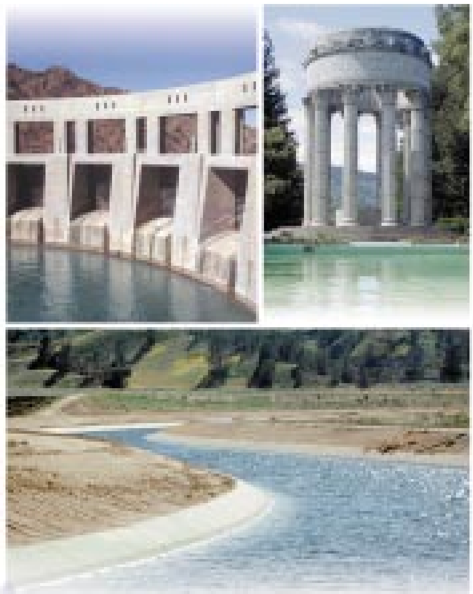


CALIFORNIA WATER PLAN UPDATE BULLETIN 160-98

Volume 1

November 1998

Pete Wilson
Governor

Douglas P. Wheeler
Secretary for Resources
The Resources Agency

David N. Kennedy
Director
Department of Water Resources

Copies of Bulletin 160-98 may be purchased for $25 from:
California Department of Water Resources
P. O. Box 942836
Sacramento, CA 94236-0001

Make checks payable to: Department of Water Resources
California residents add current sales tax

Foreword

. . .

In 1957, the Department published Bulletin 3, the *California Water Plan*. Bulletin 3 was followed by the Bulletin 160 series, published six times between 1966 and 1993, updating the *California Water Plan*. A 1991 amendment to the California Water Code directed the Department to update the plan every five years. Bulletin 160-98 is the latest in the series. The Bulletin 160 series assesses California's water needs and evaluates water supplies, to quantify the gap between future water demands and water supplies. The series presents a statewide overview of current water management activities and provides water managers with a framework for making decisions.

In response to public comments on the last update, Bulletin 160-93, this 1998 update evaluates water management options that could improve California's water supply reliability. Water management options being planned by local agencies form the building blocks for evaluations performed for each of the State's ten major hydrologic regions. Local options are integrated into a statewide overview that illustrates potential progress in reducing the State's expected future water shortages.

When the previous water plan update was released, California was just emerging from a six-year drought. This update follows the largest and most extensive flood disaster in California's history, the January 1997 floods. These two hydrologic events fittingly illustrate the complexity of water management in the State.

The Department appreciates the assistance provided by the Bulletin 160-98 public advisory committee, which met with the Department over a three-year period as the Bulletin was being prepared. The Department also appreciates the assistance provided by the many local water agencies who furnished information about their planned water management activities.

David N. Kennedy
Director

Contents

Chapter 4. Urban, Agricultural, and Environmental Water Use

Chapter 5. Technology in Water Management

Chapter 8. Options for Meeting Future Water Needs in Interior Regions of California

Chapter 9. Options for Meeting Future Water Needs in Eastern Sierra and Colorado River Regions of California

Tables

Figures

Sidebars

STATE OF CALIFORNIA

Pete Wilson, Governor

THE RESOURCES AGENCY

Douglas P. Wheeler, Secretary for Resources

DEPARTMENT OF WATER RESOURCES

David N. Kennedy, Director

Raymond D. Hart
Deputy Director

Robert G. Potter
Chief Deputy Director

Stephen L. Kashiwada
Deputy Director

L. Lucinda Chipponeri
Assistant Director for Legislation

Susan N. Weber
Chief Counsel

DIVISION OF PLANNING AND LOCAL ASSISTANCE

William J. Bennett, Chief

This Bulletin was prepared under the direction of

Jeanine Jones .... Chief, Statewide Planning

by

Naser Bateni .... Former Chief, Water Resources Evaluation
Paul Hutton .... Chief, Water Resources Evaluation
Waiman Yip .... Senior Engineer
Bob Zettlemoyer .... Senior Engineer

assisted by

Barbara Cross
Steve Cowdin
Dan Fua
Tom Hawkins
Ray Hoagland
Scott Matyac
Dick Neal
Virginia Sajac
Clara Silva

with assistance on special topics or studies by

Manucher Alemi
Linton Brown
Randy Brown
Ed Craddock
Baryohay Davidoff
Farhad Farnam
Marla Hambright
Darryl Hayes
Dale Hoffman-Floerke
Steve Kasower
John Kramer
Richard Le
Claire LeFlore
Jim Rich
Maurice Roos
Ray Tom

Data collection and regional information provided by Department District offices

Northern District
Naser Bateni, Chief

assisted by

X. Tito Cervantes
Andrew Corry
Douglas Denton
Todd Hillaire
Glen Pearson
Eugene Pixley

Central District
Karl Winkler, Chief

assisted by

Alan Aguilar
Emil Calzascia
Toccoy Dudley
Al Lind
Ed Morris
Doug Osugi
James Wieking

San Joaquin District
Lou Beck, Chief

assisted by

Jack Erickson
Robert Polgar
David Scruggs
Brian Smith
Arvey Swanson
Ernie Taylor
Iris Yamagata

Southern District
Charles White, Chief

assisted by

Glenn Berquist
Sergio Fierro
David Inouye
Vern Knoop
Kelly Lawler
Michael Maisner
Mark Stuart
Garret Tam Sing

Editorial, design, and production services were provided by

Nikki Blomquist
John Carter
Teresa Chaney
Mike Miller
Joanne Pierce
Therese Tynan

Photography provided by

Department of Water Resources, Photography Unit
Peter Stoiber, Supervising Photographer

Paul Hames
Norm Hughes
Dale Kolke
Stephen Payer

State of California
The Resources Agency
Department of Water Resources

CALIFORNIA WATER COMMISSION

Daniel F. Kriege
Chair, Capitola

Stanley M. Barnes
Vice Chair, Visalia

Donald C. Cecil .... Willows

George Gowgani, Ph.D. .... San Luis Obispo

Homer F. Lundberg .... Richvale

Michael D. Madigan .... San Diego

Martin A. Matich .... San Bernardino

Sayre M. Miller .... Clovis

Raymond E. Barsch, Executive Officer

The California Water Commission serves as a policy advisory body to the Director of the Department of Water Resources on all California water resources matters. The nine-member citizen commission provides a water resources forum for the people of the State, acts as a liaison between the legislative and executive branches of State government, and coordinates federal, State, and local water resources efforts.

1

Introduction

In 1957, the Department published Bulletin 3, the *California Water Plan*. Bulletin 3 was followed by the Bulletin 160 series, published six times between 1966 and 1993, updating the *California Water Plan*. A 1991 amendment to the California Water Code directed the Department to update the plan every five years. Bulletin 160-98 is the latest in the series.

The Bulletin 160 series assesses California's agricultural, environmental, and urban water needs and evaluates water supplies, in order to quantify the gap between future water demands and the corresponding water supplies. The series presents a statewide overview of current water management activities and provides water managers with a framework for making water resources decisions.

While the basic scope of the Department's water plan updates has remained unchanged, each update has taken a distinct approach to water resources planning, reflecting issues or concerns at the time of its publication. In response to public comments on the last update, Bulletin 160-93, the 1998 update evaluates water management actions that could be implemented to improve California's water supply reliability. Bulletin 160-93 analyzed 2020 agricultural, environmental, and urban water demands in considerable detail. These demands, together with water supply information, have been updated for the 1998 Bulletin, which also uses a 2020 planning horizon. However, much of Bulletin 160-98 is devoted to identifying and analyzing options for improving water supply reliability. Water management options available to, and being considered by, local agencies form the building

The Department's Bulletin 160 series quantifies California's managed or dedicated water uses—urban, agricultural, and environmental uses. Unmanaged uses, such as the precipitation consumed by native plants, are not quantified.

blocks of evaluations prepared for each of the State's ten major hydrologic regions. (Water supplies provided by local agencies represent about 70 percent of California's developed water supplies.) These potential local options are integrated with options that are statewide in scope, such as the CALFED Bay-Delta program, to create a statewide evaluation.

The statewide evaluation represents a snapshot, at an appraisal level of detail, of how actions planned by California water managers could reduce the gap between supplies and demands. The evaluation does not present potential measures to reduce all shortages statewide to zero in 2020. Such an approach would not reflect economic realities and current planning by local agencies. Not all areas of the State and not all water users can afford to reduce drought year shortages to zero. Bulletin 160-98 focuses on compiling those options that appear to have a reasonable chance of being implemented by water suppliers, to illustrate potential progress in reducing the State's future shortages.

Bulletin 160-98 estimates that California's water shortages at a 1995 level of development are 1.6 maf in average water years, and 5.1 maf in drought years. (As described later in the Bulletin, shortages represent the difference between water supplies and water demands.) The magnitude of shortages shown for drought conditions in the base year reflects the cutbacks in supply experienced by California water users during the recent six-year drought. Bulletin 160-98 forecasts increased shortages by 2020—2.4 maf in average water years and 6.2 maf in drought years. The future water management options identified as likely to be implemented could reduce those shortages to 0.2 maf in average water years and 2.7 maf in drought years.

The accompanying sidebar summarizes key statistics developed later in the Bulletin, to provide the reader with an overview of California's water uses.

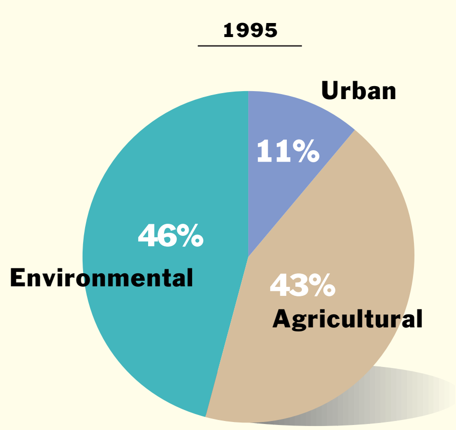
California—An Overview

Figure 1-1 shows California's size relative to that of the contiguous 48 states. California is the nation's most populous state and is also the top-ranked state in dollar value of agricultural production. Although California's present population is over 33 million people, the State still has large areas of open space and

Summary of Key Statistics

Shown below for quick reference are some key statistics presented in Chapter 4. Water use information is based on average water year conditions. The details behind the statistics are discussed later.

	1995	*2020 Forecast*	*Change*
Population (million)	32.1	47.5	+15.4
Irrigated crops (million acres)	9.5	9.2	-0.3
Urban water use (maf)	8.8	12.0	+3.2
Agricultural water use (maf)	33.8	31.5	-2.3
Environmental water use (maf)	36.9	37.0	+0.1



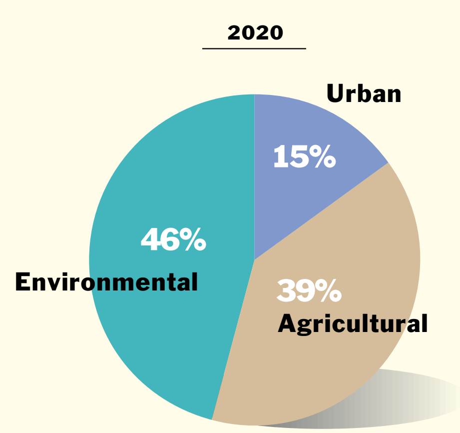


FIGURE 1-1.
California in Relation to the United States

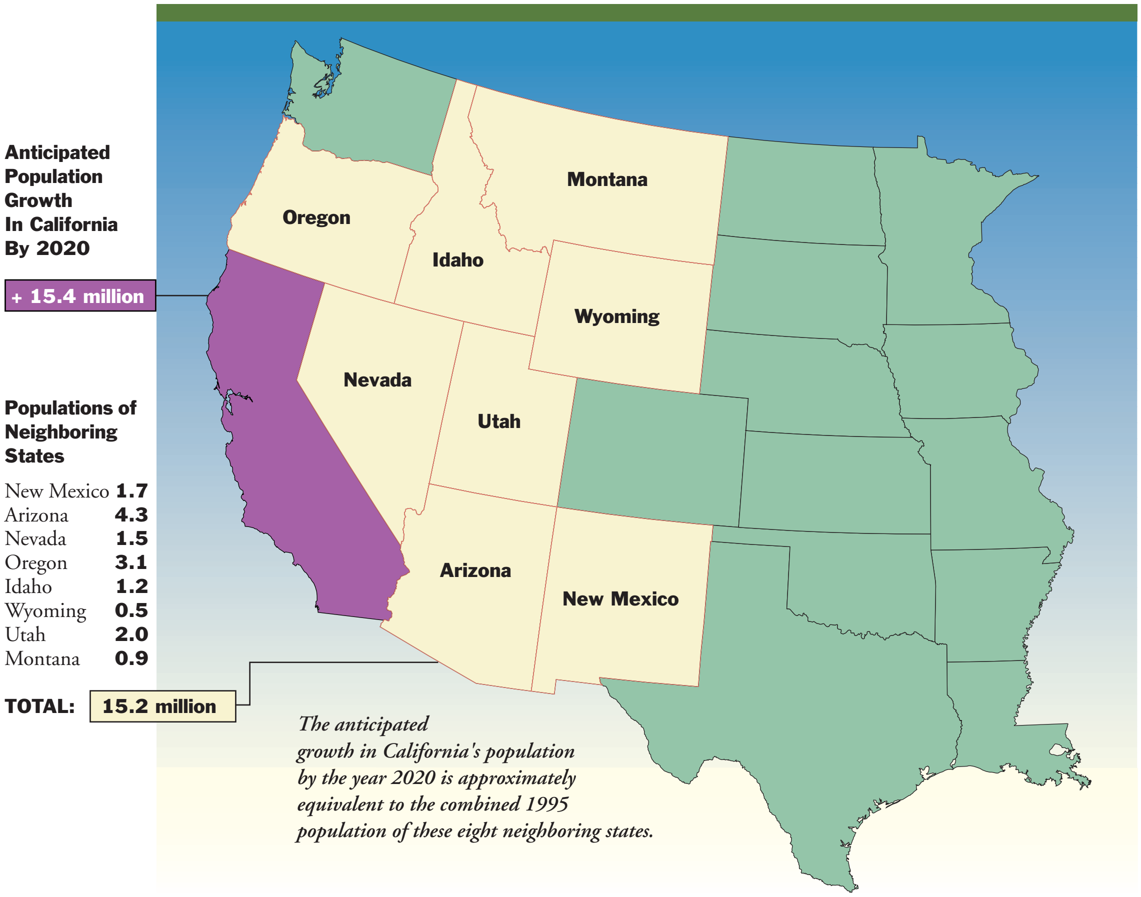
lands set aside for public use and enjoyment, including 18 national forests, 23 units of the national park system, and 355 units of the state park system. California is a state of great contrasts. Population density ranges from over 16,000 people per square mile in the City and County of San Francisco to less than 2 people per square mile in Alpine County. The highest (Mount Whitney) and lowest (Death Valley) points in the contiguous United States are located not far from each other in California. The State's average annual precipitation ranges from more than 90 inches on the North Coast to about 2 inches in Death Valley.

To put California's population into perspective, about one of every eight U.S. residents now lives in California. During the time period covered in the Bulletin (the 25 years from 1995 to 2020), California's population is forecast to increase by more than 15 million people, the equivalent of adding the present populations of Arizona, Nevada, Oregon, Idaho, Montana, Wyoming, New Mexico, and Utah to California,

Yosemite National Park is one of the U.S. Park Service's most popular facilities. Here, Half Dome is seen from the Merced River.

FIGURE 1-2.

California's Expected Population Growth Versus Neighboring States' Populations



as shown in Figure 1-2. Today, four of the nation's 15 largest cities (Los Angeles, San Diego, San Jose, and San Francisco) are located in the State.

California's population and abundant natural resources have helped create the State's trillion-dollar economy which, according to the California Trade and Commerce Agency, ranks seventh among world economic powers. California's water resources have helped it maintain its status as the nation's top agricultural state for 50 consecutive years. It is the nation's leading agricultural export state, the sixth largest agricultural exporter in the world, the nation's number one dairy state, and the producer of 55 percent of the nation's fruits, nuts, and vegetables. California is the primary U.S. producer of specialty crops such as almonds, artichokes, dates, figs, kiwifruit, olives, pistachios, and walnuts. Ten of the top 15 agricultural counties in the U.S. are in California.

Despite the State's increasing human population, many species of wildlife still call California home. Some of the larger animal species that frequently coexist with suburban development, like this opossum, are nocturnal. Suburban residents thus may not realize how widespread these species are.

