines can 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.

The Water Quality Program consists of a series of actions designed to reduce the emission of pollutants from abandoned mines and agricultural, and urban, and industrial lands to waterways in the Bay-Delta system. Contaminants concentrations in water and sediment quality can be expected to decline in the streams immediately downstream of pollutant sources. Because the behavior of these contaminants in natural aquatic systems is complex, it is difficult to predict the consequences downstream. However, it seems probable that these actions could result in minor improvements to groundwater quality in the regions where they are proposed, which includes the Delta, Bay, Sacramento River, and San Joaquin River regions.

1.5 SUMMARY OF GROUNDWATER IMPACTS OF CALFED ALTERNATIVES

Table I-1 provides a summary of potential impacts to groundwater conditions in the study area resulting from CALFED alternatives. The information provided is strictly a qualitative measure indicating the possibility of negative or positive changes as a result of a given CALFED alternative. These changes are estimated relative to the No Action Alternative.

Impacts to Delta Region groundwater resources are expected to be less-than-significant for all three CALFED alternatives in comparison to the No Action Alternative, with the exception of Subalternative 2B which includes in-Delta surface storage. Small increases in groundwater levels could be expected resulting from seepage in the vicinity of this storage facility.

Impacts to groundwater resources in the Bay Region and SWP-CVP service areas outside the Central Valley could occur for Alternative 1 (Subalternative 1A and 1B) in comparison to the No Action Alternative, resulting in possible groundwater level declines, degradation of water quality, and land subsidence. Groundwater impacts in these regions for the remaining CALFED alternative configurations were judged to be less-than-significant, or groundwater conditions were expected to be similar to No Action Alternative conditions (Table I-1).

Several configurations of Alternatives 1, 2, and 3 include groundwater storage components north and south of the Delta, the most important feature with regards to assessing potential impacts to groundwater in the Sacramento River and San Joaquin River regions. This component would consist of conjunctive use and/or groundwater banking concepts, and would operate with the basic objective of maximizing overall water supply and preserving existing surface water and groundwater resources. Groundwater storage components for the Sacramento River and San Joaquin River regions are included in CALFED Alternatives 1C, 2B, 2E, 3B, and 3D through 3I.

Potential impacts of groundwater storage components could include groundwater level declines, water quality degradation, land subsidence, increased pumping costs, costs for lowering pumps or deepening wells, reduced well yields, increased streamflow depletions, loss of native

TABLE I-1

SUMMARY OF SIGNIFICANT IMPACTS TO GROUNDWATER AS COMPARED TO NO ACTION

GROUNDWATER IMPACT	NO ACTION	ALTERNATIVE 1			ALTERNATIVE 2					ALTERNATIVE 3								
		1a	1b	1c	2a	2b	2c	2d	2e	3a	3b	3c	3d	3e	3f	3g	3h	3i
Delta Region																		
Levels	Similar to existing	Similar to No Action	Similar to No Action	Similar to No Action	Similar to No Action	Minor increase	Similar to No Action	Less-than-significant	Less-than-significant	Less-than-significant	Minor increase	Less-than-significant	Minor increase	Minor increase	Less-than-significant	Minor increase	Less-than-significant	Minor increase
Bay Region																		
Levels	Additional declines	Possible declines	Possible declines	Minor increase	Less-than-significant	Minor increase	Less-than-significant	Minor increase	Minor increase	Minor increase	Minor increase	Minor increase	Minor increase	Minor increase	Minor increase	Minor increase	Minor increase	Minor increase
Sacramento River Region																		
Levels	Additional declines	Similar to No Action	Similar to No Action	Additional declines	Similar to No Action	Additional declines	Similar to No Action	Similar to No Action	Additional declines	Similar to No Action	Additional declines	Similar to No Action	Additional declines	Additional declines	Additional declines	Additional declines	Additional declines	Additional declines
Water Quality	Possible degradation	Similar to No Action	Similar to No Action	Possible degradation	Similar to No Action	Possible degradation	Similar to No Action	Similar to No Action	Possible degradation	Similar to No Action	Possible degradation	Similar to No Action	Possible degradation	Possible degradation	Possible degradation	Possible degradation	Possible degradation	Possible degradation
River accretions/depletions	Additional losses	Similar to No Action	Similar to No Action	Additional losses	Similar to No Action	Additional losses	Similar to No Action	Similar to No Action	Additional losses	Similar to No Action	Additional losses	Similar to No Action	Additional losses	Additional losses	Additional losses	Additional losses	Additional losses	Additional losses
Land Subsidence	Possible subsidence	Similar to No Action	Similar to No Action	Possible subsidence	Similar to No Action	Possible subsidence	Similar to No Action	Similar to No Action	Possible subsidence	Similar to No Action	Possible subsidence	Similar to No Action	Possible subsidence	Possible subsidence	Possible subsidence	Possible subsidence	Possible subsidence	Possible subsidence
San Joaquin River Region																		
Levels	Additional declines	Small declines	Small declines	Additional declines	Less-than-significant	Additional declines	Less-than-significant	Less-than-significant	Additional declines	Less-than-significant	Additional declines	Less-than-significant	Additional declines	Additional declines	Additional declines	Additional declines	Additional declines	Additional declines
Water Quality	Possible degradation	Possible degradation	Possible degradation	Possible degradation	Less-than-significant	Possible degradation	Less-than-significant	Less-than-significant	Possible degradation	Less-than-significant	Possible degradation	Less-than-significant	Possible degradation	Possible degradation	Possible degradation	Possible degradation	Possible degradation	Possible degradation
River accretions/depletions	Additional losses	Possible additional losses	Possible additional losses	Additional losses	Less-than-significant	Additional losses	Less-than-significant	Less-than-significant	Additional losses	Less-than-significant	Additional losses	Less-than-significant	Additional losses	Additional losses	Additional losses	Additional losses	Additional losses	Additional losses
Land Subsidence	Possible subsidence	Possible subsidence	Possible subsidence	Possible subsidence	Less-than-significant	Possible subsidence	Less-than-significant	Less-than-significant	Possible subsidence	Less-than-significant	Possible subsidence	Less-than-significant	Possible subsidence	Possible subsidence	Possible subsidence	Possible subsidence	Possible subsidence	Possible subsidence
CVP-SWP Service Areas Outside Central Valley																		
Levels	Additional declines	Possible declines	Possible declines	Minor increase	Less-than-significant	Minor increase	Less-than-significant	Minor increase	Minor increase	Minor increase	Minor increase	Minor increase	Minor increase	Minor increase	Minor increase	Minor increase	Minor increase	Minor increase

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vegetation, and wetlands impacts. These impacts could affect parties directly involved in the groundwater storage program, and could also affect neighboring third party communities and individuals.

These potential impacts cannot be reported beyond the regional level at this time. However, the likelihood that these impacts could occur will be taken into consideration during more detailed preliminary investigations. Principles for addressing these types of issues prior to implementing a program, as well as possible mitigation strategies, also will be carefully considered.

CALFED is committed to exploring opportunities for groundwater banking and in-lieu conjunctive use of groundwater resources. However, the potential for CALFED involvement in groundwater banking and in-lieu conjunctive use creates concerns for counties and for the local water agencies where the programs might be implemented. Although direct construction impacts are generally less than for surface storage facilities, there is a potential for affecting domestic wells, farm operations, stream habitat, towns and cities. In direct response to local concerns to this issue, the Program's first priority is to listen carefully to local concerns and interests and look for opportunities where there is local interest and the potential to combine local and statewide benefits. The second priority is to develop pilot programs which demonstrate that assurances can be established. The assurances must protect local interests while promoting common benefits to counties and local water agencies, hand-in-hand with system water supply reliability benefits. Therefore, although groundwater components are included in a number of alternative configurations, CALFED recognizes the ongoing need to coordinate closely with all affected parties in the process of refining alternatives.

II. INTRODUCTION

This document reports potential impacts to groundwater resulting from CALFED Bay-Delta Program actions as compared to No Action conditions, and serves as a technical appendix to the Programmatic Environmental Impact Report/Environmental Impact Statement (PEIR/EIS). Descriptions and assumptions for the CALFED alternative configurations, common programs, and No Action are not included here. Draft documents describing these components are available and can be obtained from the CALFED Bay-Delta Program. See the Preface at the beginning of this document for more information.

Potential groundwater impacts are described for the Delta, Bay, Sacramento River, and San Joaquin River regions, and for SWP-CVP service areas outside these areas. The approach to evaluating and reporting groundwater impacts is discussed in Section III. Section IV discusses groundwater conditions under the No Action Alternative, and reports groundwater impacts associated with the CALFED common programs and the CALFED alternatives as compared to the No Action Alternative. Section V addresses related topics, and references are listed in Section VI.

This document is consistent with the goals of CALFED, the California Environmental Quality Act (CEQA), and the National Environmental Policy Act (NEPA), and reflects a level of detail appropriate for a programmatic approach to environmental review.

III. APPROACH TO EVALUATING AND REPORTING GROUNDWATER IMPACTS

This section provides background information regarding the approach to evaluating groundwater conditions for areas potentially affected by the CALFED Bay-Delta Program alternatives. The section is organized as follows:

- Study Area
- General Assessment
- Groundwater Outreach Program
- Signficance Criteria
- Preliminary Mitigation Strategies

3.1 STUDY AREA

The study area consists of groundwater-bearing regions of the Sacramento and San Joaquin valleys (Sacramento River and San Joaquin River regions respectively), the Sacramento-San Joaquin Delta (Delta), the San Francisco Bay (Bay), and SWP-CVP service areas outside the Central Valley. Impacts to groundwater are described at various levels of detail, with more emphasis on the Sacramento and San Joaquin valley regions. Theses 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.

3.2 GENERAL ASSESSMENT

Environmental impacts to groundwater resources are assessed on a qualitative basis. Groundwater modeling studies have not been conducted on the alternatives. Descriptive information for each alternative is used together with SWP and CVP 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 is given to stakeholder concerns that have been identified as part of CALFED's ongoing groundwater outreach program. Descriptions of the No Action Alternative and each CALFED alternative is provided under separate cover (see Preface at the beginning of this document for additional information).