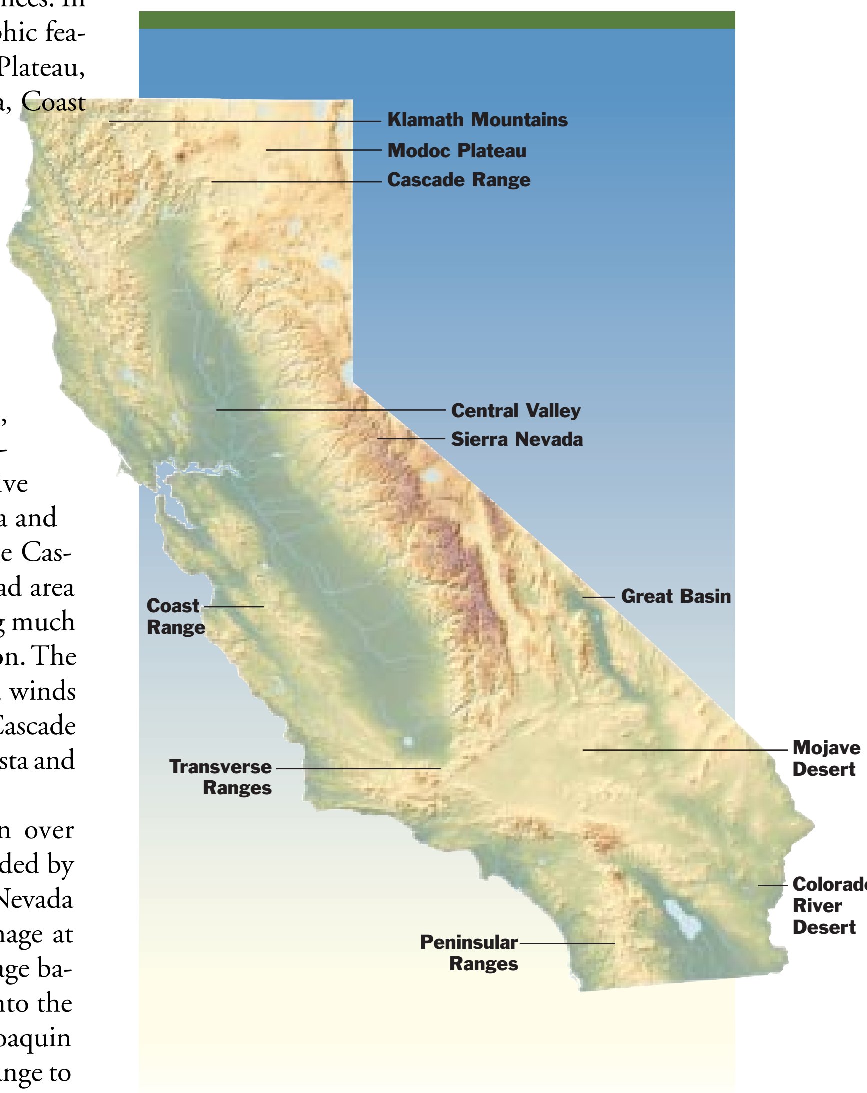
Mount Shasta, a Cascade Range volcano, dominates the horizon in the northern Sacramento Valley.

California is a state of diverse climates and landforms. Figure 1-3 is a relief map of California illustrating the State's major geomorphic provinces. In roughly north to south order, major geomorphic features are: the Klamath Mountains, Modoc Plateau, Cascade Range, Central Valley, Sierra Nevada, Coast Range, Great Basin, Transverse Ranges, Mojave Desert, Peninsular Ranges, and Colorado River Desert.

The Klamath Mountains are a rugged mountain range on the California-Oregon border. To the east, the Cascade Range is a chain of volcanic cones that stretches from California into Washington. Until the 1980 eruption of Mount St. Helens in Washington, Mount Lassen (the southernmost of the Cascade volcanos) was the most recently active volcano in the United States outside of Alaska and Hawaii. The Modoc Plateau to the east of the Cascade Range is the southernmost part of a broad area of lava flows and small volcanic cones covering much of eastern Oregon and southeastern Washington. The Pit River, a major Sacramento River tributary, winds through the Modoc Plateau and crosses the Cascade Range between two of its major volcanos—Shasta and Lassen.

The Central Valley is an alluvial basin over 400 miles long by about 50 miles wide, bounded by the Coast Range on the west and the Sierra Nevada on the east. Except for the Tulare Lake drainage at the southern end of the valley (a closed drainage basin), rivers draining the Sierra Nevada flow onto the valley floor, join with the Sacramento or San Joaquin Rivers, and flow through a gap in the Coast Range to San Francisco Bay. The Central Valley provides about

FIGURE 1-3.
Relief Map of California



80 percent of the State's agricultural production. The Sierra Nevada is a fault block mountain range whose western slopes are marked by deep river-cut canyons. Sierran rivers furnish much of California's developed surface water supplies.

The Coast Ranges are bounded on the north by the Klamath Mountains and on the south by the Transverse Ranges. The San Andreas Fault is a prominent geologic feature of the Coast Ranges; its path can readily be traced in areas where faulting has controlled the direction of watercourses such as the Gualala River on the North Coast. The San Andreas Fault extends into the San Bernardino Mountains of the Transverse Ranges geomorphic province (so called because these mountain ranges trend east-west). The Peninsular Ranges (which trend north-south) are a cluster of ranges separated by long valleys dividing, for example, the Riverside area from the Los Angeles coastal plain.

The western edge of the Mojave Desert is delineated by the Garlock Fault and by a portion of the San Andreas Fault. The Mojave is a region of interior drainage characterized by large areas of alluvium with scattered areas of recent volcanic features. The Mojave has numerous playa lakes, including Silver Lake, the terminus of the Mojave River. The Colorado River Desert to the south, also a closed drainage basin, is a lower elevation desert whose most prominent feature is the Salton Sea, which occupies a structural trough.

The Great Basin (also called the Basin and Range province) begins on the east side of California's Sierra Nevada and extends across Nevada and into Utah. Also a region of interior drainage, it is characterized by fault block mountain ranges separated by roughly north-south trending valleys, such as Owens Valley and Death Valley.

Figure 1-4 shows the location of the State's major water projects. The federal Central Valley Project is the largest water project in California and the Department's State Water Project is the second largest. (Descriptions of these, and of some of the larger local water projects, are provided in Chapter 3.) The

Looking out toward the floor of Death Valley from Zabriskie Point. Borate minerals concentrated by centuries of evaporation on the valley floor were mined here in the 1800s and hauled from the valley by mule teams.

California's Largest Water Retailers

Shown below are some of the largest annual retail water deliveries by local agencies, to illustrate the magnitude of urban and agricultural water demands. Retail delivery is the water supplied to an individual urban or agricultural customer. (Local agencies that wholesale water, such as Metropolitan Water District of Southern California or the City and County of San Francisco, have larger annual deliveries than the amounts shown here.)

Historical Maximum Annual Retail Water Deliveries

Water Agency	*Year*	*Delivery (taf)*
Agricultural		
Imperial Irrigation District	1996	2,846
Westlands Water District	1984	1,444
Glenn-Colusa Irrigation District	1984	831
Turlock Irrigation District	1976	687
Fresno Irrigation District	1995	627
Urban		
Los Angeles Department of Water and Power	1986[a]	706
City of San Diego	1989	257
East Bay Municipal Utility District	1976	249
San Jose Water Company	1987	128
City of Fresno	1996	125

[a] For fiscal year from July 1986 to June 1987.

FIGURE 1-4.
California's Major Water Projects

sidebars highlight California's largest waterbodies and provide information on historic water deliveries by California's largest water retailers, to provide a perspective on California's water resources and water use.

Bulletin 160-98 Hydrologic Regions

Figure 1-5 shows California's hydrologic regions. The Department subdivides the State into regions for planning purposes. The largest planning unit is the hydrologic region, a unit used extensively in this Bulletin. California has ten hydrologic regions, corresponding to the State's major drainage basins. The next level of delineation below hydrologic regions is the planning subarea. Some of the regional water management plans in Chapters 7-9 discuss information at the PSA level. The smallest study unit used by the Department is the detailed analysis unit. California is divided into 278 DAUs. Most of the Department's

California Water Statistics

California's Largest Lakes, Reservoirs, and Rivers

Natural (Undammed) Lakes

Lake	Storage Capacity (taf)	Comments
Salton Sea	7,500	At water surface elevation of -226 feet. This is a saline lake.
Mono Lake	2,620	At water surface elevation of 6,383.2 feet. This lake is also saline.
Eagle Lake	640	At water surface elevation of 5,107 feet. Has no outlet and is somewhat alkaline.
Goose Lake	475	At water surface elevation of 4,700 feet. Partly in Oregon. The lake is alkaline.

Reservoirs Constructed at Sites Not Previously Occupied by Pre-existing Natural Lakes

Reservoir	Capacity (taf)	Owner
Shasta	4,552	USBR
Oroville	3,538	DWR
Trinity	2,448	USBR
New Melones	2,420	USBR

Reservoirs Constructed by Damming Pre-existing Natural Lakes

Reservoir	Capacity (taf)[a]	Owner
Lake Tahoe	745	USBR
Clear Lake (Modoc County)	451	USBR
Clear Lake (Lake County)	315	YCFCWCD[b]

Rivers

Based on average annual runoff (maf)	
Sacramento River	22.4
Klamath River	11.1
San Joaquin River	6.4
Eel River	6.3

Based on watershed area (square miles)	
Sacramento River	26,548
San Joaquin River	15,946
Klamath *(California portion only)*	10,020
Amargosa River *(California portion only)*	6,442

[a] Storage capacity shown is the operable capacity of the reservoir, not the total capacity of the lake.
[b] Yolo County Flood Control and Water Conservation District

FIGURE 1-5.
California's Hydrologic Regions

California's Hydrologic Regions

North Coast	Klamath River and Lost River Basins, and all basins draining into the Pacific Ocean from the Oregon stateline southerly through the Russian River Basin.
San Francisco Bay	Basins draining into San Francisco, San Pablo, and Suisun Bays, and into Sacramento River downstream from Collinsville; western Contra Costa County; and basins directly tributary to the Pacific Ocean below the Russian River watershed to the southern boundary of the Pescadero Creek Basin.
Central Coast	Basins draining into the Pacific Ocean below the Pescadero Creek watershed to the southeastern boundary of Rincon Creek Basin in western Ventura County.
South Coast	Basins draining into the Pacific Ocean from the southeastern boundary of Rincon Creek Basin to the Mexican boundary.
Sacramento River	Basins draining into the Sacramento River system in the Central Valley (including the Pit River drainage), from the Oregon border south through the American River drainage basin.
San Joaquin River	Basins draining into the San Joaquin River system, from the Cosumnes River Basin on the north through the southern boundary of the San Joaquin River watershed.
Tulare Lake	The closed drainage basin at the south end of the San Joaquin Valley, south of the San Joaquin River watershed, encompassing basins draining to the Kern, Tulare, and Buena Vista Lakebeds.
North Lahontan	Basins east of the Sierra Nevada crest, and west of the Nevada stateline, from the Oregon border south to the southern boundary of the Walker River watershed.
South Lahontan	The closed drainage basins east of the Sierra Nevada crest, south of the Walker River watershed, northeast of the Transverse Ranges, north of the Colorado River Region. The main basins are the Owens and the Mojave River Basins.
Colorado River	Basins south and east of the South Coast and South Lahontan regions; areas that drain into the Colorado River, the Salton Sea, and other closed basins north of the Mexican border.

Bulletin 160 analyses begin at the DAU level, and the results are aggregated into hydrologic regions for presentation.

Some Trends in California Water Management Activities

Key dates in California's water history are shown in the sidebar. The late 1940s through the 1970s was a period of significant expansion of the State's infrastructure, in response to California's post-World War II population boom. During this time, the State expanded its highway system, constructed the State Water Project, and established a blueprint for a higher education system. At the federal level, many of the Central Valley Project's major facilities were constructed. There was substantial State and federal government involvement in—and funding for—water resources development, including direct financial assistance to local agencies for constructing water supply infrastructure (such as the Davis-Grunsky Act and Small Reclamation Projects Act programs).

The emergence of the environmental movement in the latter part of the 1960s began to effect a change in society's values, increasing the desire to preserve natural areas in a relatively undeveloped condition. With enactment of a number of environmental protection statutes, the State and federal governments' roles in water began to shift from development to management and regulation. In the 1970s, the "taxpayer revolt", typified by voter support for Proposition 13, reduced available funding to local agencies. (Two recent influences on funding sources for resources programs include deficit reduction goals for the federal budget and voter approval of Proposition 218, a measure to limit the ability of local governments to levy assessments.) There was a reduction in construc-

A California Water Chronology

In 2000, California will celebrate its sesquicentennial (150 years of statehood). Within this relatively short time period, the State's major water infrastructure and complex institutional framework for managing water have been developed. The following chronology highlights some key points in California's water history.

1848 Treaty of Guadalupe Hidalgo transfers California from Mexico to the U.S.
1848 Gold is discovered at Sutter's Mill on the American River.
1850 California is admitted to the Union.
1871 First reported construction of a dam on Lake Tahoe.
1884 Hydraulic mining is banned because of its impacts on navigation and contribution to flooding.
1886 Lux v. Haggin addresses competing water rights doctrines of riparianism and prior appropriation.
1887 Legislature enacts Wright Irrigation District Act, allowing creation of special districts.
1887 Turlock Irrigation District becomes first irrigation district formed under the Wright Act.
1895 World's first long-distance transmission of electric power (22 miles), from a 3,000 kW hydropower plant at Folsom to Sacramento.
1902 Congress enacts the Reclamation Act of 1902, creating the Reclamation Service, and authorizing federal construction of water projects.
1905 Salton Sea is created when the Colorado River breaches an irrigation canal and flows into the Salton Trough.
1913 First barrel of Los Angeles Aqueduct completed.
1914 California's present system of administering appropriative water rights is established by the Water Commission Act.
1922 Colorado River Compact signed.
1928 California Constitution amended to prohibit waste of water and to require reasonable beneficial use.
1928 Saint Francis Dam fails.
1929 State dam safety program goes into effect.
1929 East Bay MUD's Mokelumne River Aqueduct is completed.
1934 San Francisco's Hetch Hetchy Aqueduct is completed.
1940 All American Canal is completed.
1941 Colorado River Aqueduct is completed.
1945 Shasta Dam is completed.
1957 The Department publishes Bulletin 3, the *California Water Plan*.
1960 California voters approve the Burns-Porter Act, authorizing the sale of bonds to finance State Water Project construction.
1968 Oroville Dam is completed.
1968 Congress enacts National Wild and Scenic Rivers Act.
1969 Legislature enacts Porter-Cologne Act, the foundation of California water quality regulatory programs.
1969 Congress enacts National Environmental Policy Act.
1970 Legislature enacts California Environmental Quality Act.
1972 Legislature enacts California Wild and Scenic Rivers Act.
1973 California Aqueduct is completed.
1978 California v. U.S. held that the U.S. must obtain water rights under State law for reclamation projects, absent clear congressional direction to the contrary.
1978 SWRCB issues Decision 1485, requiring the CVP and SWP to meet specified Bay-Delta operating criteria.
1983 National Audubon Society v. Superior Court sets forth the application of public trust concepts to water rights administered by SWRCB.
1990 Congress enacts the Truckee-Carson-Pyramid Lake Water Rights Settlement Act (PL 101-618).
1992 Congress enacts the Central Valley Project Improvement Act (PL 102-575).
1994 SWRCB issues Decision 1631, requiring specified protections for Mono Lake levels.
1994 Bay-Delta Accord signed; its original three-year term was subsequently extended to a total of four years.

The founding of the San Diego Mission in 1769 is considered to mark the beginning of California's water supply development. This 1918 photo shows the ruins of the mission's dam.

Courtesy of Water Resources Center Archives, University of California, Berkeley

tion of large-scale water projects from the 1980s onward. The result of these changing circumstances was that few large-scale water management actions were able to move forward after the late 1960s. Since there is a long lead time for developing large water supply projects, the consequences were not immediately felt.

A theme now dominating much water management planning at the statewide level is ecosystem restoration (accompanied by substantial funding). Bay-Delta actions are an example of this trend—voter approval of Proposition 204 provided $460 million for State restoration actions directly associated with the Delta, and another $93 million in State matching funds for the U.S. Bureau of Reclamation's Central Valley Project Improvement Act restoration actions. USBR's annual budget for CVPIA restoration actions covered by the Restoration Fund has been in the $40 million range. Other examples of funding for environmental restoration actions are described throughout the Bulletin.

Greater local government and other stakeholder participation in statewide-level water management decision-making is an emerging trend. Formal governance structures are being employed to coordinate and manage the collective actions of local agencies. For example, CVP water users formed three joint powers authorities to contract with USBR for operation and maintenance of CVP facilities. Those JPAs have been working with USBR to develop mechanisms to allow the JPAs to finance normal operations and maintenance activities, rather than going through the congressional appropriations process. Another JPA has been formed by two county governments and two water agencies to implement Salton Sea restoration actions.

Changes Since the Last California Water Plan Update

The last *California Water Plan* update, Bulletin 160-93, was published in 1994 and used 1990-level information to represent base year water supply and demand conditions. At that time, California had recently emerged from the six-year drought and Bay-Delta issues were in a state of flux. Bulletin 160-98 uses 1995-level information to represent base year conditions, including new (interim) Bay-Delta standards.

Changes in Delta conditions are a major difference between the two bulletins. Bulletin 160-93 was based on SWRCB D-1485 regulatory conditions in the Delta, and used a range of 1 to 3 maf for unspecified future environmental water needs—a range that reflected uncertainties associated with Bay-Delta water needs and Endangered Species Act implementation. Bulletin 160-98 uses SWRCB's Order WR 95-6 as the base condition for Bay-Delta operations, and describes proposed CALFED actions for the Bay-Delta.

Bulletin 160-93 was the first *California Water Plan* update to examine the demand/supply balance for drought water years as well as for average water years, a response to water shortages experienced during the then-recent drought. Bulletin 160-98 retains the drought year analysis and also considers the other end of the hydrologic spectrum—flooding. Traditionally, water supply has been the dominant focus of the water plan updates. In response to the January 1997 flooding in Northern and Central California, Bulletin 160-98 highlights common areas in water supply and flood control planning and operations and emphasizes the benefits of multipurpose facilities.

Agreements reached in the 1994 Bay-Delta Accord were widely hailed as a truce in California's water wars. The approach taken in the Bay-Delta exemplifies some hallmarks of today's water management activities—increased participation by local governments and other stakeholders in statewide water management issues, and significant efforts to carry out ecosystem restoration actions.

Changes in Response to Bulletin 160-93 Public Comments

Other changes between the two reports resulted from public comments on Bulletin 160-93. The dominant public comment on Bulletin 160-93 was that it should show how to reduce the gap between existing supplies and future demands, in addition to making supply and demand forecasts. Bulletin 160-98 addresses that comment by presenting a compilation of local agencies' planning efforts together with potential water management options that are statewide in scope. Local agencies' plans form the base for this effort, since it is local water purveyors who have the ultimate responsibility for meeting their service areas' needs. About 70 percent of California's developed water supply is provided by local agencies.

Bulletin 160-98 excludes groundwater overdraft from the Bulletin's base year water supply estimate and is therefore the first water plan update to show an average water year shortage in its base year. (Both of the bulletins excluded future groundwater overdraft from future water supply estimates.) About 1.5 maf of the 1.6 maf base year shortage is attributable to groundwater overdraft.

Finally, Bulletin 160-98 uses applied water data, rather than the net water amounts historically used in the water plan series. This change was made in response to public comments that net water data were more difficult to understand than applied water data. This concept is explained in Chapter 4.

Changes in Future Demand/Shortage Forecasts

Bulletin 160-93 used a planning horizon of 1990-2020. Bulletin 160-98 uses a planning horizon of 1995-2020. Bulletin 160-98 uses the 2020 planning horizon because no major data changes occurred between the two reports that would justify extending the planning horizon. Urban water demands depend heavily on population forecasts—the next U.S. Census will not be conducted until 2000. Appendix 1A compares some key 2020 average year forecasts from the two bulletins.

The water plan series uses population forecasts from the Department of Finance. DOF reduced its

Flooding and threatened flooding triggered the evacuation of thousands of people in the greater Yuba City/Marysville area during the January 1997 storms.

2020 forecast for California in the period between Bulletin 160-93 and Bulletin 160-98. The reduction reflects the impacts of the economic recession in California in the early 1990s. California experienced a record negative net domestic migration then, as more people moved out of the State than moved in. This reduction in the population forecast translates to a reduction in forecasted urban water use in Bulletin 160-98.

The 2020 forecasted agricultural water demands increased from Bulletin 160-93 to Bulletin 160-98, even though the forecasted crop acreage decreased slightly. This increase resulted from elimination of the "other" category of water use shown in Bulletin 160-93, which included conveyance losses. For Bulletin 160-98, water in the "other" category was reallocated to the major water use categories to simplify information presentation. Most of the conveyance losses are associated with agricultural water use. Combining the "other" category into the major water use categories most affected the agricultural water demand forecast. As shown in Appendix 1A, when conveyance losses are factored out of the Bulletin 160-98 forecast, agricultural water use decreases between Bulletin 160-93 and Bulletin 160-98.

Bulletin 160-93 was the first water plan update to quantify environmental water use, recognizing the importance of the water that is dedicated to environmental purposes and that this water is unavailable for future development for other purposes. As illustrated earlier, the environmental sector is California's largest water using sector. Bulletin 160-98 uses the same definition and quantification procedure for environmental water use as did Bulletin 160-93.

The 2020 environmental water demand forecast increased substantially from Bulletin 160-93 to Bulletin 160-98. This increase results from implementation of the Bay-Delta Accord, inclusion of additional wild and scenic river flows, and increased instream flow requirements.

The shortage shown in Bulletin 160-98 is similar in magnitude to the low end of the shortage range reported in Bulletin 160-93. The treatment of forecasted Bay-Delta environmental water demands accounts for much of the difference. A 1 to 3 maf range of potential future environmental water demands was added to the Bulletin 160-93 base environmental water demand forecast, rather than being evaluated through operations studies, because Bay-Delta regulatory assumptions could not be determined then. This conservative approach yielded higher demands than operations studies would have provided. (Use of operations studies to calculate water supply requirements is explained in Chapter 3.)

Preparation of Bulletin 160-98

Although the water plan updates are published only every five years, the Department continuously compiles and analyzes the annual data used to prepare them. After publication of Bulletin 160-93 in 1994, the remainder of that year was devoted to finishing data evaluation deferred during the Bulletin's production. Work on Bulletin 160-98 began in 1995. A citizen's advisory committee with more than 30 members, representing a wide range of interests, was established to assist the Department in its preparation of the next water plan update. The advisory committee met with Department staff 17 times over the period of Bulletin 160-98 preparation, and in August 1997 reviewed an administrative draft that preceded release of the public review draft at the end of January 1998. The review period for the public draft extended through mid-April 1998, during which time public meetings were held and presentations were made to interested parties. The draft was also made available on the World Wide Web. Over 4,000 copies of the public review draft were distributed. Comments received on the public review draft were addressed in the final version of the Bulletin.

Public Comments on Draft

The Department received over 200 comment letters on the draft and additional comments from public meetings. A summary of the comments is provided in Appendix 1B. Many comments were provided by local agencies whose facilities and projects are described in the public draft, and dealt with edits or corrections regarding those facilities or projects. Another major class of comments dealt with policy, conceptual, or analytical subjects. Many of these comments were influenced by discussions taking place in the CALFED Bay-Delta program and reflected the commenters' positions on CALFED issues. For example, proponents of CALFED's no conveyance improvements alternative generally expressed opposition to Bulletin 160-98's exclusion of groundwater overdraft as a supply, because this approach increases overall statewide shortages. The Department received positive public comments on Bulletin 160-93 when it excluded groundwater overdraft as a supply for the first time, and also received positive comments on its treatment of overdraft for Bulletin 160-98.

Often, public comments conflicted with one another. For example, environmental organizations frequently stated that the Bulletin should include more future water conservation, while water purveyors frequently stated that levels assumed in the Bulletin were overly optimistic. Some comments suggested that the Bulletin's future water demands could be reduced by raising water prices, while others felt that the forecasted demands were too low and did not take into account future needs of California's population and agricultural economy. Likewise, some comments expressed philosophical opposition to constructing more reservoirs in California, while others emphasized the need for more storage and flood control reservoirs. The Department considered these comments in the context of the Bulletin's goal of accurately reflecting actions that water purveyors statewide would be reasonably likely to implement by year 2020.

Some comments suggested that Bulletin 160-98 (or the Department, or the State of California) advocate or express a vision on a variety of subjects—including State-funded water supply development, sustainable development, nonpoint source pollution, flood control, food production security, mandatory water pricing, and greater use of desalting (by entities other than the commenter). Such an approach is outside the scope of the Department's water plan update series. The role of the Bulletin 160 series is to evaluate present and future water supplies and demands given current social/economic policies, and to evaluate progress in meeting California's future water needs. As appropriate, the Bulletin discusses how other factors such as flood control may relate to water supply planning.

In its forecasts, the Department is making a fundamental assumption that today's conditions—facilities, programs, water use patterns, and other factors—are the basis for predicting the future. (And, as one commenter correctly pointed out, Bulletin 160-98 also assumes that California's climate will remain unchanged over the Bulletin's 25-year planning horizon.) This approach differs distinctly from the approach of establishing a desired future goal or vision, and then preparing a plan that would implement that goal or vision. Such a plan would require public acceptance that simply does not exist today.

Many of the advocacy or vision comments described above are also not within the Department's jurisdiction or the jurisdiction of other State agencies. For example, the Department's role in developing water supply for local agencies is limited to fulfilling its State Water Project contractual obligations. (The Department may provide financial assistance to local agencies for various water management programs as authorized under bond measures enacted by the Legislature and approved by the voters.) The Department has no regulatory authority to mandate how local water agencies price their water supplies, or to require that local agencies adopt one type of water management option over another. Comments such as those suggesting that the Department make plans for control of nonpoint source pollution or food production address the jurisdictional areas of other State agencies.

The subject of flood control merits special mention because of the direct relationship between operations of water supply projects and flood control projects. The purpose of the water plan update series is to evaluate water supplies, but those supplies can be affected by flood control actions such as increasing the amount of reservoir storage dedicated to flood control purposes. With memories of the disastrous January 1997 floods still fresh in peoples' minds, some commenters recommended that Bulletin 160-98 devote more attention to flood control needs, including needs such as floodplain mapping programs that are not directly related to water supply considerations. The 1997 *Final Report of the Governor's Flood Emergency Action Team* describes recommended actions to be taken based on the damages experienced in January 1997. The Department has referenced sections of that report throughout Bulletin 160-98. Bulletin 160-98 emphasizes the interaction between water supply and flood control planning, and points out the benefits associated with multipurpose water projects.

As discussed in the following section, the Department received a number of comments requesting that Bulletin 160-98 quantify future water supply uncertainties associated with ongoing programs or regulatory actions, such as the CALFED Bay-Delta program, Federal Energy Regulatory Commission hydroelectric plant relicensing, and Endangered Species Act listings. Text has been added that quantifies those actions for which data are available.

The Department also received some comments that could not be incorporated in Bulletin 160-98 because they suggested substantial changes in the scope or content of the Bulletin that could not be addressed before the Bulletin's due date to the Legislature, or suggested changes for the next update of the water plan. The scope of Bulletin 160-98 was established in coordination with the Bulletin's advisory committee in 1995, just as the scope of the next plan update (five years hence) will have to be established early in the process of preparing that update. The Department will consider these long-term comments when work begins on the next update.

Works in Progress and Uncertainties

The descriptions of major California water management activities provided in the Bulletin are generally current through July 1998. There are several pending activities that could be characterized as works in progress, including the CALFED Bay-Delta program and Colorado River water use discussions. For programs such as these, the Bulletin describes their current status and potential impacts, if known, on future water supplies. There are uncertainties associated with the outcomes of these activities, just as there are with any process that is evaluated in mid-course.

As noted at the beginning of this chapter, each water plan update focused on issues or concerns of special interest at the time of its publication. Water use for hydroelectric power generation is a good example of this focus. Bulletin 160-83 was the last water plan update to review hydropower generation use, because no major changes have occurred since the late 1970s/early 1980s, when high energy prices and favorable tax treatment for renewable energy spurred a boom in small hydropower development. Today uncertainties about water supply and water use associated with hydropower production are increasing, with the 1998 initiation of deregulation for California investor-owned utilities and the prospect of FERC relicensing of several powerplants on major Sierra Nevada rivers between 2000 and 2010. Although there is presently little information available on which to base forecasts of resultant changes in water supplies, more information is likely to be available for the next water plan update.

Colorado River interstate issues are a new addition to a statewide water picture largely dominated by Delta and CVPIA issues in the recent past. Achieving a solution to California's need to reduce its use of Colorado River water to the State's basic apportionment (a reduction of as much as 900 taf from historical uses) requires consensus among California's local agencies that use the river's water, as well as concurrence in the plan by the other basin states.

Presentation of Data in Bulletin 160-98

Water budget and related data are tabulated by hydrologic region throughout the Bulletin. The statewide totals in these tables are generally presented as rounded values. As a result, individual table entries will not sum exactly to the rounded totals.

In the water budget appendices 6A, 6E, and 10A, regional water use/supply totals and shortages are not rounded. Individual table entries may not sum exactly to the reported totals due to rounding of individual entries for presentation purposes.

Organization of Bulletin 160-98

Chapter 2 provides an overview of recent events in California water and summarizes significant changes in statutes and programs since the publication of Bulletin 160-93. An appendix for Chapter 2 summarizes some State and federal statutes affecting water management. Chapters 3 and 4 cover water supplies and water uses. Chapter 5 describes the status of technology applications relating to water supply, reflecting the continuing public interest in topics such as potential future use of seawater desalting, status of water conservation and use technologies, or fish screening technology applications.

Chapters 6-9 focus on ways to meet California's future water needs. Chapter 6 covers statewide level water management actions, including actions such as the CALFED Bay-Delta program, SWP future water supply options, and CVPIA fish and wildlife water acquisition. Chapters 7-9 evaluate regional water management options for each of the State's ten major hydrologic regions. These regional evaluations are combined in Chapter 10 into a tabulation of actions likely to be taken to meet California's future water needs. The water budget tables in Chapter 10, shown for a 2020 level of demand with future water management options, are key summaries of the Bulletin's planning process. Appendices follow at the end of the chapters in which they are referenced. Following Chapter 10 are a brief glossary and list of abbreviations and acronyms used in the text.

An executive summary of Bulletin 160-98 is available as a separate document.

1A

Comparison of 2020 Average Year Forecasts Between Bulletin 160-93 and Bulletin 160-98

Table 1A-1 compares some key 2020 average year forecasts from Bulletin 160-93 and Bulletin 160-98.

Bulletin 160-93 provided water use information as applied water, net water, and depletion. The table shows Bulletin 160-93 urban, agricultural, and environmental water use as applied water demands, to be compatible with Bulletin 160-98 applied water use data.

Bulletin 160-93 included a fourth category of water use called "other." This "other" category included major canal conveyance losses, recreation use, cooling water use, energy recovery use, and use by high water using industries. Water uses previously categorized as "other" are included in the Bulletin 160-98 urban, agricultural, and environmental water use categories according to their intended purpose. To provide a meaningful comparison with Bulletin 160-93 water use data in the table, water use previously classified as "other" was removed from the Bulletin 160-98 data.

TABLE 1A-1

2020 Average Year Forecasts

	Bulletin 160-93	*Bulletin 160-98*
Population (million)	48.9	47.5
Irrigated crop acreage (million acres)	9.3	9.2
Urban water use (maf)	12.7	11.4[a]
Agricultural water use (maf)	28.8	28.3[a]
Environmental water use (maf)	30.3-32.3	36.9[a]
Average water shortage[b] (maf)	3.7-5.7	2.4

[a] The "other" category of water use was removed to make the 160-93 and 160-98 numbers directly comparable, as described in the text.

[b] As described in the text, a major reason for the change in the shortage numbers between the two bulletins was differences in forecasted Bay-Delta environmental water demands. Shortage values are not exactly comparable, as Bulletin 160-93 presented net water shortages and Bulletin 160-98 presented applied water shortages

1B

Summary of Public Comments on Draft Bulletin 160-98

Work on Bulletin 160-98 began in 1995. A public advisory committee with more than 30 members representing a wide range of interests was established to assist the Department in preparing the water plan update. The advisory committee met with Department staff 17 times over the period of Bulletin 160-98 preparation and, in August 1997, reviewed an administrative draft that preceded the public review draft's release at the end of January 1998. Over 4,000 copies of the draft were distributed. The draft was also made available on the World Wide Web. The review period for the public draft extended through mid-April 1998, during which time eight public meetings were held and presentations were made to interested parties. The Department received about 200 letters, form letters, postcards, and other comment submissions.

Because this update of the water plan focused on local agency water management actions, the Department received many local agency comments with corrections, updates, or other changes to the draft's text on their facilities, service areas, or programs. The Department also received many comments relating to CALFED Bay-Delta program activities. CALFED's draft PEIR/PEIS was released during the Bulletin 160-98 public review period; comments on Bulletin 160-98 often reflected commenters' positions on the CALFED document. For example, proponents of CALFED's alternative one generally commented that the Bulletin's future water demand forecasts were too high.

The following sections summarize the most frequently repeated comments. Public comments often conflicted with one another. Specific comments or edits on descriptions of local agencies' facilities and programs are not included in the summary due to space limitations. Copies of comments received are available for review at the Department's office.

The Role of the State, the Department, and the Water Plan Update Series

- The Department should take the lead in planning new facilities to meet California's future needs. (Chapter 6, Chapter 10)
- The Bulletin only summarizes the actions that local agencies are taking to meet future needs. It does not acknowledge the State's responsibility for meeting California's water needs. (Chapter 6, Chapter 10)
- The State should provide financial assistance to local agencies to help them meet future water needs. Many agencies cannot afford the actions that would be required to provide reliable supplies for their service areas. (Chapter 6, Chapter 10)
- The Department should take steps to meet the future needs of water users in the area of origin. (Chapter 6, Chapter 8)
- The State should provide leadership in addressing California's serious groundwater overdraft. (Chapter 3, Chapter 4, Chapter 8, Chapter 10)
- The State should take an active role in promoting or enforcing water conservation, and should take action to reduce water waste and high water use by agriculture. (Chapter 4, Chapter 6)
- The State should require local agencies to price their water in a manner that reflects its true cost or to achieve goals such as water conservation. (Chapter 4)
- The Bulletin does not plan for the State's future—it tabulates a list of possible options. A plan should

contain a process for achieving the desired goal and should identify financing sources. (Chapter 6, Chapter 10)

- The Bulletin should prioritize the options that most urgently need to be implemented, perhaps those that would eliminate average year water shortages. (Chapter 6, Chapter 10)
- The Bulletin should plan explicitly for future flood control needs. (Chapter 3, Chapter 6, Chapter 8, Chapter 10)
- The Bulletin's scope should be expanded beyond water supply planning to include planning for nonpoint source pollution control and controlling agricultural drainage. (Chapter 6, Chapter 10)
- The Bulletin should plan for the agricultural water supply needed to maintain California's agricultural production and to grow the food that will be needed by the State's increasing population. (Chapter 4, Chapter 10)

The Bulletin in General

- The Bulletin does a good job of presenting a balanced overview of California water supplies and demands, and options for meeting future needs. (no specific chapter)
- The Bulletin has fundamental flaws in methodology and should not be used to support CALFED-related decisions. The public draft should be critiqued by an external peer review committee. (Chapter 4, Chapter 6)
- The Bulletin 160-98 switch to an applied water budget approach for presentation of information is appreciated. The applied water budget is easier to understand than the net water budgets used in previous bulletins. (Chapter 3, Chapter 4)
- The applied water budget is more confusing than the previous net water budgets. (Chapter 3, Chapter 4)
- The Bulletin should not use an applied water budget because it overstates environmental water use. (Chapter 4)
- The Bulletin should provide more detail on demand forecasting, descriptions of water management options, and cost data. Show all assumptions and background data. (Chapter 4, Chapter 6)
- Presentation of some subjects is difficult to follow. Simplify presentation. (no specific chapter)
- Status of ongoing programs/actions (CALFED, Colorado River Board 4.4 Plan negotiations, new ESA listings) should be updated. (Chapter 2, Chapter 6)
- The Bulletin should show a range of shortage outcomes to reflect uncertainties associated with new ESA listings, FERC relicensing, CVPIA supplemental water acquisition, SWRCB's Bay-Delta water rights proceedings, and CALFED. (Chapter 6, Chapter 10)