Groundwater impacts for each alternative are 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 can also be indicative of potential land subsidence in areas where clay and silt lenses susceptible to compaction are prevalent. The occurrence of land subsidence can damage water conveyance facilities, flood control and drainage levee systems, groundwater well casings, and other infrastructure.

DWRSIM simulation studies conducted for this PEIR/EIS were designed to approximate conditions under one or more of the CALFED actions. These studies provide an indication of changes in surface water supplies and streamflows, both of which can influence long-term groundwater conditions. It is 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 is also 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 this is not possible with the current modeling tools available, SWP operations must serve as a surrogate for combined SWP and CVP operation of new facilities in DWRSIM.

A summary of the CALFED alternatives and the corresponding DWRSIM study which best represents the simulation of the SWP and CVP system for these conditions is shown in Table III-1. Also shown in this table are the deficiencies of each of the simulation studies. Table III-2 lists the DWRSIM model runs that best represent the subalternatives of CALFED Alternatives 1, 2, and 3.

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

Changes in land use can have 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. However, explicit information on these types of changes has not yet been developed and is not incorporated here.

3.3 GROUNDWATER OUTREACH PROGRAM

Appropriate and effective groundwater management will be essential to the success of the CALFED Bay-Delta Program. As part of the storage and conveyance program to protect and enhance the delta, CALFED is looking to facilitate additional conjunctive

TABLE III-1
AVAILABLE DWRSIM PLANNING STUDIES
WITH IDENTIFIED DEFICIENCIES

Alternative	Studies	Major Deficiencies
Affected Env.	SWRCB-469	Includes Full Vernalis, No CVPIA Delta Actions
No Action	CALFED-472	No 2020 hydrology, Variable Demand, CVPIA Delta Actions
1A	CALFED-472	No Action Deficiencies + No ERPP & CVP/SWP Joint Use
1B	CALFED-472	1A Deficiencies
1C	CALFED-510	1A Deficiencies + No SDGS & NDGS (Groundwater Storage)
2A	CALFED-472-B	1A Deficiencies + No salinity-flow relationship for Delta Modification
2B	CALFED-510	2A Deficiencies + No SDGS, NDGS & SJRTSS (San Joaquin Storage)
2C	CALFED-472B	2A Deficiencies + No IDSS (In-Delta Storage)
2D	CALFED-298	2A Deficiencies
2E	CALFED-510	2B Deficiencies
3A	CALFED-475	2A Deficiencies
3B	CALFED-500	2B Deficiencies + No IDSS (In-Delta Surface Storage)
3C	CALFED-475	2A Deficiencies
3D	CALFED-500	3B Deficiencies
3E	CALFED-500	3B Deficiencies + No 15,000 cfs IF (study includes 5,000 cfs IF)
3F	CALFED-500	3B Deficiencies + No 15,000 cfs IF (study includes 5,000 cfs IF)
3G	CALFED-500	3B Deficiencies
3H	CALFED-500	2B Deficiencies
3I	CALFED-500	3E Deficiencies

NOTES:
SWRCB: California State Water Resources Control Board
CVPIA: Central Valley Project Impact Assessment
SDGS: South of the Delta Groundwater Storage
NDGS: North of Delta Ground Water Storage
SJRTSS: San Joaquin River Tributary Surface Storage
IDSS: In Delta Surface Storage
IF: Isolated Delta Conveyance Facility

TABLE III-2
SUMMARY OF EXISTING DWRSIM OPERATION STUDIES MOST REPRESENTATIVE OF PROGRAM ALTERNATIVES

Alternative	DWRSIM Study	Study Description
Affected Environment	1995C6F-SWRCB-469	SWRCB 1995 WQCP Study
No Action, 1A, 1B	1995C6F-CALFED-472	CALFED Benchmark Study
2A, 2C	1995C6F-CALFED-472B	Benchmark + SDI
2D	1995C6F-CALFED-498	Benchmark + SDI + SDSS
1C, 2B, 2E	1995C6F-CALFED-510	Benchmark + SDI + SRTSS + SDSS
3A, 3C	1995C6F-CALFED-475	Benchmark + SDI + 5,000 IF
3B, 3D-3I	1995C6F-CALFED-500	Benchmark + SDI + SRTSS + SDSS + 5,000 IF

NOTES:
SWRCB: California State Water Resources Control Board
WQCB: Water Quality Control Plan
SDI: South Delta Improvements
SDSS: South of Delta Off-Aqueduct Surface Storage
SRTSS: Sacramento River Tributary Surface Storage

use and groundwater banking opportunities as one way to help maximize the overall water supply and protect groundwater resources. CALFED has initiated a groundwater outreach component to help identify and address stakeholder concerns about groundwater use and management with special emphasis on conjunctive use projects.

CALFED has contacted and met with dozens of individuals, including private citizens, water managers, water district board members, and elected officials to learn about local concerns regarding conjunctive use programs, and to determine which areas would be interested in participating in a locally-controlled conjunctive use program. Additionally, CALFED has participated in workshops in both the Sacramento and San Joaquin valleys to present the status of the groundwater program and to solicit additional comments and concerns regarding conjunctive use.

3.3.1 Definitions of Common Terms

There has been much discussion in recent years about the terms used to describe various aspects of groundwater management in California. To facilitate a dialog among stakeholders, the groundwater outreach program is in the process of defining key terms to facilitate these discussions. Definitions proposed by CALFED and DWR are presented below.

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

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.

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.

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 shall be 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.

3.3.2 Summary of Stakeholder Concerns

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

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

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

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

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

3.3.3 Draft Principles for Conjunctive Use

CALFED is currently developing guiding principles for conjunctive use programs to ensure that local concerns and potential impacts are fully addressed prior to implementing a conjunctive use operation. The draft principles that have been developed to date include the following:

- Conjunctive use programs will be voluntary
- Groundwater will first be utilized to meet area of origin needs

- Transfers outside the basin will involve appropriate compensation for the resource
- Pilot programs, in addition to computer models, will be used to evaluate local conjunctive use potential and effects
- Conjunctive use projects will be overseen by a local agency that implements "interest-based negotiation," allowing stakeholder concerns to be addressed
- Monitoring and collection of baseline data will be conducted prior to extensive study and design

CALFED also has taken the lead in the formation of a committee to develop operating guidelines and principles for conjunctive use projects. The committee will consist of representatives from the groups proposing to implement the projects, as well as members representing Sacramento and San Joaquin Valley concerns. The committee will be charged with developing operating principles, including specific criteria for addressing potential impacts as a result of conjunctive use. It is important to emphasize that CALFED is committed to local operation of voluntary conjunctive use programs, and that CALFED has no intention or desire to operate or manage conjunctive use projects.

The conjunctive use committee will also outline the appropriate steps that will be required to implement a CALFED-supported conjunctive use program. While the committee has not yet completed this task, the preliminary outline for implementation of a conjunctive use project includes the following steps:

- Initiate baseline data collection and analysis efforts
- Conceptualize the potential project
- Identify stakeholders
- Develop goals and objectives, including time line
- Establish local operating entity
- Conduct technical feasibility studies
- Address political, institutional and legal issues
- Identify potential impacts
- Develop a written plan, including project monitoring and mitigation measures
- Develop contract with stakeholder involvement
- Conduct pilot study
- Fine-tune operating parameters
- Implement project
- Conduct long-term monitoring.

The CALFED Bay-Delta Program will continue to evaluate and modify its conjunctive use program with stakeholder contributions as the groundwater outreach program progresses. CALFED will look for opportunities to help communities maximize their water supplies through voluntary conjunctive use programs that are operated at the local level. CALFED will also continue to refine the guiding principles by working with the conjunctive use committee to address and mitigate potential impacts prior to implementing a conjunctive use program.

3.4 SIGNIFICANCE CRITERIA

The California Environmental Quality Act requires that significant environmental impacts that cannot be avoided must be identified in an environmental impact report. Section 15382 of the CEQA guidelines states that "A significant effect on the environment is defined as a substantial, or potentially substantial, adverse change in the physical conditions which exist in the area affected by the proposed project including land, air, water, minerals, flora and fauna, ambient noise, and objects of historic or aesthetic significance." In order to conduct the assessment of groundwater impacts systematically, thresholds of significance must be defined. The following impacts would be judged to be significant:

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

3.5 PRELIMINARY MITIGATION STRATEGIES

Strategies for mitigating the effects of the CALFED Bay-Delta Program can be incorporated within the contract between the buying and selling parties. Such strategies should be aimed at detecting changes that are undesirable or unallowable and taking the appropriate steps to reduce their effects to acceptable levels or stopping the project.

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

- groundwater levels
- land surface elevation for potential subsidence
- groundwater quality
- stream flow

Declining groundwater levels can reduce well yields and require that wells or pumps be deepened. The conjunctive use program should develop a network of monitoring wells, a monitoring schedule and procedures for periodic evaluation of the data. Such efforts will provide the information that is necessary for determining that there is storage capacity in the aquifer for recharge, or conversely, that the aquifer is full. In addition, such measurements will show when groundwater levels reach or exceed the established thresholds as discussed below.

Extensometers can be installed to monitor vertical movement of the land surface or such movement of the land surface can be monitored by global positioning system surveying. Such data will be used to determine when land subsidence occurs. In at least one part of the Central Valley, landowners and water agency staff have stated emphatically that the amount of land subsidence that they are willing to accept as a result of groundwater withdrawal is "zero."

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

Stream gages should be established on watercourses in the area. The data collected will not be immediately useful in determining what is 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 stream flow. These data may eventually play an important role in maintaining surface water rights.