Water Supplies and Demands

- There were comments on groundwater supplies or overdraft for individual groundwater basins or hydrologic regions. There were also several comments about boundaries of specific groundwater basins or sub-basins. A general comment was that the Bulletin needs to place more emphasis on good groundwater data. (Chapter 3)
- The Bulletin's treatment of 1995 and 2020 groundwater overdraft as not available as a source of supply accurately represents dependable water supplies. Groundwater overdraft is not sustainable over the long term and should not be a long-term solution to water supply needs. (Chapter 3)
- Groundwater overdraft should not be treated as creating a shortage, but should be a source of supply. Farmers will stop overdrafting groundwater when it becomes too expensive to pump. (Chapter 3)
- The high levels of groundwater overdraft shown in the San Joaquin Valley are of concern. The Bulletin should examine means to address this overdraft through long-term basin management. (Chapter 3, Chapter 8)
- There were several questions about the source of water supply data for water recycling. It was suggested that water recycling survey results be shown in an appendix. (Chapter 3, Chapter 6)
- There were several suggestions for different terminology to distinguish among water transfers, banking, exchanges, sales, and acquisitions. (Chapter 3, Chapter 6)
- The Bulletin should recognize the reality of global warming/long-term global climate change. Future hydrologic conditions will differ from today's. Existing hydrologic forecasts are based on a limited period of historical record. (Chapter 3)
- The Bulletin should evaluate the relationship of local land use planning to water supply/water

needs. Quantify the results of enactment of SB 901 (a 1995 amendment to Section 65302 of the Government Code). (Chapter 4)

- Environmental water use should be treated on an equal basis with urban and agricultural water use. The only environmental demands forecasted in the Bulletin are those required by laws or agreements. The Bulletin forecasts urban and agricultural uses based on needs, not minimum legal requirements. (Chapter 4)
- North Coast wild and scenic rivers should not be counted as environmental water use. The magnitude of their flow is so great that it skews the rest of the environmental water uses. North Coast wild and scenic rivers should not be counted as environmental water use because no one is seriously planning to develop them. (Chapter 4)
- The Bulletin should emphasize that the environment once received 100 percent of the water and now receives much less. Environmental water supplies are needed for more uses than recognized in the Bulletin—for non-listed species of fish and wildlife, flushing flows through the Golden Gate, and other aquatic resources. (Chapter 4)
- The Bulletin puts environmental water use in proper perspective with other water uses—that the environment is California's largest water using sector. (Chapter 4)
- The Bulletin understates future environmental demands because it uses Bay-Delta Accord requirements which expire in 1998 and present ESA requirements. Water requirements for recently listed fish species will likely increase future environmental demands. (Chapter 4)
- The Bulletin should place more emphasis on environmental water conservation. Conservation is required of the urban and agricultural sectors, but not of the environmental sector. (Chapter 4, Chapter 6)
- CVPIA supplemental water needs shown in USBR's draft CVPIA PEIS should not be counted as future environmental water demands because they falsely inflate future shortages. CVPIA supplemental water needs should not be counted as future environmental water demands because water users will not sell such large quantities of water to USBR. (Chapter 4)
- The Bulletin correctly includes CVPIA supplemental water needs as future environmental water demands. (Chapter 4)
- The Bulletin should recognize environmental water needs for the Colorado River delta area in Mexico. (Chapter 4, Chapter 9)
- More attention should be given to environmental water needs at the south end of the San Francisco Bay. (Chapter 7)
- Urban water use forecasts are too high because they are based on normalized data, not on actual water data. (Chapter 4)
- Water pricing should be explicitly considered in future demand forecasts. The definition of demand should be revised to make demand a function of price. (Chapter 4)
- There were several comments stating that water demand is not price inelastic. (Chapter 4)
- Much more conservation is possible than is shown in the Bulletin. Price should be used to achieve or enforce conservation. (Chapter 4, Chapter 6)
- Increased market penetration of horizontal axis washing machines will result in greater conservation amounts than forecasted in the Bulletin. Urban landscaping changes will also result in greater conservation. (Chapter 4, Chapter 6)
- The assumption that water agencies statewide will implement BMPs should be clarified. Not all BMPs can be quantified. (Chapter 4)
- The Bulletin overstates potential demand reductions from implementing BMPs. Agencies are only obligated to implement measures that are cost-effective for their service areas. (Chapter 4)
- Water conservation should not be implemented unless it is cost effective. Water savings do not necessarily result in depletion reductions. (Chapter 4, Chapter 6)
- The Bulletin should provide more information on its conservation assumptions, and data to substantiate forecasted conservation. (Chapter 4, Chapter 6)
- The Bulletin should discuss CVPIA water conservation plans and the effects of CVPIA tiered pricing. (Chapter 4, Chapter 6)
- The Bulletin should discuss lack of data available for city/county implementation of AB 325 (model landscaping ordinance). (Chapter 4, Chapter 6)
- There were several comments that the Bulletin's forecasts of future irrigated acreage underestimated acreage for specific areas. (Chapter 4)
- Forecasts of irrigated acreage and crop mix in past water plan updates (e.g., Bulletin 160-83) do not seem to be coming true (were too high). The Bul-

letin should acknowledge uncertainties in the forecasts. (Chapter 4)

- The Bulletin should give equal treatment to forecasts of agricultural and urban water use. Urban water use is forecasted based on the needs of California's future population. Agricultural needs should be based on maintaining California agriculture's proportionate share of in-state, national, and global food and fiber production. (Chapter 4)
- The Bulletin's irrigated acreage forecast does not include the effects of proposed large-scale land use conversion from irrigated agriculture to wildlife habitat, such as that proposed in CALFED's ecosystem restoration program. (Chapter 4)
- The Bulletin provides a realistic assessment of the potential for agricultural water conservation. (Chapter 4, Chapter 6)
- The potential for agricultural water conservation is much greater than is shown in the Bulletin. The Bulletin did not consider the impacts of reducing federal crop and water subsidies on forecasted demands. (Chapter 4, Chapter 6)
- The Bulletin incorrectly characterizes shortages as the gap between forecasted supplies and demands. There is no shortage if water users are unwilling to pay the amount needed to acquire new water. It is generally not economically rational to reduce shortages to zero. (Chapter 6, Chapter 10)
- The Bulletin should shift from requirements-based planning to reliability-based planning. (Chapter 6)

Future Water Management Options

- The Bulletin places too much emphasis on structural solutions to future water needs and not enough on nonstructural solutions. (Chapter 6, Chapters 7-9)
- Pricing and marginal costs should be explicitly included in the evaluation of future water management options. Use demand and supply curves to illustrate role of cost in evaluating future supplies. (Chapter 4, Chapter 6)
- Environmental impacts from new projects must be balanced against gains in environmental water supplies. Benefits of developing additional water supplies should be weighed against benefits of protecting other natural resources. (no specific chapter)
- No new reservoirs should be constructed in California. (Chapter 6, Chapters 7-9)
- California needs additional reservoirs. (Chapter 6, Chapters 7-9)
- As a matter of policy, the Bulletin should give priority to options that use existing supplies more efficiently, or reallocate existing supplies, before considering new water development projects. (Chapter 6, Chapters 7-9)
- As a matter of policy, the Bulletin should give priority to options that create new water supplies (reservoirs). (Chapter 6, Chapters 7-9)
- The Bulletin should emphasize that implementing conjunctive use projects in some areas is constrained by the lack of surface water available for recharge. (Chapter 6)
- California's future water needs can be met through increased conservation and water marketing. A modest reallocation of agricultural water supplies would satisfy the needs of California's growing urban population. (Chapter 6, Chapter 10)
- Retirement of agricultural lands should not be considered as a future water supply option. (Chapter 6)
- Land retirement costs shown in the Bulletin are too high—economic multipliers were not used for any other water management option. (Chapter 6)
- Land retirement costs shown in the Bulletin are too low. (Chapter 6)
- More emphasis should be given to integrating water supply and flood control benefits. Flood control needs should be emphasized. (Chapter 6, Chapter 8, Chapter 10)
- Multiple benefits of water conservation and recycling should be acknowledged. Conservation and recycling should be treated as new supplies regardless of where they are implemented (e.g., in inland regions). (Chapter 4, Chapter 6)
- Multipurpose benefits of new reservoirs should be emphasized. New reservoirs are increasingly important as future options, because demand hardening due to increased water conservation efforts has removed past flexibility in responding to droughts. (Chapter 6, Chapter 10)
- The Bulletin correctly recognizes that conservation and recycling create new water only where that water would otherwise be lost to the ocean or to another unusable source. (Chapter 4, Chapter 6)
- It is unrealistic to assume further conservation beyond BMPs and EWMPs. There is no way of accurately quantifying future conservation. (Chapter 6)

- There is no evidence suggesting that the 80 percent ET_0 target for urban landscaping could be attained statewide. The urban BMPs and AB 325 have been in effect for some time and have not shown that this level is being achieved. (Chapter 4, Chapter 6)
- Distribution uniformity values assumed for the future agricultural water conservation options may be unrealistically high with present agricultural technology. (Chapter 6)
- The Bulletin should recognize that there are no accurate numbers for estimated acreage of urban landscape—either existing landscape acreage or potential future acreage. (Chapter 6)
- The Bulletin places undue reliance on conservation as a panacea for reducing future shortages. (Chapter 4, Chapter 6)
- Much more future conservation can be achieved beyond BMPs and EWMPs. Reduction of outdoor water use for landscape is not costly and can be phased in over time. More agricultural acreage can be converted from inefficient irrigation techniques to drip irrigation. (Chapter 6)
- The Bulletin does not give water transfers/water marketing equal treatment with construction of new reservoirs. The Bulletin substantially understates the future potential for water marketing. (Chapter 6)
- Water transfers do not create new water supplies—they are a reallocation of existing uses. The future market for water transfers will be much less than is shown in the Bulletin. (Chapter 6)
- There were several comments regarding treatment of potential future transfers in the water budgets—whether transfers should or should not be shown as a supply if no sellers had been identified, whether transfers should be identified as options if an environmental document had not been completed, whether transfers should be subject to a real water test. (Chapter 3, Chapter 6)
- The water budgets do not show enough water supplies from potential future transfers. (Chapter 3, Chapter 6)
- New water supplies from transfers should not be shown in the water budgets. (Chapter 3, Chapter 6)
- The Bulletin does not adequately analyze third-party impacts resulting from water transfers. (Chapter 6)
- The "real water" concept in water transfers is not valid—the Department is just trying to protect the SWP. (Chapter 6)
- The Bulletin does not take into account that competition for supplies from transfers will limit the amount of water available. Well-funded environmental restoration programs such as CVPIA's supplemental water program and the CALFED program will reduce supplies available for others. (Chapter 3, Chapter 6)
- Pending regulatory actions and additional ESA listings may further reduce the amount of water that could be available for transfer. (Chapter 6)
- Area of origin protections need to be explicitly recognized as a limitation to transfers. (Chapter 6)
- The Bulletin should recognize salinity constraints in Southern California water supplies that limit local agencies ability to implement water recycling projects. (Chapter 6, Chapter 7)
- As technology improves, there is increasing potential for desalting San Joaquin Valley agricultural drainage water as part of larger projects for urban/agricultural water transfers or exchanges. (Chapter 8)
- The Bulletin should place more emphasis on seawater desalting in the future. Additional research and development funds should be devoted to desalting. (Chapter 6)
- The State should support marine transport of freshwater (tankers or water bags). The Department should work with interested parties to develop this option. (Chapter 6)
- Forest thinning should be given serious consideration as a source of future water supply. (Chapter 6)

2

Recent Events In California Water

This chapter highlights key infrastructure and institutional changes that have occurred since the publication of Bulletin 160-93, and reviews the status of selected programs. An overview of significant legislative actions is provided, and the legislative framework for California water management is summarized in the appendix.

Infrastructure Update

A common theme in previous updates of the *California Water Plan* has been the need to respond to California's continually increasing population. Population growth brings with it the need for new or expanded infrastructure. This section provides a very brief overview of the largest infrastructure projects which are now under construction or have been recently completed. Some of these projects are described in more detail in later chapters.

California's increasing population is a driving factor in future water management planning.

Large dams under construction or recently completed are listed in Table 2-1. Large conveyance projects under construction or recently completed are listed in Table 2-2. Information about smaller-scale new water supply facilities, including water recycling and desalting plants, can be found in Chapter 5 and Chapters 7-9.

TABLE 2-1

Large Dams Under Construction or Recently Completed

Dam	*Constructing Agency*	*Estimated Capacity (taf)*	*Reservoir Purpose*	*Project Cost[a] (million $)*
Seven Oaks	USACE	146	flood control	366
Los Vaqueros	CCWD	100	offstream storage[b]	450
Eastside	MWDSC	800	offstream storage	2,000

[a] Project construction include costs for land acquisition, environmental mitigation, and associated facilities (such as pipelines and road relocations).
[b] Offstream storage for water quality and emergency service; no new water supply created.

TABLE 2-2

Major Water Conveyance Facilities Since 1992

Facility	*Constructing Agency*	*Status*	*Length (miles)*	*Maximum Capacity (cfs)*
Coastal Branch Aqueduct	DWR	completed 1997	100	100
Eastside Reservoir Pipeline	MWDSC	completed 1997	8	1,000
East Branch Enlargement	DWR	completed 1996	100	2,880
Mojave River Pipeline	MWA	started 1997	70	94
Old River Pipelines (Los Vaqueros Project)	CCWD	completed 1997	20	400
East Branch Extension	DWR	started 1998	14	104
Inland Feeder Project	MWDSC	started 1997	44	1,000
Morongo Basin Pipeline	MWA	completed 1994	71	100
New Melones Water Conveyance Project	SEWD and CSJWCD	completed 1993	21	500

TABLE 2-3

Large Structural Fishery Restoration Projects

Project	*Owner*	*Description*
Shasta Dam Temperature Control Device	USBR	An approximately $83 million modification to the dam's outlet works to allow temperature-selective releases of water through the dam's powerplant was completed in 1997.
Red Bluff Diversion Dam Research Pumping Plant	USBR	A $40 million experimental facility to evaluate fishery impacts of different types of pumps diverting Sacramento River water into the Tehama-Colusa and Corning Canals was contructed in 1995.
Butte Creek fish passage	Western Canal Water District and others	A multi-component project to improve fish passage by removing small irrigation diversion dams from the creek. By 1998, five diversion dams will have been removed.
Maxwell Irrigation District fish screen	Maxwell ID	An 80 cfs diversion on the Sacramento River was screened in 1994.
Pelger Mutual Water Company fish screen	PMWC	A 60 cfs diversion on the Sacramento River was screened in 1994.

Table 2-3 lists some of the largest examples of recently completed structural environmental restoration actions. Several more fish screening projects in the Sacramento River system are expected to begin construction or to be completed in 1998. Details on these facilities can be found in Chapters 5 and 8. Table 2-4 shows a sampling of completed smaller restoration projects.

Legislative Update

This section summarizes major changes within the last five years to State and federal statutes affecting water resources management, together with the status of ongoing efforts to reauthorize some key federal statutes. The existing statutory and regulatory framework for California water management is summarized in Appendix 2A.

State Statutes

Local Water Supply Reliability. In 1995, the Legislature enacted three bills dealing with water supply reliability and long-range planning to serve future water needs. Two of the bills (Statutes of 1995, Chapters 330 and 854) amended requirements for preparing urban water management plans by requiring that local agencies make a specified assessment of the reliability of their water supplies. (Water agencies serving more than 3,000 customers or 3 taf annually are required to prepare urban water management plans and to update the plans at least every five years.) Local water agencies are required to evaluate the reliability of their supplies for varying water year types.

The third bill (Statutes of 1995, Chapter 881) requires that cities and counties making specified land use planning decisions, such as amending a general plan, consult with local water agencies to determine if water supply is available. The bill also requires that findings by local water agencies on water supply availability be incorporated into cities' or counties' environmental documents for the proposed action. To date, there are no statewide data available on local agen-

TABLE 2-4

Sample Restoration Projects Funded in Part by the SWP's 4-Pumps Program

Location	*Description*	*Implementing Agency(ies)*	*Capital Costs*	*Completion Date*
Suisun Marsh Fish Screening Project				
Suisun Marsh	Design, construct, and install seven fish screens on diversions for managed wetlands within Suisun Marsh.	Suisun Resource Conservation District, DFG, DWR, USBR	$2,000,000	1997
Durham Mutual Fish Screens and Ladder				
Butte Creek at Durham Mutual Dam	Install two fish screens and an improved high volume fish ladder to eliminate entrainment and improve fish passage.	Durham Mutual Water Company, USBR, DWR, DFG	$930,000	1998
Parrot-Phelan Fish Ladder				
Butte Creek at Parrot-Phelan Dam	Design and construct a pool-and-chute fish ladder to provide fish passage.	DFG, USBR, DWR	$800,000	1995
Mill Creek Water Exchange Project				
Mill Creek	Fund operation of an irrigation well to replace diversions (up to 25 cfs) bypassed to provide flows for anadromous fish.	DFG, DWR	$559,000	Phase II-Summer 1994
Magneson Salmon Habitat Restoration and Predator Habitat Isolation Project, Merced River				
Merced River (River Mile 29-30)	Restore river channel and isolate abandoned gravel pit.	DFG, DWR	$336,000	1996
Stanislaus River Spawning Habitat Restoration, 3 Riffles				
Stanislaus River	Restore salmon spawning gravel at three sites.	DFG, DWR	$209,000	1994

The Department's Coastal Branch extension from Kings County to Santa Barbara County was completed in 1997.

cies' implementation of these new requirements. The statute did not require reporting on consultations or findings to the State CEQA clearinghouse or to any external agency.

Financing Water Programs and Environmental Restoration Programs (Proposition 204). California voters approved Proposition 204—the Safe, Clean, Reliable Water Supply Act—in 1996. The act authorized the issuance of $995 million in general obligation bonds to finance water and environmental restoration programs throughout the state. Approximately $600 million of these bonds would provide the State share of costs for projects to benefit the Bay-Delta and its watershed, including $390 million of this amount to implement CALFED's ecosystem restoration program for the Bay-Delta. These latter funds would be available after final federal and State environmental documents are certified and a cost-sharing agreement is executed between the federal and State governments. Table 2-5 summarizes programs authorized for Proposition 204 funding.