Threshold values for each of these parameters should be established by the committee. For example, after the program has operated for some time, it may become clear that when groundwater levels decline to a certain threshold level, subsidence begins. Thus, when groundwater levels approach that threshold, groundwater extraction must cease. Similarly, if groundwater quality samples indicate that lower quality groundwater is flowing toward the aquifer because of the gradient established by extraction, the committee would agree that a certain percentage increase in specific chemical or mineral constituents would require the cessation or appropriate reduction in extraction.

In conclusion, the monitoring program for each conjunctive use project must be tailored to fit the requirements and thresholds established by the local committee overseeing the project. 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. The Conaway Ranch project is an example of a well designed monitoring program that allows for the evaluation of the effects of groundwater extraction.

It is CALFED's position that conjunctive use projects should be thoroughly monitored, so that any detrimental impacts can be identified quickly, preferably during the pilot testing. Appropriate mitigation measures, ranging from reduction in pumping to cessation of the project, can then be effectively implemented by the local committee.

IV. ENVIRONMENTAL IMPACTS/CONSEQUENCES

Environmental impacts to groundwater conditions associated with the study area are discussed in this section. Groundwater conditions associated with the No Action Alternative are compared against Existing Conditions. Groundwater conditions associated with the CALFED alternatives are reported as a comparison with groundwater conditions for the No Action Alternative. The section is organized as follows:

- No Action Alternative Groundwater Conditions
- Impacts of CALFED Common Programs
- Impacts of CALFED Alternatives

4.1 NO ACTION ALTERNATIVE GROUNDWATER CONDITIONS

The No Action Alternative represents conditions in the future assuming a projected 2020 level of development without implementation of CALFED actions, and provides a base condition for comparison with each of the CALFED alternatives. The No Action Alternative assumes the SWRCB's May 1995 Water Quality Control Plan and includes selected upstream ESA requirements and CVPIA flow prescriptions. Additional details regarding the definition and assumptions of the No Action Alternative are provided in Appendix E, Operation Assumptions for the No Action Alternative (CALFED, Draft-1997).

DWRSIM model output data was used on a limited basis to assess possible changes in surface water and groundwater use, and streamflows. The DWRSIM run representing the No Action Alternative is the CALFED Benchmark Study (Table III-2). The DWRSIM run representing the Existing Conditions was based on State Water Resources Control Board (SWRCB) simulation reflecting the 1995 Water Quality Control Plan, and is referred to as SWRCB

1995 WQCP Study (Table III-2).

The No Action Alternative is compared with the Existing Conditions on a qualitative basis in the following paragraphs.

4.1.1 Delta Region - Groundwater Conditions

The Delta Region, shown in Figure IV-1, extends approximately from Sacramento in the north to Tracy in the south, and to Pittsburg to the west.

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

4.1.2 Bay Region - Groundwater Conditions

The Bay Region, shown in Figure IV-2, including Suisun, San Pablo, Central and South bays, extends about 85 miles from the east end of Chipps Island, near the City of Antioch westward and southward to the mouth of Coyote Creek, near the City of San Jose. Nine counties surround the Bay Region: Marin, San Francisco, San Mateo, Santa Clara, Alameda, Contra Costa, Solano, Napa, and Sonoma.

With increasing populations and the resulting increased water demand, water agencies in the Bay Region are looking at a number of options to increase supplies as well as to ensure 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 will continue to be initiated, and enhanced where already in place.

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

4.1.3 Sacramento River Region - Groundwater Conditions

The northern third of the Central Valley regional aquifer system is located in the Sacramento River Region. Referring to Figure IV-3, this region extends from north of Redding to the Sacramento-San Joaquin Delta (Delta) in the south. DWR identifies this area of the aquifer as the Sacramento Valley basin and the Redding basin (California DWR, 1975), together covering over 5,500 square-miles. For the purposes of this technical appendix, references made to the Sacramento River Region are assumed to 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, with the exception of a groundwater depression in the Yolo County area. Groundwater levels along the east side of the Sacramento River Region would be similar

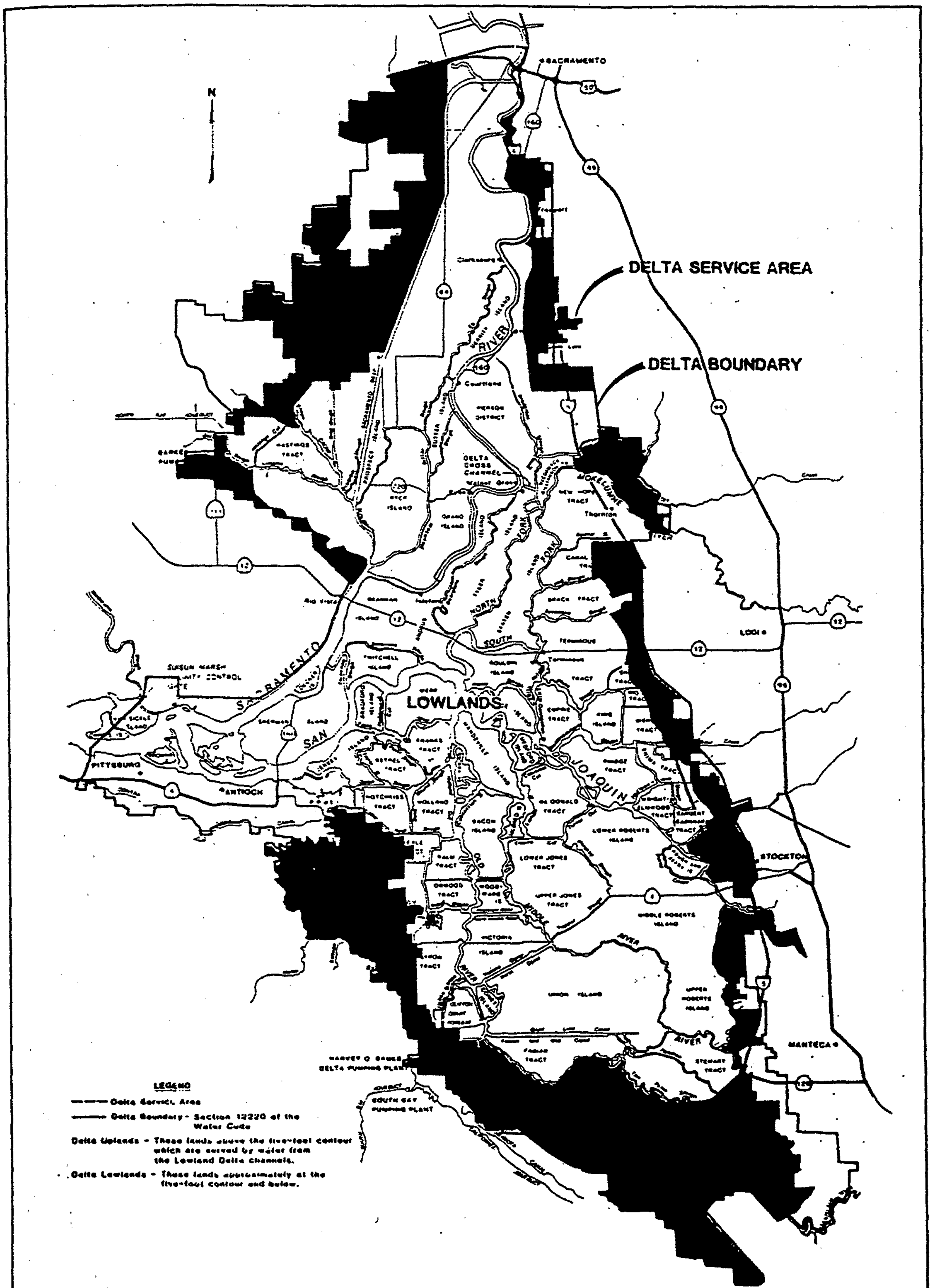

FIGURE IV-1
STATUTORY DELTA SERVICE AREA

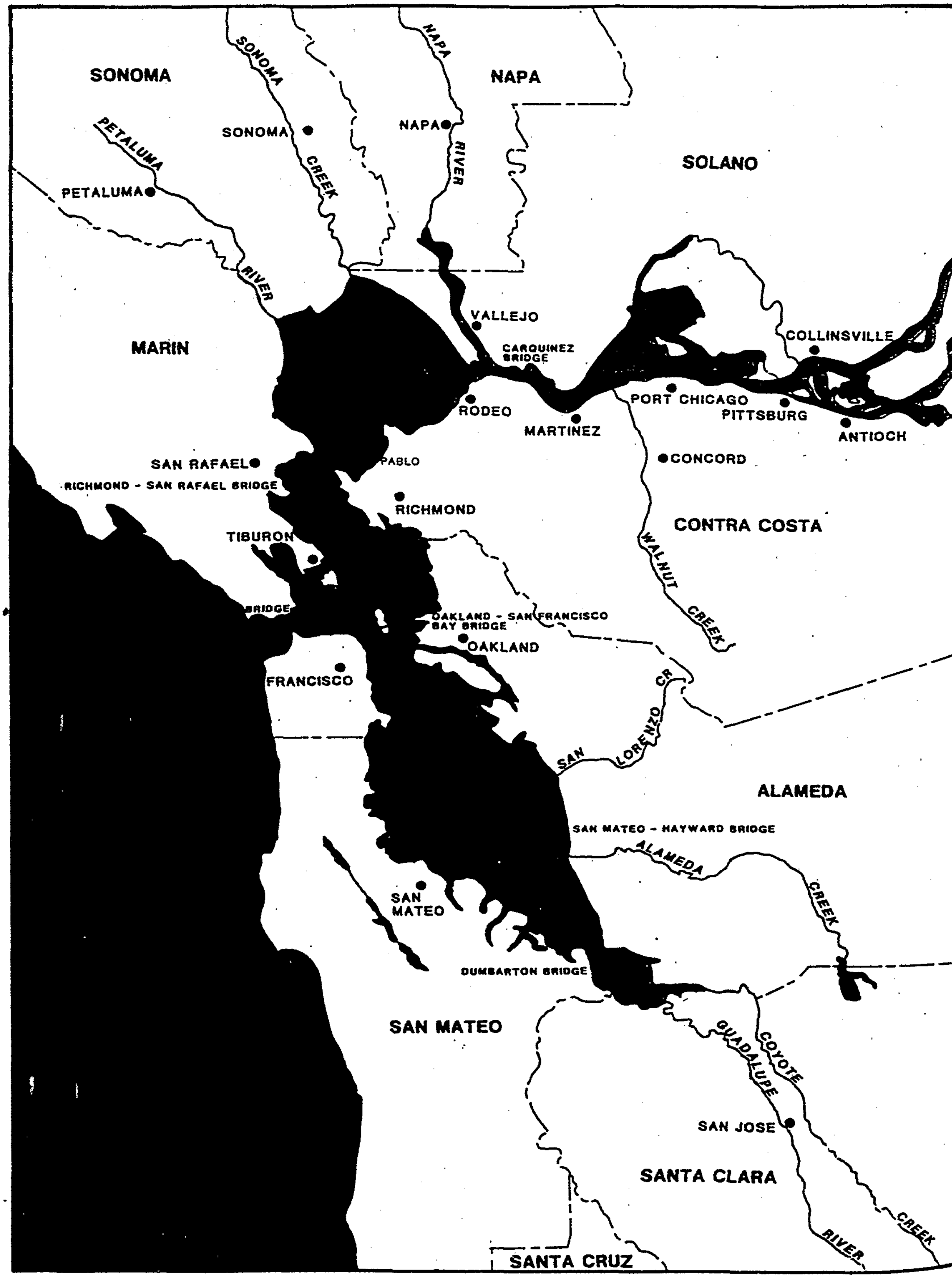

FIGURE IV-2
BAY REGION

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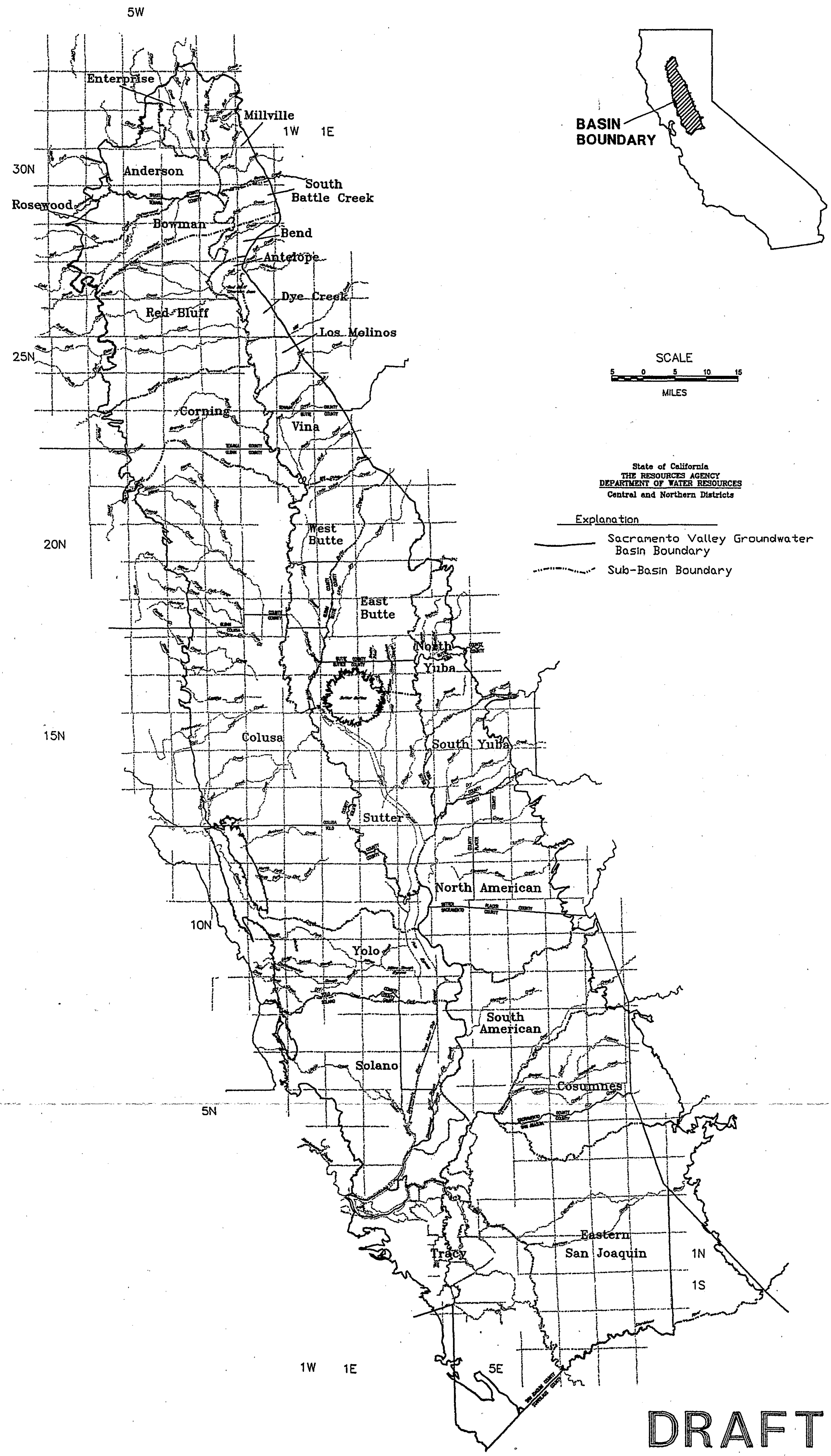

FIGURE IV-3
SACRAMENTO VALLEY GROUNDWATER SUB-BASIN BOUNDARIES

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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.

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

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

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

On-going groundwater management planning efforts in some parts of the Sacramento River Region could prevent or minimize these impacts summarized above, however, adoption of formal programs has not occurred.

4.1.4 San Joaquin River Region - Groundwater Conditions

The southern two-thirds of the Central Valley regional aquifer system is located in the San Joaquin River Region. Referring to Figure IV-4, this region 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.

Population projections indicate that more than twice as many people would reside in the San Joaquin River Region by 2020. 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 just shift water use from agricultural to urban uses.

Changes in imported surface water supplies will likely result in impacts to groundwater in some areas of this region. Areas that rely on Delta exports for all or a portion of their supplies face great uncertainty in terms of water supply reliability due to the uncertain outcome of a number of actions undertaken to protect aquatic species in the Delta. Because groundwater has been historically 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 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

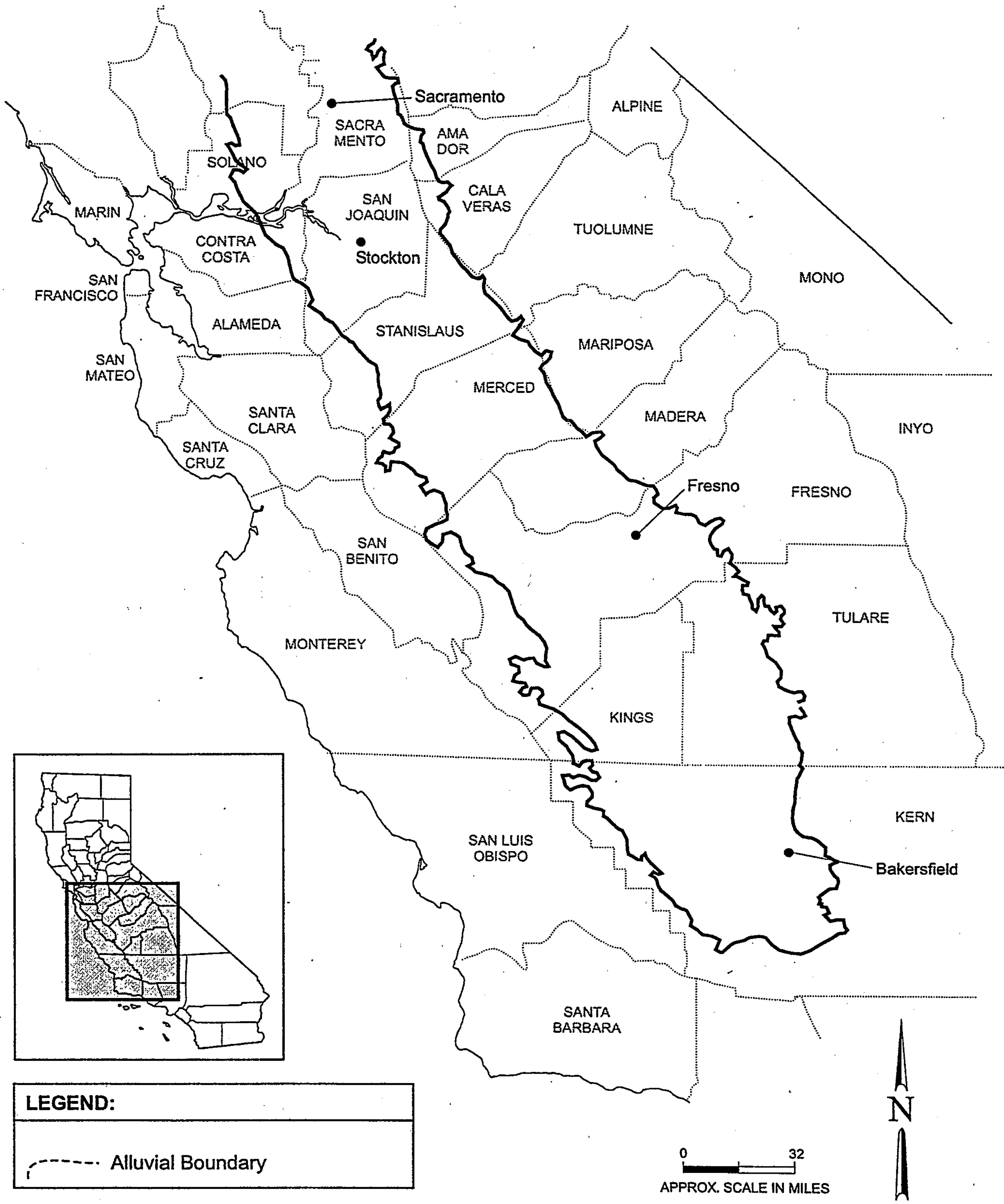


FIGURE IV-4

SAN JOAQUIN RIVER REGION

groundwater quality for the San Joaquin River Region could be further impaired as compared to existing conditions in areas that experience 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. Since mineral concentrations are usually 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 impacts on a local scale, however, impacts in unmanaged areas could still occur.