TABLE 2-5

Proposition 204 Funding Breakdown

Program	*Dollars (in millions)*
Delta Restoration	**193**
CVPIA State share	93
Category III State share	60
Delta levee rehabilitation	25
South Delta barriers	10
Delta recreation	2
CALFED administration	3
Clean Water and Water Recycling	**235**
State Revolving Fund Clean Water Act loans	80
Clean Water Act grants to small communities	30
Loans for water recycling projects	60
Loans for drainage treatment and management projects	30
Delta tributary watershed rehabilitation grants and loans	15
Seawater intrusion loans	10
Lake Tahoe water quality improvements	10
Water Supply Reliability	**117**
Feasibility investigations for specified programs	10
Water conservation and groundwater recharge loans	30
Small water project loans and grants, rural counties	25
Sacramento Valley water management and habitat improvement	25
River parkway program	27
CALFED Bay-Delta Ecosystem Restoration Program	**390**
Flood Control Subventions	**60**
Total	**995**

Proposition 218. Voter approval of Proposition 218 in November 1996 changed the procedure used by local government agencies for increasing fees, charges, and benefit assessments. Benefit assessments, fees, and charges that are imposed as an "incident of property ownership" are now subject to a majority public vote. Proposition 218 defines "assessments" as any levy or charge on real property for a special benefit conferred to the real property, including special assessments, benefit assessments, and maintenance assessments. Proposition 218 further defines "fee" or "charge" as any levy (other than an ad valorem tax, special tax, or assessment), which is imposed by an agency upon a parcel or upon a person as an incident of property ownership, including a user fee or charge for a property-related service.

Although there are many tests to determine if a fee or charge is subject to the provisions of Proposition 218, the most significant one is whether the agency has relied upon any parcel map for the imposition of the fee or charge. There is currently uncertainty in the interpretation of Proposition 218 requirements, especially as they relate to certain water-related fees and charges. From one point of view, Proposition 218 could be interpreted as a comprehensive approach to regulate all forms of agency revenue sources. This broad interpretation would include all fees and charges for services provided to real property. Types of water-related charges and fees that may be affected by Proposition 218's requirements include meter charges, acreage-based irrigation charges, and standby charges.

Additional legislation or judicial interpretation may be needed to clarify the application of Proposition 218 to fees and charges used by water agencies. Several water industry groups are working on proposals for clarifying legislation. To date, there has been one water-related legislative clarification of Proposition 218. A 1997 statute clarified that assessments imposed by water districts and earmarked for bond repayment are not subject to the proposition's voter approval requirements.

Municipalities and special districts are beginning to seek voter approval of assessments as required by Proposition 218. Many assessments to fund existing programs have been receiving voter approval. There has been at least one example, however, of a water agency whose proposed assessment was not approved. Monterey County Water Resources Agency did not receive voter approval for an assessment to support existing programs—groundwater quality monitoring, water conservation, and nitrate management outreach—funded by water standby charges. Examples of MCWRA's proposed assessment charges were $1.67 per irrigated acre for agricultural land use and $2.26 per parcel for single-family dwellings.

Water Recycling. In 1995, provisions of the Water Code, Fish and Game Code, Health and Safety Code, and other statutes were amended to replace terms such as wastewater "reclamation" and "reclaimed water" with "water recycling" and "recycled water." The legislation was intended to enhance public acceptance of recycled water supplies.

MTBE. Detection of methyl tertiary butyl ether in water supplies soon after it was approved for use as an air pollution-reducing additive in gasoline has raised concerns about its mobility in the environment. Legislation enacted in 1997 included several provisions dealing with MTBE regulation, monitoring, and studies. One provision required the Department of Health Services to establish a primary (health-based) drinking water standard for MTBE by July 1999, and a secondary (taste and odor) drinking water standard by July 1998. (MTBE can be detected by taste at very low concentrations, hence the early requirement for a secondary drinking water standard.)

Federal Statutes

Safe Drinking Water Act. The Safe Drinking Water Act, administered by the U.S. Environmental Protection Agency in coordination with the states, is the chief federal regulatory legislation dealing with drinking water quality. The 104th Congress reauthorized and made significant changes to the SDWA, which had last been reauthorized in 1986. Major changes included:

- Establishing a drinking water state revolving loan fund, to be administered by states in a manner similar to the existing Clean Water Act State Revolving Fund. Loans would be made available to public water systems to help them comply with national primary drinking water regulations and to upgrade water treatment systems.
- The standard-setting process for drinking water contaminants established in the 1986 amendments was changed from a requirement that EPA adopt standards for a set number of contaminants on a fixed schedule to a process based on risk assessment and cost/benefit analysis. The 1996 amendments require EPA to publish (and periodically update) a list of contaminants

not currently subject to NPDWRs and to periodically determine whether to regulate at least five contaminants from that list, based on risk and benefit considerations.

- A requirement that states conduct vulnerability assessments in priority source water areas expanded existing source water quality protection provisions. States are authorized to establish voluntary, incentive-based source protection partnerships with local agencies. This activity may be funded from the new SRF.
- As a result of the 1996 amendments, EPA adopted a more ambitious schedule for promulgating the Disinfectant/Disinfection By-Products Rule and the Enhanced Surface Water Treatment Rule. The first phase of the D/DBP Rule is proposed to take effect in late 1998, as is an interim ESWTR. More stringent versions of both rules are proposed to follow in 2002. This subject is discussed in more detail in Chapter 3.

Clean Water Act Reauthorization. The Clean Water Act, administered by EPA in coordination with the states, is the chief federal regulatory statute controlling point and nonpoint source discharges to surface water. The CWA additionally provides federal authority for wetlands protection and regulation of dredging and filling. CWA reauthorization proposals were heard in the 103rd and 104th Congresses, but no legislation was enacted. The act's broad scope complicates reauthorization.

Some of the topics covered in reauthorization proposals have included funding levels for the SRF program; changes to the water quality standard setting process (such as special recognition of environmental benefits of discharging treated wastewater to streams in arid areas); recognition of impacts of introduced aquatic species on species of concern in the water quality standard setting process; Good Samaritan liability provisions for remediation measures at abandoned mines; new programs for nonpoint source management and regulation of combined sanitary/stormwater sewers; new stormwater management requirements for municipalities; recognition of state primacy in water quantity allocation; and expanded statutory treatment of wetlands protection.

Endangered Species Act Reauthorization. As with the CWA, ESA reauthorization proposals were heard in past congresses, but no legislation has been enacted. Some proposed changes included amending the act to focus on preserving ecological communities rather than on preserving a single species or subspecies, providing for stakeholder participation and peer-reviewed science in the species listing process, addressing management of candidate species, streamlining the Section 7 consultation process, quantifying recovery plan objectives, and providing assurances and regulatory relief for nonfederal landowners.

Reclamation, Recycling, and Water Conservation Act of 1996. This act amended Title 16 of PL 102-575 by authorizing federal cost-sharing in additional wastewater recycling projects. (PL 102-575 had authorized federal cost-sharing in specified recycling projects.) The additional California projects are shown below, along with the nonfederal sponsors identified in the statute.

- North San Diego County area water recycling project (San Elijo Joint Powers Authority, Leucadia County Water District, City of Carlsbad, Olivenhain Municipal Water District)
- Calleguas Municipal Water District recycling project (CMWD)
- Watsonville area water recycling project (City of Watsonville)
- Pasadena reclaimed water project (City of Pasadena)
- Phase 1 of the Orange County regional water reclamation project (Orange County Water District and County Sanitation Districts of Orange County)
- Hi-Desert Water District wastewater collection and reuse facility (HDWD)
- Mission Basin brackish groundwater desalting demonstration project (City of Oceanside)
- Effluent treatment for the Sanitation Districts of Los Angeles County with the City of Long Beach (Water Replenishment District of Southern California, OCWD)
- San Joaquin area water recycling and reuse project (San Joaquin County, City of Tracy)

Federal cost-sharing in these projects is authorized at a maximum of 25 percent for project construction and federal contributions for each project are capped at $20 million. Funds are not to be appropriated for project construction until after a feasibility study and cost-sharing agreement are completed. Federal cost-sharing may not be used for operations and maintenance.

The act also authorizes the Department of Interior to cost-share up to 50 percent (planning and design) in a Long Beach desalination research and development project. Local sponsors are the City of Long Beach, Central Basin Municipal Water District, and MWDSC.

Water Desalination Act of 1996. This act authorizes DOI to cost-share in non-federal desalting projects at levels of 25 percent or 50 percent (for projects which are not otherwise feasible unless a federal contribution is provided). Cost-shared actions can be research, studies, demonstration projects, or development projects. The authorization provides $5 million per year for fiscal years 1997 through 2002 for research and studies, and $25 million per year for demonstration and development projects. The act requires DOI to investigate at least three different types of desalting technology and to report research findings to Congress.

National Invasive Species Act of 1996 (PL 104-332). NISA reauthorized and amended the Nonindigenous Aquatic Nuisance and Prevention and Control Act of 1990. The purpose of the legislation was to provide tools for management and control of aquatic nuisance species, such as zebra mussels. NISA reauthorized a mandatory ballast management program for the Great Lakes, an area already heavily infested with zebra mussels, and created an enforceable national ballast management program for all U.S. coastal regions. The act requires detailed reporting on ballast exchange by cargo vessels. Ship ballast water has been identified as a likely mode of introduction for many of the nonindigenous invertebrates identified in the Bay-Delta, now home to at least 150 introduced plant and animal species.

The zebra mussel has caused millions of dollars in increased operations and maintenance costs to Great Lakes water users. Preventing the mussels' spread is a priority in invasive species management.

State and Federal Programmatic Actions

SWP Monterey Agreement Contract Amendments

The Monterey Agreement among the Department and SWP water contractors was signed in December 1994. This agreement set forth principles for making changes in SWP water supply contracts, which would then be implemented by an amendment (Monterey amendment) to each contractor's SWP contract. The amendment has been offered to all SWP contractors. Those contractors that sign the amendment will receive the benefits of it, while those that do not will have their water supply contracts administered such that they will be unaffected by the amendment. As of December 1997, 26 of the 29 contractors had signed the amendment.

Changes to SWP Water Allocation Rules. The amendment states that during drought years project supplies are to be allocated proportionately on the basis of contractors' entitlements. The amendment allocates water to urban and agricultural purposes on equal basis, deleting a previous initial supply reduction to agricultural contractors.

Permanent Sales of Entitlement. The amendment provides for transfer of up to 175 taf of annual entitlement from agricultural use. The first transfer made was relinquishment of 45 taf of annual entitlement (40,670 acre-feet from Kern County Water Agency, 4,330 acre-feet from Dudley Ridge Water District) back to the SWP, as part of the transfer of the Kern Water Bank property to these agencies. This relinquishment reduces the total SWP contractual commitment. The amendment provides for an additional 130 taf/yr of existing agricultural entitlement to be sold on a permanent basis to urban contractors, on a willing buyer-willing seller basis. As of April 1997, 25 taf/yr of KCWA entitlement had been purchased by Mojave Water Agency for recharge in Mojave's groundwater basin. Other potential permanent transfers are being discussed.

Storing Water Outside a Contractor's Service Area and Transfers of Non-Project Water. While some of the amendment's benefits help the larger SWP contractors, the ability to store water outside a contractor's service area is a significant benefit to the smaller contractors. Many SWP urban contractors do not have significant water storage opportunities in their service areas. This provision of the Monterey amendment allows a contractor to store water in another agency's reservoir or groundwater basin. Examples include water storage programs with Semitropic Water Storage District (a member agency of KWCA).

Several water exchanges are moving forward following approval of the Monterey amendment. Dudley Ridge Water District has entered into an exchange agreement with San Gabriel Valley Municipal Water District. Solano County Water Agency has developed an exchange program with MWA whereby SCWA provides a portion of its entitlement in wetter years in return for a lesser amount of water in dry years. While these exchanges cannot be directly attributed to the amendment, the amendment facilitates their implementation.

Finally, the amendment provides a mechanism for using SWP facilities to transport non-project water for SWP water contractors. (The Department uses other contractual arrangements for wheeling water for the CVP and for other non-SWP water users.)

Annual Turnback Pool. Prior to the amendment, water allocated to contractors that was not used during a year would revert to the SWP at the end of the year. No compensation was provided to the contractor for this water, and no other contractors could make use of these supplies during the year. The turnback pool is an internal SWP mechanism which provides for pooling potentially unused supplies early in the year for purchase by other SWP contractors at a set price. The pool was not intended as a water market, but rather as an incentive to return unneeded water early in the year for reallocation among SWP contractors on a willing-buyer basis. The turnback pool operated successfully on a trial basis during 1996, when more than 200 taf were reallocated. If neither the SWP nor individual SWP contractors wish to use water placed into the pool, that water may then be sold to entities that are not SWP contractors.

Other Operational Changes. The amendment established a procedure to transfer ownership of the Department's KWB property to KCWA and Dudley Ridge Water District. The amendment allows contractors repaying costs of constructing the Castaic and Perris terminal reservoirs to increase their control and management of a portion of the storage capacity of each reservoir to optimize the operation of local and SWP facilities. This is expected, for example, to improve drought year supplies for MWDSC, Castaic Lake Water Agency, and Ventura County Flood Control and Water Conservation District.

CVPIA Implementation

CVPIA made significant changes to the CVP's legislative authorization, amending the project's purposes to place fish and wildlife mitigation and restoration on a par with water supply, and to place fish and wildlife enhancement on a par with power generation. Key areas of CVPIA implementation are summarized below. A more detailed summary of the act is provided in Appendix 2A. USBR and USFWS released a draft programmatic EIS on CVPIA implementation for public review in November 1997. The draft PEIS describes, among other things, estimated water supply impacts of federal implementation of the act, and illustrates the consequences of different alternatives for fish and wildlife supplemental water acquisition. A final EIS is scheduled to be released in 1999.

Renewal of CVP Water Service Contracts. CVPIA prohibited execution of new CVP water service contracts (with minor exceptions), except for fish and wildlife purposes, until all of the many environmental restoration actions specified in the statute had been completed. The act also provided that existing long-term water service contracts be renewed for 25-year terms, as opposed to their previous 40-year terms. Only interim renewals (not more than three years) are allowed until the PEIS required by the act is completed. Beginning in October 1997, most existing long term contracts are subject to a monetary hammer clause encouraging early renewal. Renewed contracts will incorporate new provisions required by CVPIA, such as tiered water pricing. Since USBR has not completed the PEIS, all contract renewals to date have been interim renewals. USBR has had more than 60 interim contract renewals from the date of enactment through 1996, representing over 1 maf/yr of supply.

Transfers of Project Water. CVPIA authorized transfer of project water outside the CVP service area, subject to many conditions, including a right of first refusal by entities within the service area. Several conditions, including right of first refusal by entities within the service area, terminate in 1999. Transfers must be consistent with State law, be approved by USBR, and be approved by the contracting water district if the transfer involves more than 20 percent of its long-term

CVPIA's Dedicated Water

Section 3406(b)(2) describes the dedicated water as follows:

Upon enactment of this title dedicate and manage annually 800,000 acre-feet of Central Valley Project yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by this title; to assist the State of California in its efforts to protect the waters of the San Francisco Bay-San Joaquin Delta Estuary; and to help meet such obligations as may be legally imposed upon the Central Valley Project under State or Federal law following the date of enactment of this title, including but not limited to additional obligations under the federal Endangered Species Act. For the purpose of this section, the term "Central Valley Project yield" means the delivery capability of the Central Valley Project during the 1928-1934 drought period after fishery, water quality, and other flow and operational requirements imposed by terms and conditions existing in licenses, permits, and other agreements pertaining to the Central Valley Project under applicable State or Federal law existing at the time of enactment of this title have been met.

contract supply. USBR has published interim guidelines for administration of this provision, pending formal promulgation of rules and regulations. As of this writing, no out of service area transfers have been approved or implemented.

Fish and Wildlife Restoration Actions. One of the most controversial elements of CVPIA implementation has been management of the 800 taf/yr of CVP yield (see sidebar) dedicated by the act to fishery restoration purposes. This water is available for use on CVP controlled streams (river reaches downstream from the project's major storage facilities on the Sacramento, American, and Stanislaus Rivers) and in the Bay-Delta.

The ambiguity of the statutory language and the use of dedicated water in the Bay-Delta Accord have generated many questions, including whether the water may be exported from the Delta after it has been used for instream flow needs in upstream rivers, and if the water may be used for Bay-Delta purposes beyond Bay-Delta Accord requirements. Initially, USBR and USFWS attempted to develop guidelines or criteria for its management. Subsequent to CALFED's creation, the CALFED Operations Group became a forum for attempting to resolve dedicated water. In November 1997, DOI released its final administrative proposal on management of the dedicated water issues. The proposal's release was subsequently challenged in legal action filed by some CVP water contractors.

A main purpose of the dedicated water is meeting the act's goal of doubling natural production of Central Valley anadromous fish populations from their average 1967-91 levels by year 2002. Release of water to the San Joaquin River from Friant Dam is excluded from this program. CVPIA authorizes USBR and USFWS to acquire additional, supplemental water from willing sellers to help achieve the doubling goal. Details of supplemental water acquisition are presented

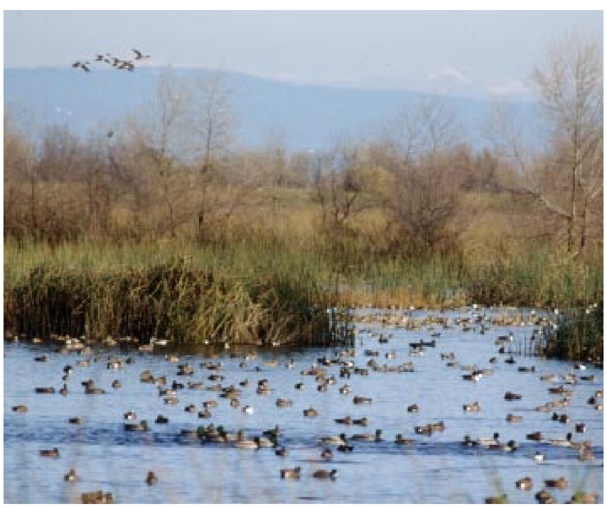
Looking at the upstream face of Shasta Dam, with the temperature control device at the center of the photo. At this high reservoir level, only a small portion of the TCD is visible. The structure is bolted to the face of the dam, covering the powerplant intakes.