4.1.5 SWP-CVP Service Areas Outside the Central Valley - Groundwater Conditions

The 30 long-term water supply contractors of the SWP are organized into six service areas: Feather River, North Bay, South Bay, Central Coast, San Joaquin Valley, and Southern California, and are shown in Figure IV-5. The CVP service areas are shown in Figure IV-6. The groundwater resources of the Central Coast and Southern California areas are discussed below.

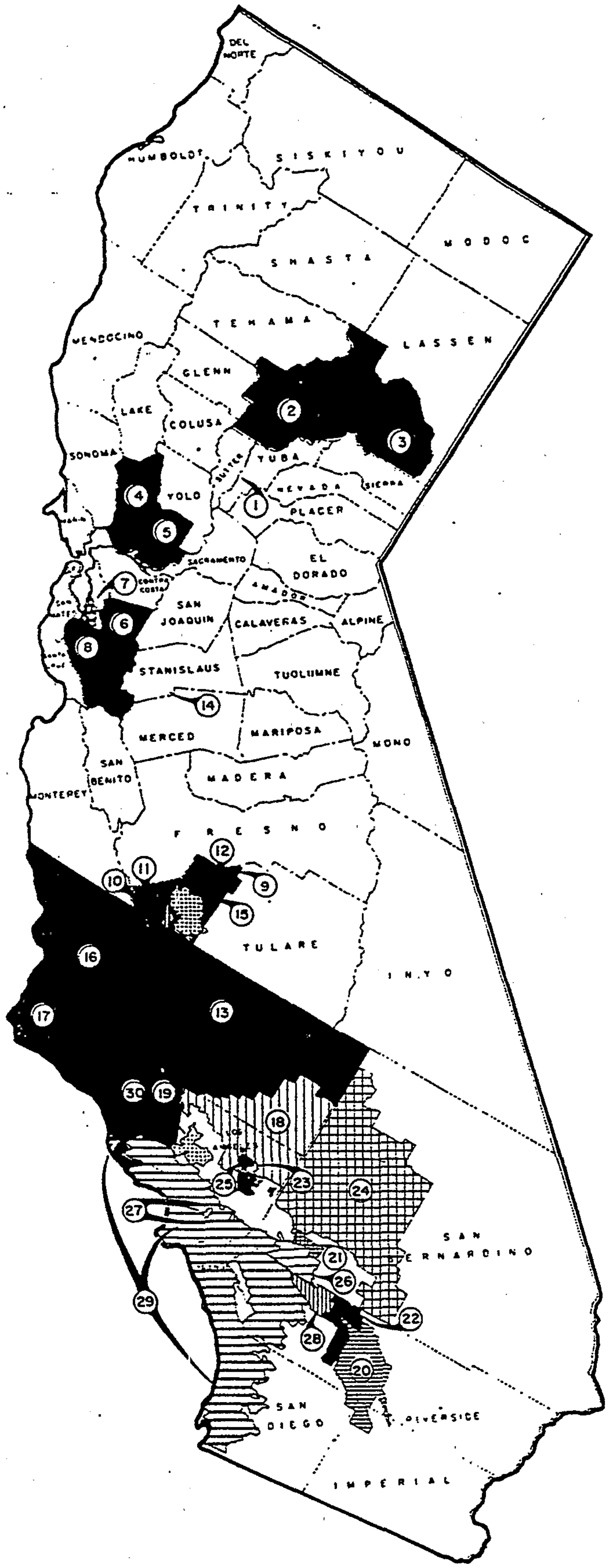
In this region there are numerous groundwater basins along the coast and inland valleys. Many of the basins are adjudicated or managed by a public agency. Additional imported supplies from the SWP Coastal Branch of the California Aqueduct could reduce future groundwater overdraft in the coastal areas. On the contrary, areas that rely on Delta exports for all or a portion of their supplies face great uncertainty in terms of water supply reliability due to the uncertain 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.

4.2 IMPACTS OF CALFED COMMON PROGRAMS

All of the CALFED Bay-Delta Program alternatives include four "common programs": ecosystem restoration, water quality, water use efficiency, and levee system integrity. It is recognized that common programs implemented under one alternative may meet program goals more successfully than the same common programs implemented under a different alternative. However, given the programmatic nature of the impact analysis for the PEIR/EIS, it is not possible to distinguish these potential differences. Impacts to groundwater as a result of these programs are discussed by region below.

4.2.1 Delta Region - Groundwater Conditions

Ecosystem Restoration Program. The Ecosystem Restoration project involves restoration of approximately 150,000 acres of terrestrial and aquatic wildlife habitat. Delta islands and land bordering waterways would be converted from current agricultural uses to wildlife habitat, including riparian corridors, floodways, meander belts, wetlands and open water. Some agricultural lands would serve a second purpose as seasonal wetlands. Water diversions would be screened to exclude fish, modifications would be made to diversion structures to improve fish passage, and some undesirable species would be controlled. SWP and CVP operations would be modified to better



Location No.	Contracting Agency	Maximum Annual Entitlement (acre-feet)
	UPPER FEATHER AREA	
1	City of Yuba City	9,600
2	County of Butte	27,500
3	Plumas County Flood Control and Water Conservation District	2,700
	Subtotal	39,800
	NORTH BAY AREA	
4	Napa County Flood Control and Water Conservation District	25,000
5	Solano County Flood Control and Water Conservation District	42,000
	Subtotal	67,000
	SOUTH BAY AREA	
6	Alameda County Flood Control and Water Conservation District, Zone 7	46,000
7	Alameda County Water District	42,000
8	Santa Clara Valley Water District	100,000
	Subtotal	188,000
	SAN JOAQUIN VALLEY AREA	
9	County of Kings	4,000
10	Devil's Den Water District	12,700
11	Dudley Ridge Water District	57,700
12	Empire West Side Irrigation District	3,000
13	Kern County Water Agency	1,153,400
14	Oak Flat Water District	5,700
15	Tulare Lake Basin Water Storage District	118,500
	Subtotal	1,355,000
	CENTRAL COASTAL AREA	
16	San Luis Obispo County Flood Control and Water Conservation District	25,000
17	Santa Barbara County Flood Control and and Water Conservation District	45,486
	Subtotal	70,486
	SOUTHERN CALIFORNIA AREA	
18	Antelope Valley-East Kern Water Agency	138,400
19	Castaic Lake Water Agency	41,500
20	Coachella Valley Water District	23,100
21	Crestline-Lake Arrowhead Water Agency	5,800
22	Desert Water Agency	38,100
23	Littlerock Creek Irrigation District	2,300
24	Mojave Water Agency	50,800
25	Palmdale Water District	17,300
26	San Bernardino Valley Municipal Water District	102,600
27	San Gabriel Valley Municipal Water District	28,800
28	San Gorgonio Pass Water Agency	17,300
29	The Metropolitan Water District of Southern California	2,011,500
30	Ventura County Flood Control District	20,000
	Subtotal	2,497,500
	TOTAL STATE WATER PROJECT	4,217,786

FIGURE IV-5
SWP SERVICE AREAS AND CONTRACTING AGENCIES

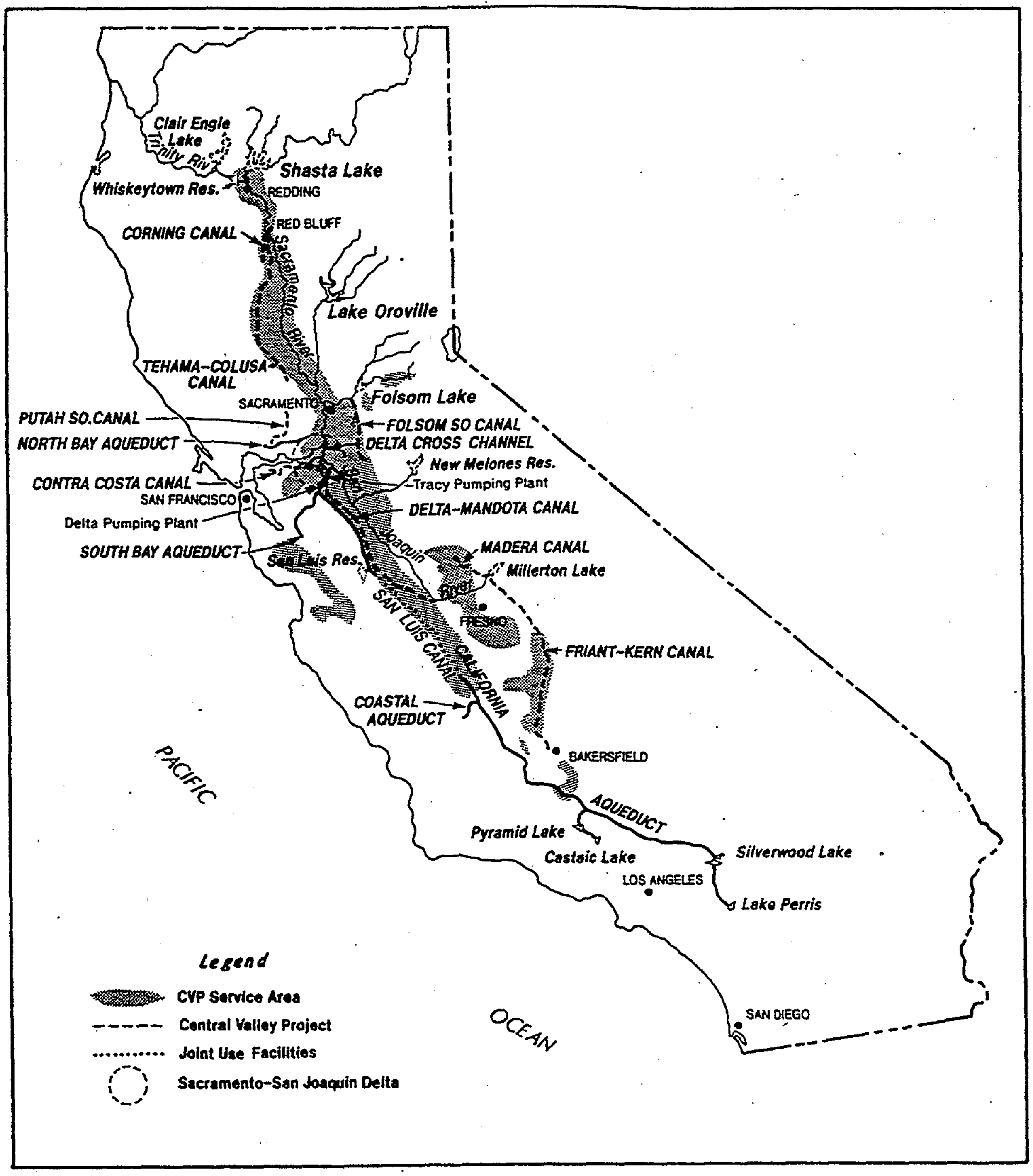


FIGURE IV-6
CVP AND ITS SERVICE AREAS

provide water for environmental purposes. Habitat restoration would involve large-scale construction operations affecting considerable areas of land and water.

A series of programmatic actions are proposed for the Delta as part of the Ecosystem Restoration Program Plan. These actions are listed in Table IV-1, along with the associated magnitude in the form of acreage or miles, and the type of land use potentially affected. With regards to groundwater conditions, substantial changes in agricultural land use can result in reduced deep percolation from the applied water. It is possible that there could be an overall reduction in recharge of the Delta groundwater resources as a result of these actions.

Water Quality program. The Water Quality Program consists of a series of actions designed to reduce the emission of pollutants from abandoned mines and agricultural, and urban, and industrial lands to waterways in the Bay-Delta system. Actions include source control measures to prevent pollutants from entering the aqueous environment, treatment to remove pollutants from discharged wastewater, and management measures to minimize the adverse environmental effects of discharged pollutants. The program also includes relocation of water supply intakes to take advantage of better water quality. The program includes the following actions for the Delta Region:

- Action 1: Reduce heavy metals emissions by source control and treatment of mine drainage.
- Action 2: Reduce emissions of contaminants in urban and industrial runoff by enforcement of existing regulations and provision of incentives.
- Action 3: Reduce emissions of contaminants from wastewater treatment plant discharges by enforcement of existing regulations and provision of incentives.
- Action 4: Reduce emissions of contaminants in agricultural surface runoff.
- Action 5: Reduce emissions of contaminants in agricultural subsurface drainage.
- Action 6: Relocate diversions to improve water supply quality.

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

Water Use Efficiency Program. The Water Use Efficiency Program includes programmatic actions to ensure that California's water supplies are used efficiently. The physical scope of water use efficiency actions is limited to improvements that can affect Bay-Delta water supplies and focuses on opportunities that are implementable at the local water supplier and end-user level. The Water Use Efficiency Program differs from other components of the CALFED project in that it does not consist of specific actions. Instead it is primarily concerned with establishing and implementing policies which would encourage municipal water agencies and irrigators to take actions which would increase the efficiency of water use. Many water users are already increasing the efficiency of their water use in response to growing physical water shortages, public

TABLE IV-1
ECOSYSTEM RESTORATION PROGRAM PLAN
PROGRAMMATIC ACTIONS FOR DELTA REGION

	Programmatic Action	Magnitude	Affected Land Use
1.	Restore tidal perennial aquatic habitat, and tidal emergent wetlands.	33,000 - 45,000 acres	Agricultural lands
2.	Restore tidally influenced freshwater marsh.	20,000 - 25,000 acres	Agricultural lands
3.	Restore tidally influenced channels and distributary sloughs.	150 - 250 miles 900 - 2,300 acres	Agricultural lands and instream areas
4.	Restore shallow water habitat.	7,000 acres	Agricultural lands
5.	Restore shoals.	500 acres	Agricultural lands
6.	Create deep open water areas within restored freshwater emergent wetland areas.	500 acres	Existing freshwater emergent marsh
7.	Create shallow open water areas within restored freshwater emergent wetland areas.	1,500 - 2,000 acres	Existing freshwater emergent marsh
8.	Restore seasonal wetlands.	34,000 acres	Agricultural lands
9.	Restore riparian habitat.	75 - 220 miles, 700 - 8,000 acres	Agricultural lands
10.	Protect additional existing riparian woodlands.	500 acres	Existing riparian lands
11.	Restore non-tidal emergent wetlands.	15,000 acres	Agricultural lands
12.	Restore channel islands.	200 - 800 acres	Agricultural lands, island peninsulas, or instream areas

policy and sentiment that favors efficient water use, and economics. Practices to be encouraged include reductions in losses from water systems, adoption of efficient water management practices by agriculture, implementation of urban best management practices for water conservation, increased wastewater reuse and market-driven water transfers.

This program does not address specific geographic regions, instead it focuses on the five elements listed in Table IV-2. For each programmatic action, an attempt was made to determine if, in general, the action could have potentially significant impacts on groundwater resources.

Agricultural water use efficiency can result in both beneficial and adverse impacts to groundwater conditions. Demand for groundwater can decline as agricultural water use becomes more efficient, having a positive impact on groundwater conditions. However, agricultural water conservation resulting in either reductions in deep percolation from applied water or seepage from conveyance facilities results in reduced groundwater recharge, thereby reducing long-term yields expected from the groundwater basin. This in turn can result in declines in long-term groundwater storage and levels in adjacent areas, causing third party impacts in the form of increased energy costs, modifications to well pump bowls to keep them below the groundwater level, and/or abandonment of the well. Urban water use efficiency can have the same affect as agricultural water use, when the actions involves more efficient use of urban water for outdoor purposes.

Water recycling generally would be expected to have a beneficial impact on groundwater conditions since in this case, future water supplies would be augmented by the availability of recycled water, thus reducing the dependence on groundwater as a supplemental supply.

The impact of water transfers on groundwater conditions depends largely to what extent the transfer may involve groundwater substitution. In the event groundwater substitution occurs, groundwater level declines can 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.

Levee System Integrity Program. The Levee System Integrity Program consists of several actions designed to improve the stability of levees in the Delta and thus reduce the risk of catastrophic flooding due to levee failure. Existing levees may simply be strengthened to PL-99 standa:ds or new setback levees built to the same standard. Approximately 1,000 miles of existing levees would be strengthened. Where new levees are built they will have two purposes: reduction in risk of flooding and creation of wildlife habitat. Some islands or parts of islands would be flooded to control land subsidence (subsidence resulting from the oxidation of peat soils). This could provide opportunities for habitat restoration. The lands needed for the levee system integrity program are currently used for agriculture.

The Levee System Integrity Program programmatic actions associated with the Delta Region are summarized in Table IV-3, along with the associated magnitude in the form of acreage or miles, and the type of land use potentially affected. Thousands of acres of agricultural land could be consumed by these actions. The conversion of land from agricultural cropland to levee could

TABLE IV-2
WATER USE EFFICIENCY PROGRAM
PROGRAMMATIC ACTIONS

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 IV-3
LEVEE SYSTEM INTEGRITY PROGRAM
PROGRAMMATIC ACTIONS FOR DELTA REGION

	Programmatic Action	Magnitude	Affected Land Use
1.	Rehabilitate Existing Levees to PL-99 Standards.	1,100 miles of levees 10,000 - 15,000 acres	Agricultural lands
2.	Create new setback levees.	22,500 - 37,500 acres	Agricultural lands
3.	Shallow flooding for subsidence control.	10,000 acres	Agricultural lands

potentially reduce the deep percolation of applied water, potentially impacting long-term groundwater storage conditions as compared to existing conditions. However, the complex relationship occurring between the surface and subsurface systems in the vicinity of these levees makes it difficult to assess the significance of this possible impact at a programmatic level. On a regional basis, however, the potential for adverse effects on groundwater conditions as compared to the existing conditions are judged to be less-than-significant.

4.2.2 Bay Region - Groundwater Conditions

With regards to potential impacts to groundwater conditions, the Levee System Integrity Program only affects areas within the Delta Region and is not discussed further here. The Water Use Efficiency Program is defined as policy actions intended to improve water use in all regions. The general discussion under section 4.2.1 with regards to potential impacts to groundwater conditions as a result of these policy actions applies to the Bay Region as well and is not discussed further here.

Ecosystem Restoration Program. A series of programmatic actions are proposed for the Bay Region as part of the Ecosystem Restoration Program Plan. These actions are listed in Table IV-4, along with the associated magnitude in the form of acreage or miles, and the type of land use potentially affected. Actions 1, 4, and 7 would result in a reduction in agricultural lands which could cause a reduction in deep percolation from applied water. However, on a regional basis the acreages are small and any impact to groundwater conditions in this region are judged to be less-than-significant.

Water Quality program. The Water Quality Program consists of a series of actions designed to improve water quality in the Bay-Delta system and support all beneficial uses including drinking water supply, recreation, agricultural and industrial water supply, and protection and enhancement of aquatic life. The program includes actions similar to Actions 2 and 3 described previously under the Delta Region, Water Quality Program, and involve reduction of emissions from urban and industrial runoff, and contaminants from wastewater treatment plant discharges.

Similar to the Delta Region, it seems probable that these actions will result in minor improvements to groundwater quality in the Bay region.