CVPIA Waterfowl Habitat Provisions

Most CVPIA environmental restoration measures address fishery needs. Several provisions specifically address restoring and enhancing waterfowl habitat. The act authorizes a 10-year voluntary incentive program for farmers to flood their fields to create waterfowl habitat, and directs USBR and USFWS to prepare reports on the water supply reliability of private wildlife refuges and on water needs for 120,000 acres of additional wetlands identified in a plan by the Central Valley Habitat Joint Venture (see Chapter 4). CVPIA's major waterfowl habitat provision is a requirement that, by 2002, USBR and USFWS must provide specified levels of water supply for certain federal, State, and private refuges. Part of this water supply is to come from reallocating existing CVP supplies, and part from acquisition from willing sellers. Requirements for specific refuges are summarized in Chapter 4. The act also authorizes DOI to construct or acquire conveyance facilities or wells needed to supply water to the refuges.

in Chapter 6. CVPIA further allocates additional CVP water supply for instream use in the Trinity River, reducing the quantity of water which the project could otherwise divert, by requiring that an instream flow of 340 taf/yr be maintained through water year 1996 while USFWS finishes a long-term instream flow study. As discussed in Chapter 7, USFWS now recommends instream flows much greater than 340 taf/yr.

CVPIA enumerates specific physical restoration measures that the federal government must complete for fishery and waterfowl habitat restoration. The largest completed measures are a temperature control device at Shasta Dam and a research pumping plant at Red Bluff Diversion Dam. CVPIA allocated part of the costs of some restoration measures to the State of California; the remaining costs are being paid by federal taxpayers and by CVP water and power contractors. Some of the smaller restoration actions include individual fish-screening projects that USBR and USFWS are cost-sharing with local agencies under the anadromous fish screening program. Examples of these projects are described in Chapter 8.



Part of the CVP water supply reallocated by CVPIA to environmental purposes is used to provide a firm water supply for specified federal, State, and private wildlife refuges. The Secretary of Interior is additionally directed to acquire supplemental water supply to meet the full habitat needs of these refuges.

CVPIA required USBR to impose a surcharge on CVP water and power contracts for deposit into a Restoration Fund created by the act. Monies deposited into the fund are appropriated by Congress to help fund CVPIA environmental restoration actions. The act authorizes appropriation of up to $50 million (1992 dollars) per year for the restoration actions. Annual deposits into the fund vary with water and power sales. CVPIA environmental restoration actions can be funded from the general federal treasury, as well as from the Restoration Fund.

Land Retirement Program. CVPIA authorized DOI to carry out an agricultural land retirement program for lands receiving CVP water. The statute specified that targeted lands be lands that "are no longer suitable for sustained agricultural production because of permanent damage resulting from severe drainage or agricultural wastewater management problems, groundwater withdrawals, or other causes." The retirement of these lands would result in improved water conservation in a contracting district, or would help implement recommendations of the San Joaquin Valley Drainage Program's 1990 report. USBR published interim guidelines for administration of a pilot program, pending formal promulgation of rules and regulations. The federal guidelines were developed in coordination with a state land retirement program established in 1992 under Water Code Section 14902 et seq. The State statute limited the retirement program to drainage-impaired lands. The State land retirement program has never been funded, and thus no State acquisitions have been made. By November 1997, the federal land retirement program had made one purchase—about 600 acres of drainage-impaired land in Westlands Water District that will be managed for wildlife habitat. Recently, USBR solicited proposals from landowners wishing to participate in the retirement program and received offers to sell lands amounting to 31,000 acres.

CVP Reform Act Bill and CVPIA Administration. In 1995, the CVP Water Association sponsored introduction of HR 1906, the Central Valley Project Reform Act of 1995, a bill which would have made extensive amendments to CVPIA. That bill was opposed by the federal administration and did not pass out of the House. DOI took up CVPIA implementation issues raised by the water users in a 1996 administrative process that produced a series of concept papers outlining issues with federal implementation of CVPIA.

USBR initially prepared interim guidelines on many provisions of the act, with the intent that the guidelines would remain in place until rules and regulations were promulgated for sections of CVPIA involving discretionary actions by the federal government. In some cases, the concept papers produced in the administrative process attempt to clarify or augment the interim guidelines. USBR has not formally promulgated rules and regulations for any CVPIA provision.

Other Programs and Reports. USBR has developed criteria for evaluating water conservation plans of CVP contractors, as required by the act (see Chapter 4), and has been reviewing contractors' plans for compliance with the criteria. As of March 1998, over 70 water agencies had submitted plans pursuant to the criteria. The Department, DFG, USBR, and USFWS negotiated a master State-federal cost-sharing agreement for environmental restoration actions whose costs the act allocated in part to California. Funding for the State's share of those costs was provided by voter approval of Proposition 204.

From a water supply standpoint, certain CVPIA-mandated reports are of special interest. USFWS has prepared several draft documents relating to estimated Central Valley environmental water needs and water management actions for the AFRP. The most recent draft of the AFRP was published in May 1997. In 1995, USBR released an appraisal-level least-cost CVP yield increase plan, required by the act to identify options for replacing the water supply dedicated to environmental purposes. Although the act directed that the plan be prepared, USBR was not required to implement it.

Title Transfer of Reclamation Projects

In the 1990s, there was increasing interest in title transfer of federal water projects (or components of projects) to nonfederal ownership. Generally, transfer proposals can be divided into three broad categories—USBR's westwide program for small uncomplicated projects, general congressional action dealing with principles for transfer of certain types of projects, and water user-initiated transfers of specific projects. There was additionally a brief period of State-federal negotiations on title transfer of the CVP. Transfer of a federal project or its components to nonfederal ownership would normally require congressional authorization.

In 1995, USBR announced that it was initiating a westwide program to transfer title of uncomplicated reclamation projects. Uncomplicated projects were defined as small, single-purpose projects—typically distribution and conveyance systems (without hydropower or conservation storage components)—which could easily be transferred to project beneficiaries. The projects would have no competing interests, would not be hydrologically integrated with other projects, and would have simple financial arrangements. Transfer of a distribution system would not necessarily "defederalize" a project's service area. For example, a local agency could acquire title to a distribution system but still hold a water service contract with USBR for the water supply made available for diversion. In this instance, the service area would probably continue to be subject to existing federal requirements such as Reclamation Reform Act acreage limitations and water conservation regulations. USBR indicated that it will not entertain transfers of large projects in their entirety under this program. Transfer of isolated elements of such projects can be considered under the program. One transfer being negotiated under the administrative program is that of the Contra Costa Canal, a CVP facility, to Contra Costa Water District. If USBR and CCWD can successfully negotiate terms and conditions, they would then seek congressional authorization for the transfer. Other California reclamation facilities considered for transfer under the administrative program include the CVP's Clear Creek Community Services District distribution system. Title to the San Diego Aqueduct, a conveyance facility origi-

Negotiations have been in progress on transferring title of the Contra Costa Canal from USBR to CCWD. The transfer would include the 48-mile-long canal, two regulating reservoirs, and associated pumping plants. The canal's maximum capacity is 350 cfs, decreasing to 22 cfs at its terminus.

nally constructed under Department of Defense authorization and subsequently turned over to USBR to manage, was transferred to nonfederal entities in 1997.

Legislation was introduced in the 104th Congress that would have directed DOI to transfer title of reclamation projects whose construction costs had been repaid by the project beneficiaries. This legislation was not enacted. There were several proposals for transfers of individual projects during the 104th Congress, none of which were approved.

In 1992, California and the United States signed a memorandum of agreement on a process to transfer title of the CVP to California. The federal government subsequently declined to pursue transfer negotiations due to a change in the federal administration and 1992 enactment of CVPIA. In 1995, local agencies that operate and maintain much of the CVP system formed a joint powers authority to explore transferring title of the CVP to the local agencies. The CVP Authority proposed to introduce title transfer legislation in the 104th Congress, but legislation was not introduced. Solano Project water users also pursued transfer legislation in the 104th Congress. That effort was put on hold while an adjudication of Putah Creek water rights proceeded.

FERC Relicensing

The Federal Energy Regulatory Commission administers a program of licensing nonfederal hydroelectric power plants. FERC licenses establish conditions on the owners' operation of their plants; typical conditions include instream flow requirements and other fishery protection measures. Licenses for many California hydropower plants will be coming up for renewal in the near future. FERC has begun to schedule regulatory activities for plants with licenses expiring in 2000 to 2010 (Table 2-6). The relicensing process affords resource agencies and individuals the opportunity to seek changes in instream flow requirements, such as those suggested in CVPIA's draft AFRP. Hydropower generation is a nonconsumptive water use, but changes in the amount and timing of water diverted for power generation can affect other uses downstream. The impact of deregulation of the electric power industry on relicensing decisions is uncertain. Current owners of some generating facilities (especially smaller plants) may sell their generation assets in response to deregulation.

Water supply impacts of relicensing are difficult to quantify, in part because impacts are site-specific. Some plants subject to relicensing, for example, currently have no bypass flow requirements. It is likely that relicensing would establish bypass flows at these sites. Other plants subject to relicensing already have substantial bypass flows, and it is not clear what changes relicensing would bring.

Recent ESA Listings

Since publication of Bulletin 160-93, there has been action on federal listing of several fish species having statewide water management significance. In August 1997, the National Marine Fisheries Service listed two coastal steelhead populations as threatened (from the Russian River south to Soquel Creek, and

TABLE 2-6

California Hydropower Projects - License Years 2000 - 2010
(projects over 1,000 kW)

License Expiration Date	*Project*	*Stream*	*Licensee*	*Capacity (1,000 kW)*
June 2000	Lower Tule	Middle Fork Tule River	Southern California Edison	2.0
September 2000	Hat Creek No. 1 & 2	Hat Creek & Pit River	Pacific Gas & Electric	20.0
February 2002	El Dorado	South Fork American River	PG&E	20.0
April 2003	San Gorgonio No. 1 & 2	San Gorgonio Creek	SCE	2.3
August 2003	Vermillion Valley	Mono Creek	SCE	N/A
September 2003	Poe	North Fork Feather River	PG&E	142.8
October 2003	Pit	Pit River	PG&E	317.0
April 2004	Santa Felicia Reservoir	Piru Creek Santa Clara River	United Water Conservation District	1.4
October 2004	Upper North Fork Feather River	North Fork Feather River	PG&E	342.0
December 2004	Donnells & Beardsley	Middle Fork Stanislaus River	Oakdale & South San Joaquin Irrigation Districts	64.0
December 2004	Tulloch	Stanislaus River	OID and SSJID	17.1
December 2004	Stanislaus - Spring Gap	South Fork Stanislaus River	PG&E	175.8
February 2005	Borel	Kern River	SCE	9.2
March 2005	Portal	Rancheria Creek Big Creek	SCE	10.0
April 2005	Kern Canyon	Kern River	PG&E	11.5
February 2006	Klamath	Klamath River	Pacificorp	231.0
January 2007	Feather River	Feather River	DWR	844.0
March 2007	Kilarc & Cow Creek	Old Cow Creek & Cow Creek	PG&E	8.9
July 2007	Upper American River	South Fork American River	SMUD	722.3
July 2007	Chili Bar	South Fork American River	PG&E	7.0
November 2007	Mammoth Pool	San Joaquin River	SCE	181.0
February 2009	Big Creek No. 2A & 8	South Fork San Joaquin River	SCE	480.1
February 2009	Big Creek 3	San Joaquin River	SCE	177.5
February 2009	Big Creek No. 1 & 2	Big Creek & San Joaquin River	SCE	225.9
March 2009	South Fork	Kelly Ridge Canal	Oroville-Wyandotte Irrigation District	104.1
April 2009	Santa Ana No. 3	Santa Ana River	SCE	1.5

from the Pajaro River south to the Santa Maria River), and one population as endangered (from the Santa Maria River south to Malibu Creek). NMFS deferred listing decisions for six months for other California populations—from the Elk River in Oregon to the Trinity River in California, from Redwood Creek to the Gualala River, and in the Central Valley—due to scientific disagreement about the sufficiency and accuracy of the data available for listing determinations. In March 1998, NMFS listed the Central Valley population as threatened, and deferred listing of the two north coast populations in favor of working with California and Oregon on state conservation plans.

Also in 1997, NMFS listed the Southern Oregon/Northern California coast evolutionarily significant unit of coho salmon as threatened. In 1996, NMFS listed coho salmon in the central coast ESU (from Punta Gorda in Humboldt County south to the San Lorenzo River) as threatened.

In 1998, NMFS proposed several runs of chinook salmon for listing—the spring-run in the Central Valley ESU as endangered, the fall and late-fall runs in the Central Valley ESU as threatened, and the spring and fall runs in the Oregon/California coastal ESU as threatened. NMFS expects to make its decision on listing in 1999. The spring-run chinook salmon has been listed as a candidate species under the California ESA.

USFWS proposed in 1994 to list a resident Delta fish species, the Sacramento River splittail, but a congressional moratorium on listing of new species prevented USFWS from working on the proposal until 1996. USFWS again proposed to list splittail in 1996, but received significant public comments on new scientific information for splittail. As of July 1998, the extended public comment period is just ending. USFWS is expected to make a decision after that time.

USFWS has also listed or proposed for listing species whose limited range would result in localized water management impacts. For example, the red legged frog, found primarily in the Central Coast area, was listed as threatened in 1996. Another example is the Santa Ana sucker, found in the Santa Ana River, proposed for listing in 1998.

San Francisco Bay and Sacramento-San Joaquin River Delta

Bay-Delta Accord and CALFED

Representatives from the California Water Policy Council, created to coordinate activities related to State long-term water policy, and the Federal Ecosystem Directorate, created to coordinate actions of federal agencies involved in Delta programs, signed a Framework Agreement for the Bay-Delta estuary in June 1994. Working together, these agencies are known as CALFED. The Framework Agreement improved coordination and communication between State and federal agencies with resource management responsibilities in the estuary. It covered the water quality standards setting process; coordinated water project operations with requirements of water quality standards, endangered species laws, and CVPIA; and provided for cooperation in planning long-term solutions to problems affecting the estuary's major public values.

In December 1994 State and federal agencies, working with stakeholders, reached agreement on the "Principles for Agreement on Bay-Delta Standards Between the State of California and the Federal Government" (commonly referred to as the Bay-Delta Accord) that would remain in effect for three years. Provisions of the Bay-Delta Accord covered water quality standard setting and water project operational constraints, ESA implementation and use of real-time monitoring data, and improvement of conditions not directly related to Delta outflow. Parties to the accord committed to fund "non-flow Category III" measures at $60 million per year for the agreement's three-year term. The accord was subsequently extended for a fourth year. An Operations Group composed of representatives from the State and federal water projects and the other CALFED agencies was established to coordinate project operations. Stakeholders from water agencies and environmental and fishery groups participate in Operations Group meetings.

Water Quality Standard Setting. SWRCB adopted a water quality control plan for the Bay-Delta in May 1995, incorporating agreements reached in the accord. In June 1995, SWRCB adopted Order WR 95-6, an interim order amending terms and conditions of SWRCB's D-1485 and the SWP's and CVP's water right permits to resolve inconsistencies with D-1485 requirements and the projects' voluntary implementation of accord standards. The interim order will expire when a water right decision allocating final responsibilities for meeting the 1995 objectives is adopted, or on December 31, 1998, whichever comes first. SWRCB released a revised draft EIR for implementing the water quality control plan in 1998, and intends to issue a water right decision implementing the order by the end of 1998. The DEIR has eight flow alternatives:

(1) SWP and CVP Responsible for D-1485 Flow Objectives.
(2) SWP and CVP Responsible for 1995 Bay-Delta Water Quality Control Plan Flow Objectives.
(3) Water Right Priority Alternative (The CVP's Friant Unit is assumed to be an in-basin project.)
(4) Water Right Priority Alternative (The CVP's Friant Unit is assumed to be an export project.)
(5) Watershed Alternative–Monthly average flow requirements are established for major watersheds based on Delta outflow and Vernalis flow objectives and the watersheds' average unimpaired flow. The parties responsible for providing the required flows are water users with storage in foothill reservoirs that control downstream flow to the Delta, and water users with upstream reservoirs that have a cumulative capacity of at least 100 taf who use water primarily for consumptive uses.
(6) Recirculation Alternative–USBR is required to make releases from the Delta-Mendota Canal to meet the Vernalis flow objectives.
(7) San Joaquin Basin Negotiated Agreement–San Joaquin Basin water right holders' responsibility to meet the plan objectives is based on an agreement titled "Letter of Intent among Export Interests and San Joaquin River Interests to Resolve San Joaquin River Issues Related to Protection of Bay-Delta Environmental Resources."
(8) San Joaquin Basin Negotiated Agreement–Vernalis flow objectives are replaced by target flows contained in the agreement.

CALFED Long-Term Solution-Finding Process for Bay-Delta. The June 1994 Framework Agreement called for a State-federal process to develop long-term solutions to Bay-Delta problems related to fish and wildlife, water supply reliability, natural disasters, and water quality. The CALFED program is managed by an interagency team under the policy direction of CALFED member agencies, with public input provided by the Bay-Delta Advisory Council. BDAC is a 31-member advisory panel representing California's agricultural, environmental, urban, business, fishing, and other interests who have a stake in the long term solution to Bay-Delta problems.

The CALFED program's first phase identified problems in and goals for the Bay-Delta, and developed a range of alternatives for long-term solutions. This phase concluded with a September 1996 report identifying three broad solutions, each of which included a range of water storage options, a system for conveying water, and some programs that were common to all alternatives. The second phase consisted of preparing a programmatic EIR/EIS covering three main alternatives for conveyance of water across the Delta—an existing system alternative, a through-Delta alternative, and a dual Delta conveyance alternative. A first public review draft of the PEIR/PEIS was released in March 1998. CALFED expects to issue a second draft PEIR/PEIS by the end of 1998. The revised draft would identify CALFED's draft preferred alternative.