4.2.3 Sacramento River Region - Groundwater Conditions

With regards to potential impacts to groundwater conditions, the Levee System Integrity Program only affects areas within the Delta Region and is not discussed further here. The Water Use Efficiency Program is defined as policy actions intended to improve water use in all regions. The general discussion under section 4.2.1 with regards to potential impacts to groundwater conditions as a result of these policy actions applies to the Sacramento River Region as well and is not discussed further here.

Ecosystem Restoration Program. A series of programmatic actions are proposed for the Sacramento River Region as part of the Ecosystem Restoration Program Plan. These actions are listed in Table IV-5, along with the associated magnitude in the form of acreage or miles, and the type of land use potentially affected. It is possible that there could be an overall reduction in recharge of the Sacramento River Region groundwater resources as a result of Action 1.

TABLE IV-4
ECOSYSTEM RESTORATION PROGRAM PLAN
PROGRAMMATIC ACTIONS FOR BAY REGION

	Programmatic Action	Magnitude	Affected Land Use
1.	Restore tidal perennial aquatic habitat and tidal emergent wetlands.	10,000 - 14,000 acres	Agricultural land
2.	Restore tidally influenced channels and distributary sloughs.	10 miles, 60 - 90 acres	Agricultural land
3.	Create deep open water within restored freshwater emergent wetlands.	500 acres	Existing freshwater emergent marsh
4.	Restore seasonal wetlands.	7,000 acres	Agricultural land
5.	Restore riparian habitat.	10 - 15 miles, 20 - 80 acres	Agricultural land
6.	Protect vernal pool habitat.	500 -1,000 acres	Cultivated agricultural land or pasture
7.	Restore perennial grasslands.	1,000 acres	Agricultural land

TABLE IV-5
ECOSYSTEM RESTORATION PROGRAM PLAN
PROGRAMMATIC ACTIONS FOR SACRAMENTO VALLEY REGION

	Programmatic Action	Magnitude	Affected Land Use
1.	Restore riparian habitat.	25,000 - 75,000 acres	Agricultural land
2.	Provide annual gravel replacement to improve spawning habitat.	96,000 - 161,000 tons annually	No stream banks and adjacent land use
3.	Repair or rehabilitate spawning gravels on Mill and Cottonwood Creeks.	18 - 28 miles	No instream existing spawning riffles
4.	Install fencing on Cow Creek to protect riparian vegetation.	100,000 - 150,000 linear feet (2-4 acres)	Pasture
5.	Install fish screens on all diversions greater than 250 cfs, and two-thirds of all remaining diversions.		Instream
6.	Upgrade fish passage facilities at Anderson-Cottonwood Irrigation District, RBDD, Big Chico Creek, and Lindo Channel.		Instream
7.	Eliminate, relocate, or screen all diversions in lower Cache and Putah Creeks and the Yolo and Sutter Bypasses.		Instream
8.	Prevent straying of adult salmon and steelhead by installing a rack at the mouth of Grover Diversion Canal.		Instream
9.	Preserve or restore floodplain and existing channel meander characteristics of Clear, Cottonwood and Stony Creeks.	31 - 40 miles	Stream banks and adjoining land use
10.	Relocate M&T Diversion from Big Chico Creek to the Sacramento River.		Instream
11.	Reconfigure Folsom Dam shutters to improve management of Folsom Reservoir's coldwater pool.		None
12.	Reconfigure Nimbus Dam turbine intakes to improve ability to regulate temperature of releases.		None

Water Quality program. The Water Quality Program consists of a series of actions similar to those proposed for the Delta Region. Actions 1 through 4 discussed previously under the Delta Region, Water Quality Program are also proposed for the Sacramento River Region, with the same intent of improving overall water quality conditions in the region and the Bay-Delta system.

To the extent that these actions benefit surface water quality conditions, the dynamic stream-aquifer link that exists between surface water and underlying groundwater resources could result in long-term secondary improvements in groundwater quality conditions in the Sacramento River Region.

4.2.4 San Joaquin River Region - Groundwater Conditions

With regards to potential impacts to groundwater conditions, the Levee System Integrity Program only affects areas within the Delta Region and is not discussed further here.

Ecosystem Restoration Program. A series of programmatic actions are proposed for the San Joaquin River Region as part of the Ecosystem Restoration Program Plan. These actions are listed in Table IV-6, along with the associated magnitude in the form of acreage or miles, and the type of land use potentially affected. The possible reductions in agricultural lands as a result of these actions is minimal, and impacts to groundwater resources would be less-than-significant.

Water Quality program. The objectives of the Water Quality Program for the San Joaquin River Region are similar to those proposed for the Delta and Sacramento River regions. The specific actions recommended were discussed previously under the Delta Region, Water Quality Program (see Actions 1 through 5).

To the extent that these actions benefit surface water quality conditions, the dynamic stream-aquifer link that exists between surface water and underlying groundwater resources could result in long-term secondary improvements in groundwater quality conditions. The reduction in contaminant emissions in subsurface drainage could have a significant positive impact on water quality conditions associated with the shallow groundwater along the west side of the San Joaquin Valley.

Water Use Efficiency Program. The Water Use Efficiency Program is defined as policy actions intended to improve water use in all regions. In the San Joaquin River Region, deep percolation of applied water is a major contributor of groundwater long-term yield. 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 will decrease this deep percolation and reduce future groundwater recharge, thus reducing future long-term groundwater yield available from the groundwater basin. This in turn can result in declines in long-term groundwater storage and levels in adjacent areas, causing third party 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.

TABLE IV-6
ECOSYSTEM RESTORATION PROGRAM PLAN
PROGRAMMATIC ACTIONS FOR SAN JOAQUIN VALLEY REGION

	Programmatic Action	Magnitude	Affected Land Use
1.	Restore or improve management of riparian habitat.	1,500 - 5,000 acres	Agricultural lands
2.	Provide annual gravel replacement to improve spawning habitat.	12,000 - 25,000 tons annually	Stream banks and adjacent land use
3.	Install or improve fish screens on the North San Joaquin Conservation District diversion and at Woodbridge Dam.		Instream
4.	Prevent straying of adult salmon and steelhead by installing a temporary weir on the San Joaquin River upstream form the confluence with the Merced River.		Instream
5.	Preserve or restore floodplain and existing channel meander characteristics.	33 - 56 miles	Stream banks and adjacent land use
6.	Restore perennial aquatic habitat.	1000 acres	Existing emergent marsh or wetlands
7.	Restore seasonal wetland habitat.	3,000 acres	Agricultural lands adjacent to existing seasonal wetlands

4.2.5 SWP-CVP Service Areas Outside the Central Valley - Groundwater Conditions

The Levee System Integrity Program, the Water Quality Program, and the Ecosystem Restoration Program do not have programmatic actions specified in this region, and are not discussed further here. The Water Use Efficiency Program is defined as policy actions intended to improve water use in all regions. The general discussion under section 4.2.1 with regards to potential impacts to groundwater conditions as a result of these policy actions applies to this region as well and is not discussed further here.

4.3 IMPACTS OF CALFED ALTERNATIVES

4.3.1 Delta Region - Groundwater Conditions

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

Alternative 2. Alternative 2 includes five subalternatives, 2A through 2E. Subalternatives 2B and 2E include new storage (surface and groundwater) north and south of the Delta, and in-Delta surface storage (Subalternative 2B only). Subalternative 2D includes new surface storage south of the Delta. Subalternatives 2A and 2C do not include any new storage. The potential groundwater impacts in the Delta Region are discussed below.

Subalternatives 2A and 2C. On a long-term average annual basis, surface hydrology in the Delta Region under Subalternatives 2A and 2C would be similar to the No Action Alternative, resulting in little change in flow and surface water supplies in the Delta. As a result, groundwater conditions in the Delta Region for Subalternatives 2A and 2C would be similar to No Action Alternative groundwater conditions.

Subalternatives 2B, 2D, and 2E. Water supplies provided to the Delta Region under Subalternative 2B, 2D, and 2E are not expected to change relative to the No Action Alternative on a long-term basis, resulting in little change in groundwater pumping. Streamflows into and out of the Delta do change as a result of the new storage, primarily affecting the monthly distribution of flow. However, long-term annual conditions are not expected to change significantly relative to the total flow through the Delta. Seepage from the in-Delta surface storage component included in Subalternative 2B could increase groundwater levels in the vicinity of the storage facility, possibly waterlogging adjacent low-lying farmlands. Any adverse impacts to groundwater conditions in the Delta Region as a result of Subalternatives 2D and 2E in comparison to the No Action Alternative are judged to be less-than-significant.

Alternative 3. There are nine possible subalternatives for Alternative 3. The subalternatives have been organized into two groups for purposes of discussing groundwater impacts.

Subalternatives 3A and 3C. Subalternatives 3A and 3C include south-Delta improvements and a 5,000 cfs isolated facility. This combination provides the potential to deliver water more efficiently for Delta outflow and Delta export. It could also 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 are small relative to total inflow. In addition, surface water supplies to the Delta Region would be similar to the No Action Alternative. In summary, any adverse impacts to groundwater conditions in the Delta Region as a result of Subalternatives 3A and 3C in comparison to the No Action Alternative are judged to be less-than-significant.

Subalternatives 3B, and 3D through 3I. Subalternatives 3B, and 3D through 3I include south-Delta improvements, a 5,000 cfs isolated facility, and north of Delta and south of Delta storage (both surface and groundwater). Subalternatives 3B, 3D, 3E, 3G, and 3I also include in-Delta surface storage. Groundwater impacts associated with this feature would be similar to those described under Subalternative 2B. Similar to Subalternatives 2D and 2E, the effect of Subalternatives 3F and 3H are minimal in terms of changes in the Delta that could impact long-term groundwater conditions.

4.3.2 Bay Region - Groundwater Conditions

Alternative 1. The potential groundwater impacts in the Bay Region are discussed below for Subalternatives 1A through 1C.

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

Subalternative 1C. Subalternative 1C would result in a positive benefit 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 Subalternative 1C would be similar to the No Action Alternative groundwater conditions, with the possibility of slightly improved conditions.

Alternative 2. The potential groundwater impacts in the Bay Region are discussed below for Subalternatives 2A through 2E.

Subalternatives 2A and 2C. A decrease in water supplies exported from the Delta to the Bay Region could occur under

Subalternatives 2A and 2C, similar to those observed for Subalternatives 1A and 1B. However, the decrease is 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, and groundwater impacts of these subalternatives in comparison to the No Action Alternative would be less-than-significant for the Bay Region.

Subalternative 2B, 2D, and 2E. The Subalternatives 2B, 2D, and 2E indicate that small increases in water supply to the Bay Region would occur, like those observed for Subalternative 1C. Groundwater conditions in the Bay Region as a result of Subalternative 2B, 2D, and 2E would be similar to the No Action Alternative groundwater conditions, with the possibility of slightly improved conditions.

Alternative 3. The potential groundwater impacts in the Bay Region are discussed below for Subalternatives 3A through 3I.

Subalternatives 3A and 3C. Subalternatives 3A and 3C provide a positive benefit in terms of surface water supply exported from the Delta to the Bay Region, similar to benefits associated with Subalternative 1C. Groundwater conditions in the Bay Region as a result of Subalternative 3A and 3C would be similar to the No Action Alternative groundwater conditions, with the possibility of slightly improved conditions.

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

4.3.3 Sacramento River Region - Groundwater Conditions

Several configurations of Alternatives 1, 2, and 3 include groundwater storage components north and south of the Delta, the most important feature with regards to assessing potential impacts to groundwater in the Sacramento River Region. This component would consist of conjunctive use and/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 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 with 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. These outreach efforts are discussed under Section III.

Groundwater storage components for the Sacramento River Region are included in CALFED Alternatives 1C, 2B, 2E, 3B, and

3D through 3I. In general, these programs would rely on groundwater supplies during dry years, when surface water supplies are generally 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.

Alternative 1. The potential groundwater impacts in the Sacramento River Region are discussed below for Subalternatives 1A through 1C.

Subalternatives 1A and 1B. Subalternatives 1A and 1B consist of various surface water related actions. There are no groundwater storage components included in either subalternative. In comparison to the No Action Alternative, surface water supply conditions in the Sacramento River Region are expected to be similar under Subalternatives 1A and 1B. Very little change in groundwater use would be expected as a result of these subalternatives in comparison to the No Action Alternative. From a regional perspective, groundwater conditions in the Sacramento River Region for Subalternatives 1A and 1B would be similar to No Action Alternative groundwater conditions.

Subalternative 1C. A groundwater storage component would be implemented in the Sacramento River Region under Subalternative 1C. 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 are usually higher in groundwater than in surface water, increased use of groundwater for irrigation could increase salt loading to soils, groundwater, and surface water.

Potential 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 impacts could affect parties directly involved in the groundwater storage program, and could also affect neighboring third party communities and individuals.

The occurrence of these impacts depends upon many factors. For example, land subsidence caused by groundwater level declines, has only been observed in the Davis-Zamora area of the region. However, given the right geologic conditions, it is possible that additional groundwater development in other areas of the Sacramento River Region could also result in land subsidence. The possibility of such an impact would need to be taken into consideration during more detailed preliminary investigations. Principles for addressing these types of issues prior to implementing a program, as well as possible mitigation strategies, were summarized previously in Section III.

In general, groundwater storage programs have less construction-related impacts than developing or expanding surface storage facilities, due to fewer land use changes. Construction-related impacts, caused by development of this type of project, on groundwater storage, flow, or quality are judged to be less-than-significant.

Streamflows (simulated by DWRSIM) are altered in the Sacramento River Region as a result of CALFED storage and conveyance components represented in this subalternative. Streamflow conditions tend to be lower in winter months and higher in summer months in comparison to the No Action Alternative, primarily 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 could impact 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 may also occur when groundwater levels are lowered and less water is available in root zones. Lowered groundwater levels could also have a negative effect on wetlands.

Cumulative impacts resulting from this subalternative and other water management programs planned for the region could further exacerbate these potential impacts to groundwater. Close coordination between potential programs is required in order to effectively evaluate likely groundwater impacts. As part of the CALFED outreach effort, stakeholder concerns with regards to cumulative impacts will be identified. These concerns will continue to be carefully considered during future phases of the CALFED Bay-Delta Program. Regardless of the program, if unacceptable groundwater impacts are expected, adjustments to the various programs responsible for these impacts would be made.

Alternative 2. The potential groundwater impacts in the Sacramento River Region are discussed below for Subalternatives 2A through 2E.

Subalternatives 2A, 2C, and 2D. Similar to Subalternatives 1A and 1B, surface water supply conditions on a long-term basis are not expected to change significantly in the Sacramento River Region under Subalternatives 2A, 2C, and 2D, as compared to the No Action Alternative. As a result, little change in groundwater use in this region is expected in comparison to the No Action Alternative. From a regional perspective, groundwater conditions in the Sacramento River Region for Subalternatives 2A, 2C, and 2D would be similar to No Action Alternative groundwater conditions.

Subalternatives 2B and 2E. The most important feature of Subalterantives 2B and 2E affecting groundwater conditions in the Sacramento River Region is the groundwater storage component. This component would be similar to that proposed for Subalternative 1C, and the potential impacts to groundwater conditions in the Sacramento River Region would be similar to those described under Subalternative 1C.

Alternative 3. The potential groundwater impacts in the Sacramento River Region are discussed below for Subalternatives 3A through 3I.

Subalternatives 3A and 3C. Similar to Subalternatives 1A and 1B, surface water supply conditions on a long-term basis are not expected to change significantly in the Sacramento River Region under Subalternatives 3A and 3C, as compared to the No Action Alternative. As a result, little change in groundwater use in this region is expected in comparison to the No Action

Alternative. From a regional perspective, groundwater conditions in the Sacramento River Region for Subalternatives 3A and 3C would be similar to No Action Alternative groundwater conditions.

Subalternatives 3B, and 3D through 3I. The most important feature of Subalterantives 3B, and 3D through 3I affecting groundwater conditions in the Sacramento River Region is the groundwater storage component. This component would be similar to that proposed for Subalternative 1C, and the potential impacts to groundwater conditions in the Sacramento River Region would be similar to those described under Subalternative 1C.

4.3.4 San Joaquin River Region - Groundwater Conditions

The configurations of Alternatives 1, 2, and 3 that include a groundwater storage component for the Sacramento River Region, also include a similar component for the San Joaquin River Region. A majority of the 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 the 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 reducing demands for water diversions from the Delta or the San Joaquin River. Banked groundwater could also be extracted for use in the California Aqueduct, which could reduce the demand for Delta diversions during critical periods.

The CALFED groundwater outreach program discussed previously under the Sacramento River Region has extended the same efforts into the San Joaquin River Region, and is currently focussing on determining areas that would be interested in participating in a locally-controlled program.

Alternative 1. The potential groundwater impacts in the San Joaquin River Region are discussed below for Subalternatives 1A through 1C.

Subalternatives 1A and 1B. Water supply exports from the Delta to the San Joaquin River Region could decrease as a result of Subalternatives 1A and 1B in comparison to the No Action Alternative. Increases in the amount of groundwater pumping in response to these changes could occur, resulting in groundwater impacts to areas receiving Delta export water. These 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.

Subalternative 1C. Groundwater storage components would be implemented in the San Joaquin River Region under Subalternative 1C. Operation of the groundwater storage component could result in similar groundwater impacts to those discussed in the Sacramento River Region under Subalternative 1C. The potential for land subsidence is of considerable concern in this region given the large, regional occurrence of land subsidence along the west side and southern San Joaquin Valley (see "Draft Affected Environment Technical Report: Groundwater").

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 have historically been to low to support such habitat.

Streamflows are not altered in the San Joaquin River Region as a result of CALFED storage components represented in this subalternative, resulting in no direct impacts from these conditions on groundwater-surface water interaction.

Alternative 2. The potential groundwater impacts in the San Joaquin River Region are discussed below for Subalternatives 2A through 2E.

Subalternatives 2A, 2C, and 2D. Surface water supply conditions could improve in the San Joaquin River Region in comparison to the No Action Alternative as a result of Subalternatives 2A, 2C, and 2D. However, the amount of groundwater pumping reduced in response to these changes is unknown, and for the purposes of this assessment are assumed to be negligible on a long-term basis. Groundwater conditions associated with these subalternatives would be similar to the No Action Alternative conditions.

Subalternatives 2B and 2E. The most important feature of Subalternatives 2B and 2E affecting groundwater conditions in the San Joaquin River Region is the groundwater storage component. This component would be similar to that proposed for Subalternative 1C, and the potential impacts to groundwater conditions in the region would be similar to those described under Subalternative 1C.

Alternative 3. The potential groundwater impacts in the San Joaquin River Region are discussed below for Subalternatives 3A through 3I.

Subalternatives 3A and 3C. For reasons similar to those discussed under Subalternatives 2A, 2C, and 2D, groundwater impacts associated with these subalternatives in comparison to the No Action Alternative are judged to be less-than-significant for the San Joaquin River Region.

Subalternatives 3B, and 3D through 3I. The most important feature of Subalternatives and 3D through 3I affecting groundwater conditions in the San Joaquin River Region is the groundwater storage component. This component would be similar to that proposed for Subalternative 1C, and the potential impacts to groundwater conditions in the region would be similar to those described under Subalternative 1C.

4.3.5 SWP-CVP Service Areas Outside the Central Valley - Groundwater Conditions

The potential groundwater impacts of Alternatives 1, 2, and 3 in the SWP-CVP service areas outside the Central Valley, as compared to the No Action Alternative, would be similar to those discussed for the Bay Region.

V. RELATED TOPICS

VI. REFERENCES

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