The third phase would involve staged implemen-

CALFED's Ecosystem Restoration Program calls for extensive creation of new habitat in the Delta. Construction of setback levees would allow restoration of riparian and riverine aquatic habitats, benefitting fish and wildlife.

tation of the preferred alternative over a time period of several decades and will require site-specific compliance with NEPA and CEQA. Current plans are for an initial implementation period of 7 to 10 years, during which only common program elements would be implemented (water conservation measures, ecosystem restoration, levee improvements). Any conveyance or storage facilities would be constructed in a later phase of implementation.

ESA Administration. The Bay-Delta Accord established several principles governing ESA administration in the Bay-Delta during the agreement's term.

- The accord is intended to improve habitat conditions in the Bay-Delta to avoid the need for additional species listings during the agreement's term. If additional listings do become necessary, the federal government will acquire any additional water supply needed for those species by buying water from willing sellers.
- There is intended to be no additional water cost to the CVP and SWP resulting from compliance with biological opinion incidental take provisions for presently listed species. The CALFED Operations Group is to develop operational flexibility by adjusting export limits.
- Real-time monitoring is to be used to the extent possible to make decisions regarding operational flexibility. CALFED commits to devote significant resources to implement real-time monitoring.

An aerial view of the Montezuma Slough salinity control structure. The structure includes three 36-foot wide radial gates, a 66-foot wide barge access, and a boat lock.

Suisun Marsh

SWRCB's D-1485 required USBR and the Department to develop a plan to protect the Suisun Marsh. The Suisun Marsh Preservation and Restoration Act of 1979 authorized the DOI to enter into an agreement with California for cost-sharing in activities to protect the marsh's fish and wildlife resources. A plan was subsequently developed and initial water supply distribution systems called for in the plan were completed in 1981.

In 1986 PL 99-546 authorized the federal government to contract with Suisun Resource Conservation District, DFG, and the Department for mitigating effects of the SWP, CVP, and other upstream diversions on marsh water quality. The agreement, approved in March 1987, described proposed facilities to be constructed, a construction schedule, cost-sharing responsibilities, water quality standards, soil salinity, water quality monitoring, and purchase of land to mitigate the impacts of the Suisun Marsh facilities themselves. As provided by the agreement, a salinity control structure on Montezuma Slough was completed in 1989. The structure has effectively reduced salinity in Montezuma Slough and eastern regions of the marsh, and to a lesser degree, in most of the western regions of the marsh.

Because of the effectiveness of the salinity control structure and the increased Delta outflows called for in SWRCB's Order WR 95-6, parties to the 1987 Suisun Marsh Preservation Agreement are amending the agreement to focus on funding water management activities instead of constructing the large-scale facilities initially planned. Activities such as improving discharge facilities, screening portable pumps, employing a water manager, and constructing joint-use water management facilities among landowners will enable landowners to effectively use water from marsh sloughs.

Delta Protection Commission

The Delta Protection Act of 1992 established the Delta Protection Commission and charged it with preparing a plan for land uses within the primary zone of the Delta, and with working with local governments to ensure that their general plans are brought into conformance with the Commission's plan. Delta counties—including Solano, Yolo, Sacramento, San Joaquin, and Contra Costa—are required to comply with findings of the plan. In February 1995, the Commission adopted the *Land Use and Resource*

Management Plan for the Primary Zone of the Delta (Delta Plan). The major goals of the Delta Plan include the following:

- Preserve and protect the natural resources of the Delta, including soils.
- Promote protection of remnants of riparian habitat.
- Promote seasonal flooding and agricultural practices to maximize wildlife use.
- Promote levee maintenance and rehabilitation to preserve land areas and channel configurations in the Delta.
- Protect the Delta from excessive construction of utilities and other infrastructure. Where construction of new infrastructure is appropriate, minimize the impacts of new construction on levees, wildlife, and agriculture.
- Protect the unique character and qualities of the primary zone by preserving its cultural heritage and strong agricultural base. Encourage residential, commercial, and industrial development in existing developed areas.
- Support long-term viability of commercial agriculture and discourage inappropriate development of agricultural lands.
- Protect long-term water quality in the Delta.
- Promote continued recreational use of the land and waters of the Delta; ensure that facilities that allow such uses are constructed and maintained; protect landowners from unauthorized recreational uses on private lands; and maximize dwindling public funds for recreation by promoting public-private partnerships and multiple use of Delta lands.
- Support the improvement and long-term maintenance of Delta levees by coordinating permit reviews and guidelines for levee maintenance; develop a long-term funding program for levee maintenance; protect levees in emergency situations; and give levee rehabilitation and maintenance priority over other uses of levee areas.

As originally authorized, the Delta Protection Commission was to expire in January 1997. Its expiration date was extended to January 1, 1999. The Commission is currently studying existing recreational uses in the Delta in conjunction with the Department of Boating and Waterways and the Department of Parks and Recreation. The Commission continues to monitor proposed land use changes in the Delta.

San Francisco Estuary Project

The San Francisco Estuary Project, begun in 1987, is a federal-State partnership established under Clean Water Act authority to develop a plan for protecting and restoring the estuary while maintaining its beneficial uses. The project, jointly sponsored by EPA and by the State, is financed by federal appropriations and matching funds from State and local agencies.

In 1993, the SFEP's Comprehensive Conservation and Management Plan was completed and signed by the State and federal governments. The CCMP contained 145 specific action items to protect and restore the estuary, classified into the following programs: aquatic resources, wildlife, wetlands management, water use, pollution prevention and reduction, dredging and waterway modification, land use, public involvement and education, and research and monitoring. Since no specific funding exists for implementing these action items, progress has continued under existing federal, State, and local programs. A 1996 SFEP progress report on CCMP implementation identified ten priorities to be implemented over the next five years:

(1) Expand, restore, and protect Bay-Delta wetlands.
(2) Integrate and improve regulatory and scientific monitoring programs.
(3) Create economic incentives that encourage local governments to implement measures to protect and enhance the estuary.
(4) Improve management and control of urban runoff.
(5) Prepare and implement watershed management plans throughout the estuary.
(6) Reduce and control introduction of exotic species.
(7) Build awareness about CCMP implementation.
(8) Increase public awareness about the estuary's natural resources and the need to protect them.
(9) Implement a regional monitoring program.
(10) Work with CALFED and others to address program priorities.

Coordinated Operation Agreement Renegotiation

In 1986, the Department and USBR signed a Coordinated Operation Agreement obligating the CVP and the SWP to coordinate their operations to meet D-1485 standards. The agreement authorizes DOI to operate the CVP in coordination with the SWP to meet State water quality standards for the Bay-Delta (unless DOI determines such operation to be inconsistent with Congressional directives), and provides a formula for sharing the obligation to provide water to meet water quality standards and other in-basin uses. It sets forth the basis for CVP and SWP operation to ensure that each project receives an equitable share of Central Valley runoff and guarantees that the two systems will operate more efficiently during periods of drought than they would if operated independently. Under the COA, the USBR also agreed to meet its share of future water quality standards established by SWRCB.

Article 14 of the COA provides for periodic review of project operation and of the COA, and for future adjustments to the sharing formula if assumed conditions used to calculate the sharing formula change. Since COA execution, biological opinions for winter-run chinook salmon and Delta smelt have imposed new operational constraints on both the CVP and the SWP. In addition, the Bay-Delta Accord has established standards which the two projects are voluntarily meeting, pending implementation of the standards through SWRCB's water rights proceedings. As a result of these changes, the Department and USBR have begun a review of the sharing formula.

Interstate Issues

California receives most of its water supply from intrastate rivers and groundwater basins. The Colorado River, shared among seven states, contributes a substantial water supply to Southern California, and other smaller interstate rivers are locally important sources. The status of apportionment actions on rivers with long-standing interstate issues is discussed below. There is currently no significant activity on interstate groundwater basins. Within the last decade, there had been concerns in California about proposed large-scale groundwater development projects in northern Nevada that could affect interstate basins, but these projects have not been implemented.

USBR's dam on Lake Tahoe regulates releases for downstream water users in Nevada.

Truckee-Carson River System

The Truckee-Carson-Pyramid Lake Water Rights Settlement Act (Title II of PL No. 101-618) settled several water rights disputes affecting the waters of Lake Tahoe, the Truckee River, and the Carson River. Of most importance to California, the act made an interstate apportionment of these waters between the States of California and Nevada. (It was the first Congressional apportionment since the Boulder Canyon Project Act of 1928.) The act addresses several other issues, including settlement of water supply disputes between the Pyramid Lake Paiute Tribe of Indians and other users of the Truckee and Carson Rivers. The act also addresses environmental concerns, such as recovery of listed fish species in Pyramid Lake.

Many of the act's provisions—including the interstate apportionment between California and Nevada—will not take effect until several conditions have been satisfied, including dismissal of specified lawsuits and negotiation and adoption of a Truckee River Operating Agreement. The act requires that a TROA be negotiated among DOI and the States of California and Nevada, after consultation with other parties as may be designated by DOI or by the two states. The TROA addresses interstate water allocation and implements an agreement between Sierra Pacific Power Company and the United States which provides for storing water in upstream reservoirs for Pyramid Lake fish and for emergency drought water supplies for the Reno-Sparks area. TROA negotiation has been ongoing since 1991. A draft TROA is being analyzed in an EIS/EIR prepared by DOI. The Department is the State lead agency for CEQA compliance. The draft EIS/EIR was released for public review in 1998 and is expected to be completed in 1999.

Walker River

There are currently no significant interstate actions pending on the Walker River. A proposed interstate allocation of the Walker River was negotiated at one time but was not implemented. The Walker

River was not included in the settlement legislation for the adjoining Truckee and Carson River Basins. In the recent past, interstate activities on the Walker River have involved water quality and fishery issues associated with river operations and not water allocation issues.

Klamath River

An interstate compact providing for administration of the Klamath River was adopted by California and Oregon and ratified by Congress in 1957. The compact is managed by a Commission consisting of the Director of the Oregon Water Resources Department, the Director of the California Department of Water Resources, and a non-voting federal representative who serves as chairperson.

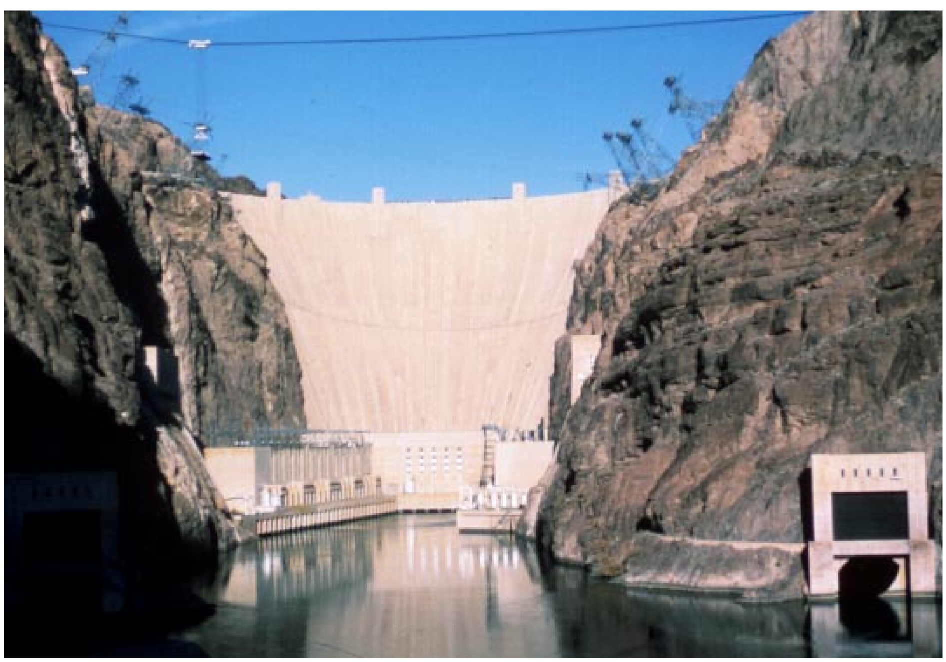
For the Compact's first 39 years, there was little controversy concerning the upper river basin. Recent changes in operation of USBR's Klamath Project facilities to protect listed fish species have affected irrigation supplies available from the project. The State of Oregon has begun a comprehensive water rights adjudication for its portion of the basin. USBR is drafting a new operations plan for its project to formalize procedures for meeting the needs of listed fish species in Klamath Lake and listed anadromous fish downstream in the lower river. The Klamath River Compact Commission began facilitating a process in cooperation with USBR and basin water users to identify voluntary solutions to water shortages affecting the upper basin. The effort seeks to achieve agreement on ways to secure sufficient water for all needs, rather than on asserting claims to rights.

Colorado River

Colorado River water management activities are described in detail in Chapter 9. The major issue facing California is its use of Colorado River water in excess of the amount apportioned to it by the existing body of statutes, court decisions, and agreements controlling use of the water supply among the seven basin states. California's basic apportionment of river water is 4.4 maf of consumptive use per year (plus a share of surplus flows, when available), as compared to its present consumptive use of up to 5.3 maf/yr. California's use has historically exceeded the basic apportionment because California has been able to divert and use Arizona's and Nevada's unused apportionments, and to divert surplus water. With completion of the Central Arizona Project and the 1996 enactment of groundwater banking legislation, Arizona used more than its basic apportionment in 1997.

California has been meeting with the other basin states to develop a plan for California to reduce its use of Colorado River water to the State's basic apportionment. A draft plan has been developed by the Colorado River Board of California and the local agencies it represents. As described in detail in Chapter 9, the plan includes actions such as water transfers from agricultural users of river water to urban users in the South

USBR's Hoover Dam on the Colorado River was a major engineering feat at the time of its construction and provided jobs for thousands of Depression-era workers. Today, the dam is an important source of water and power for Southern California.



Coast Region, lining of portions of the All American and Coachella Canals, and groundwater banking. As presently envisioned, implementing California's plan would occur in two phases, with projects that are presently well-defined (e.g., canal lining, a San Diego/ Imperial Valley water transfer) implemented in the first phase.

Regional and Local Programs

Local Agency Groundwater Management Programs

In most western states, the rights to the use of surface water and groundwater resources are administered by the states. California administers rights to surface water at the State level, but not rights to groundwater. In California, groundwater may be managed under a variety of authorities, ranging from judicial adjudication of individual basins to several forms of local agency management. Some local agencies have specific statutory authority to manage groundwater resources in their service areas. Other local agencies may manage groundwater under authority provided by general enabling legislation, such as Water Code Section 10750 *et seq.* A few counties have adopted local ordinances dealing with groundwater management.

The 1992 enactment of AB 3030 (Water Code Section 10750 *et seq.*) provided broad general authority for local agencies to adopt groundwater management plans and to impose assessments to cover the cost of implementing the plans. To date, about 150 local agencies have adopted AB 3030 groundwater management plans. Under other groundwater management authorities, there are 7 agencies with AB 255 plans and over 50 agencies with some other form of statutory authority.

The number of agencies adopting AB 3030 plans is increasing. Quantifying the number of plans adopted is somewhat uncertain, since there is no requirement in the statute that agencies adopting plans file copies of those plans with the Department or SWRCB. A tabulation of agencies with AB 3030 plans, together with agencies managing groundwater under some other authority, can be found in the Department's 1998 report to the Legislature on local agency groundwater management.

Watershed-Based Planning

There has been increased interest in watershed-based planning, sometimes prompted by water quality regulatory programs. Watersheds and sub-watersheds are logical units for implementing SDWA source water protection programs and CWA nonpoint source pollution control programs. "Watershed planning" can have a range of meanings—some people associate watershed planning with small, community-based watershed restoration efforts, often carried out via a coordinated resources management plan. Others think of larger-scale efforts that focus on nonpoint source pollution control, such as SWRCB's watershed management initiative. Some watershed-based planning activities are reviewed below.

Nonpoint Source Pollution Control Watershed Planning. SWRCB and the nine regional water quality control boards are implementing a watershed management approach to administering water pollution control programs, addressing point and nonpoint

USBR's Spring Creek Debris Dam was constructed to control runoff reaching the Sacramento River from part of the Iron Mountain Mine site.

TABLE 2-7

Partial List of Targeted Watersheds and Watershed Activities Identified for the Watershed Management Initiative

Regional Board	*Targeted Watershed*	*Targeted Watershed Priorities/Activities*
Region 1 North Coast	Russian/Bodega	Fish restoration, erosion/sedimentation control, riparian enhancement
	Lost River and Klamath River upstream of Iron Gate Dam	Stream restoration on Clear Lake tributaries (Modoc County)
	Shasta River and tributaries	Irrigation return flows, nutrient and temperature reductions, irrigation water conservation
	Scott River and tributaries	Temperature reduction, irrigation water conservation, erosion/ sedimentation control
	Other Klamath River tributaries upstream of Scott River confluence	Fish restoration, erosion/sedimentation control
	Garcia Watershed	Fish restoration, erosion/sedimentation control, temperature reduction
	Humboldt Bay	Fish restoration, erosion/sedimentation control
Region 2 San Francisco Bay	Napa River	Riparian and wetland restoration, sedimentation control, volunteer monitoring
	Petaluma River	Riparian and wetland restoration, sedimentation control, animal waste control, volunteer monitoring
	Tomales Bay	Riparian restoration, sedimentation control, mine waste management, on-site disposal, volunteer monitoring
	San Francisquito Creek	Riparian and wetland restoration, sedimentation control, urban runoff prevention and control, volunteer monitoring
	Walnut Creek	Riparian restoration, sedimentation control, urban runoff prevention and control, volunteer monitoring
	Suisun Marsh	Riparian and wetland restoration, sedimentation control, construction and agricultural activities, volunteer monitoring and education
	Alameda Creek	Riparian and wetland restoration, sedimentation control, construction and agricultural activities, groundwater protection, volunteer monitoring and education
Region 3 Central Coast	Salinas River	Agricultural activities, erosion/sedimentation control, riparian and wetland enhancement and restoration
	Morro Bay	Erosion/sedimentation control, abandoned mines, road construction, agricultural activities, riparian and wetland enhancement and restoration
	San Lorenzo	Erosion/sedimentation control, road construction and maintenance, riparian and wetland enhancement and restoration
	Pajaro River	Nonpoint source pollution control, riparian and wetland enhancement and restoration
	Santa Maria River	Nonpoint source pollution control, riparian and wetland enhancement and restoration

TABLE 2-7
Partial List of Targeted Watersheds and Watershed Activities Identified for the Watershed Management Initiative (continued)

Regional Board	*Targeted Watershed*	*Targeted Watershed Priorities/Activities*
Region 4 Los Angeles	Calleguas Creek	Reduce nutrients, pesticides, and sediments in irrigation water; restore aquatic and riparian habitats; flood control; enhance recreational uses
	Ventura River Watershed	Restore aquatic habitats; implement flood control; enhance recreational uses
	Los Angeles River	Restore aquatic and riparian habitats; enhance recreational uses; reduce pollutants
	Santa Monica Bay	Reduce pollutants from boatyards and marinas; enhance recreational uses; restore wetlands
Region 5 Central Valley	Lower San Joaquin River Watershed	Selenium, agriculture, dairies, temperature, urban runoff
	Sacramento-San Joaquin Delta	Agriculture, sediments, bacteria, dredged material, dissolved oxygen, urban runoff
	Lower Sacramento River Watershed	Agriculture, urban runoff, mercury, heavy metals, nitrates, septic systems, fisheries
	Cache Creek Watershed and Clear Lake	Nutrients (algal blooms), mercury
	Pit River	Hydromodification, nutrients (algal blooms), dissolved oxygen, turbidity/sedimentation, temperature, agriculture, grazing, silvaculture
	Tulare Lake	Salts, pesticides, boron, chloride, molybdenum, sulfate, dissolved oxygen, bacteria, used oil
Region 6 Lahontan	Lower Truckee River	Roadside drainage, erosion control, urban runoff, fisheries habitat improvement, wetlands enhancement, stream restoration
	Upper Truckee River	Sedimentation control, nutrients from watershed disturbances; watershed education; restoration of wetland function, riparian areas, and/or river morphology and function
	Carson River	Erosion control, disposal of livestock waste, watershed education, wetland/riparian restoration
Region 7 Colorado River	Imperial Valley Watershed	Agricultural pollution control
	Coachella Valley Watershed	Agricultural pollution control, groundwater protection
Region 8 Santa Ana	Chino Basin Watershed	Agricultural runoff, dairies, salt build-up in groundwater
	Newport Bay Watershed	Toxics, nutrients, pathogens, sediments
Region 9 San Diego	San Diego Bay - all tributaries	Urban runoff, public education
	San Diego Bay	Copper leaching from boat hulls, oil spills
	Otay River Valley	Urban runoff, public education, pollutant loadings
	Sweetwater River	Heavy metals, petroleum products, public education, nutrient transport, sediment transport
	Aliso Creek	Coliform contamination
	Santa Margarita River	Nitrogen and phosphorus loading from agriculture

pollution sources. In 1997, SWRCB, RWQCBs, and EPA began a new program known as the Watershed Management Initiative. Targeted watersheds and watershed priorities or activities were identified for each of California's nine RWQCBs. Examples of targeted watersheds and watershed priorities or activities are listed in Table 2-7. Federal CWA funding administered by SWRCB may be used to work on priority programs.

Upper Sacramento River Fisheries and Riparian Habitat Plan. In 1986, State legislation (SB 1086) called for preparation of a management plan to protect, restore, and enhance the fishery, riparian habitat, and wildlife of the upper Sacramento River. The plan, published in 1989, was prepared by an advisory council working closely with a wide range of agency representatives and stakeholders. The plan recommended implementation of 20 fishery improvement actions, several of which (for example, constructing a temperature control device at Shasta Dam and improving fish passage at USBR's Red Bluff Diversion Dam) were subsequently included in CVPIA. Other actions, such as habitat restoration at Mill Creek, are being implemented largely under State authorities with the participation of local property owners and other stakeholders.

In 1992, the Upper Sacramento River Advisory Council was reconvened by the Secretary for Resources to "complete its earlier work concerning riparian habitat protection and management, including the development of a specific implementation program." The council in turn established a riparian committee to define the inner and outer zones of a proposed conservation area, provide the basic framework of the riparian plan, and evaluate and recommend a suitable organizational structure to implement the riparian plan. Detailed mapping of the riparian corridor continues, and the committee is continuing to refine mechanisms to manage the proposed conservation area.

San Joaquin River Management Program. The San Joaquin River Management Program was authorized by 1990 State legislation that established an advisory council and action team, and directed the Secretary for Resources to coordinate their activities in preparing a program to develop solutions to meet water supply, water quality, flood protection, fisheries, wildlife habitat, and recreation needs on a specified segment of the San Joaquin River. Members of the advisory council and action team included State, federal, and local agencies and stakeholders representing a variety of interests. The members developed a consensus-based plan addressing resource issues listed in the authorizing legislation; the plan was published in 1995. Subsequent State legislation extended the original 1995 termination of the program and further

USBR is evaluating the fishery impacts of different types of pump diversions to the Tehama-Colusa Canal. One alternative for improving fish passage at Red Bluff Diversion Dam would be to leave the dam's gates in the raised position and use a pumping plant to make TCC diversions. The research plant contains three pumps–one helical pump and two Archimedes screw pumps (right side of photo).

directed SJRMP to work with programs such as CVPIA and CALFED to seek funding for actions recommended in the 1995 plan.

The plan recommended implementation of specific projects and further study of other projects, such as enlargement of Friant Dam and construction of Montgomery Reservoir offstream storage reservoir for fishery water supply. Some of the recommended projects are being implemented, including a pilot program for real-time management of agricultural drainage discharge to the San Joaquin River. Other recommended projects may be implemented through CVPIA's AFRP or the CALFED Category III program.

Conservancies. Other mechanisms for watershed-based planning are conservancies created by special enabling legislation. These conservancies are usually focused on land acquisition or management activities. Two conservancies have a water-related orientation. The Tahoe Conservancy was created in 1984 to acquire and manage property in the Lake Tahoe Basin for the primary purpose of maintaining the lake's water quality. Other authorized purposes of the conservancy are to provide access to public lands, preserve wildlife habitat, and perform environmental restoration projects. The conservancy is governed by a seven-member board, with members from the City of South Lake Tahoe, El Dorado County, Placer County, the Resources Agency, Department of Finance, and two members appointed by the Legislature. A representative of the U.S. Forest Service is a non-voting board member. Since voter enactment of the 1982 Lake Tahoe Acquisitions Bond Act, the conservancy has spent about $85 million in land acquisition and erosion control projects in the basin.

The San Joaquin River Conservancy was created by 1992 legislation to acquire and manage lands along the river in Fresno and Madera Counties for recreational and wildlife habitat. As established in the enabling legislation, the conservancy is governed by a board of six voting members and seven non-voting ex-officio members.

Non-Governmental Organizations. Some watershed-based planning activities are being carried out by voluntary non-governmental organizations, often in the form of non-profit corporations. These NGOs are typically focused on resource issues in small watersheds, where they may partner with a resource conservation district to carry out specific projects. Examples of such efforts are found on Mill Creek and Deer Creek in the Sacramento Valley, where local landowners banded together to improve fishery habitat on the creeks. Actions taken or being considered include addressing fish passage problems at water diversion structures, using groundwater for irrigation instead of surface water during times critical to fish passage, and fencing riparian habitat to exclude livestock.

Implementation of Urban Water Conservation MOU

The 1991 *Memorandum of Understanding Regarding Urban Water Conservation in California* defined a set of urban best management practices and procedures for their implementation, and established a California Urban Water Conservation Council composed of MOU signatories (local water agencies, environmental groups, and other interested parties). More than 200 entities have signed the MOU. The CUWCC has monitored implementation of BMPs and reported progress annually to the SWRCB. The council developed a plan providing for ongoing review of BMPs and potential BMPs. In late 1996, the council initiated a review of the BMPs to clarify expectations for implementation and to develop an implementation evaluation methodology. Revised BMPs were adopted in 1997, as described in Chapter 4.

Implementation of Agricultural Efficient Water Management Practices MOU

The Agricultural Efficient Water Management Practices Act of 1990 (AB 3616) required the Department to establish an advisory committee to develop EWMPs for agricultural water use. Negotiations among agricultural water users, environmental interests, and governmental agencies on a MOU to implement EWMPs were completed in 1996. The MOU established an Agricultural Water Management Council to oversee EWMP implementation, much like the organizational structure that exists for urban BMPs, and also provided a mechanism for its signatories to evaluate and endorse water management plans. By May 1998, the MOU had been signed by 31 agricultural water suppliers irrigating about 3 million acres of land, as well as by over 60 other entities. More detail on the agricultural MOU is provided in Chapter 4.

2A

Institutional Framework for Allocating and Managing Water Resources in California

In California, water use and supplies are controlled and managed under an intricate system of federal and State laws. Common law principles, constitutional provisions, State and federal statutes, court decisions, and contracts or agreements all govern how water is allocated, developed, or used. All of these components constitute the institutional framework for allocation and management of water resources in California.

This appendix presents an overview of California's institutional framework, highlighting some of the more recent changes. Summarized here are major constitutional requirements, statutes, court decisions, and agreements that form the groundwork for many water resource management and planning activities. Changes since the publication of Bulletin 160-93 are covered in the Chapter 2 text.

Allocation and Management of California's Water Supplies

The following subsections condense basic water rights laws and doctrines governing allocation and use of California's water supplies.

California Constitution Article X, Section 2

The keystone of California's water law and policy, Article X, Section 2 of the California Constitution, requires that all uses of the State's water be both reasonable and beneficial. It places a significant limitation on water rights by prohibiting the waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water.

Riparian and Appropriative Rights

California operates under a dual system of water rights for surface water which recognizes both riparian rights and appropriative rights. Under the riparian doctrine, the owners of land have the right to divert, but not store, a portion of the natural flow of water flowing by their land for reasonable and beneficial use upon their land adjacent to the stream and within its watershed, subject to certain limitations. Generally, all riparian water right holders must reduce their water use in times of water shortages. Under the prior appropriation doctrine, a person may acquire a right to divert, store, and use water regardless of whether the land on which it is used is adjacent to a stream or within its watershed, provided that the water is used for reasonable and beneficial uses and is surplus to water from the same stream used by earlier appropriators. The rule of priority between appropriators is "first in time is first in right."

Water Rights Permits and Licenses

The Water Commission Act, which took effect in 1914 following a referendum, recognized the overriding interest of the people in the waters of the State, but provided that private rights to use water may be acquired in the manner provided by law. The act established a system of State-issued permits and licenses to appropriate water. Amended over the years, it now appears in Division 2 (commencing with Section 1000) of the Water Code. These provisions place responsibility for administering appropriative water rights with

SWRCB; however, the permit and license provisions do not apply to pre-1914 appropriative rights (those initiated before the act took effect in 1914). The act also provides procedures for adjudication of water rights, including court references to SWRCB and statutory adjudications of all rights to a stream system.

Groundwater Management

Generally, groundwater is available to any person who owns land overlying the groundwater basin. Groundwater management in California may be accomplished either by a judicial adjudication of the respective rights of overlying users and exporters, or by local management of rights to extract and use groundwater as authorized by statute or agreement. Statutory management may be granted to a public agency that also manages surface water, or to a groundwater management agency created expressly for that purpose by a special district act.

In 1991, the Water Code was amended by AB 255 to allow local water agencies overlying critically overdrafted groundwater basins to develop groundwater management plans. Only a few local agencies adopted plans pursuant to that authorization. In 1992, the Legislature adopted new sections authorizing another form of groundwater management, also available to any local agency that provides water service, if the groundwater was not subject to management under other provisions of law or a court decree. Plans adopted pursuant to the 1992 statute (commonly called AB 3030 plans) may include control of salt water intrusion; identification and protection of wellhead and recharge areas; regulation of the migration of contaminated water; provisions for abandonment and destruction of wells; mitigation of overdraft; replenishment; monitoring; facilitating conjunctive use; identification of well construction policies; and construction of cleanup, recharge, recycling, and extraction projects by the local agency.

Public Trust Doctrine

In the 1980s, the public trust doctrine was used by courts to limit traditional water rights. Under the equal footing doctrine of the U.S. Constitution, each state has title to tidelands and the beds of navigable lakes and streams within its borders. The public trust doctrine—recognized in some form by most states—embodies the principle that the state holds title to such properties within the state in trust for the beneficial use of the public, and that public rights of access to and use of tidelands and navigable waters are inalienable. Traditional public trust rights include navigation, commerce, and fishing. California law has expanded the traditional public trust uses to include protection of fish and wildlife, preserving trust lands in their natural condition for scientific study and scenic enjoyment, and related open-space uses.

In 1983, the California Supreme Court extended the public trust doctrine's limitation on private rights to appropriative water rights. In *National Audubon Society v. Superior Court of Alpine County,* the court held that water right licenses held by the City of Los Angeles to divert water from streams tributary to Mono Lake remain subject to ongoing State supervision under the public trust doctrine. The court held that public trust uses must be considered and balanced when rights to divert water away from navigable water bodies are considered. The court also held that California's appropriative rights system and the public trust doctrine embody important precepts which ". . . make the law more responsive to the diverse needs and interests involved in planning and allocation of water resources." Consequently, in issuing or reconsidering any rights to appropriate and divert water, the State must balance public trust needs with the needs for other beneficial uses of water. In 1994, the SWRCB issued a final decision on Mono Lake (Decision 1631) in which it balanced the various uses in determining the appropriate terms and conditions of the water rights permit for the City of Los Angeles. The public trust doctrine will also be applied by the SWRCB in its current consideration of water rights in the Bay-Delta.

Since the 1983 National Audubon decision, the public trust doctrine has been involved in several other cases. In *United States v. State Water Resources Control Board* (commonly referred to as the Racanelli Decision and discussed below), the State Court of Appeal reiterated that the public trust doctrine is a significant limitation on water rights. The public trust doctrine was also a basis for the decision in *Environmental Defense Fund v. East Bay Municipal Utility District.* In this case, EDF claimed that EBMUD should not contract with USBR for water diverted from the American River upstream from the Sacramento urban area in a manner that would harm instream uses including recreational, scenic, and fish and wildlife preservation purposes. The Superior Court upheld the validity of EBMUD's contract with USBR, but placed limitations on the timing and amounts of deliveries to EBMUD. As a result of these cases, the SWRCB now routinely implements the public trust doctrine through regulations and through terms and conditions in water rights permits and licenses.

Federal Power Act

The Federal Power Act created a federal licensing system administered by the Federal Energy Regulatory Commission and required that a license be obtained for nonfederal hydroelectric projects proposing to use navigable waters or federal lands. The act contains a clause modeled after a clause in the Reclamation Act of 1902, which disclaims any intent to affect state water rights law.

In a number of decisions dating back to the 1940s, the U.S. Supreme Court held that provisions of the Reclamation Act and the Federal Power Act preempted inconsistent provisions of law. Decisions under both acts found that these clauses were merely "saving clauses" which required the United States to follow minimal state procedural laws or to pay just compensation where vested nonfederal water rights are taken.

In *California v. United States* (1978), however, the U.S. Supreme Court disavowed dicta in a number of earlier Supreme Court decisions which stated that under the Reclamation Act the United States need not comply with state water law. It held that the Reclamation Act clause requires the USBR to comply with conditions in state water rights permits unless those conditions conflict with "clear Congressional directives." In *California v. FERC* (1990), commonly referred to as the Rock Creek Decision, the U.S. Supreme Court rejected California's argument that the Federal Power Act clause required deference to state water law, as the Reclamation Act did. The Supreme Court distinguished between the two acts, finding that the Federal Power Act envisioned a broader and more active oversight role than did the Reclamation law. The Federal District Court case of *Sayles Hydro Association v. Maughan* (1993), reinforced this view by holding that federal law prevents any state regulation of federally licensed power projects other than determining proprietary water rights.

In 1994, the U.S. Supreme Court issued a decision referred to as the Elkhorn decision or Tacoma decision (*PUD No. 1 of Jefferson County and City of Tacoma v. Washington Department of Ecology)*. The Supreme Court held that a state minimum instream flow requirement is a permissible condition of a Clean Water Act Section 401 certification, in response to a proposal to construct a hydroelectric project on the Dosewallips River. Pursuant to Section 401 of the Clean Water Act, the project proponents were required to obtain state certification for the hydroelectric project. The State of Washington set an instream flow requirement in its certification process to protect the river's designated use as fish habitat. Section 303 of the Clean Water Act requires states to establish water quality standards for intrastate waters, with the standards to include both numeric water quality criteria and designated uses.

Area of Origin Protections

During the years when California's two largest water projects, the CVP and SWP, were being planned and developed, area of origin provisions were added to the water code to protect local Northern California supplies from being depleted as a result of the projects. County of origin statutes reserve water supplies for counties in which the water originates when, in the judgment of the SWRCB, an application for the assignment or release from priority of State water right filings will deprive the county of water necessary for its present and future development. Watershed protection statutes are provisions which require that the construction and operation of elements of the CVP and the SWP not deprive the watershed, or area where water originates (or immediately adjacent areas which can be conveniently supplied with water) of the prior right to water reasonably required to supply the present or future beneficial needs of the watershed area or any of its inhabitants or property owners.

The Delta Protection Act, enacted in 1959 (not to be confused with the Delta Protection Act of 1992, which relates to land use), declares that the maintenance of an adequate water supply in the Delta—to maintain and expand agriculture, industry, urban, and recreational development in the Delta area and provide a common source of fresh water for export to areas of water deficiency—is necessary for the peace, health, safety, and welfare of the people of the State, and is subject to the County of Origin and Watershed Protection laws. The act requires the SWP and the CVP to provide salinity control in the Delta and an adequate water supply for water users in the Delta.

In 1984, additional area of origin protections were enacted covering the Sacramento, Mokelumne, Calaveras, and San Joaquin Rivers; the combined Truckee, Carson, and Walker Rivers; and Mono Lake. The protections prohibit the export of groundwater from the combined Sacramento River and Delta Basins, unless the export is in compliance with local groundwater plans.

Environmental Regulatory Statutes and Programs

Endangered Species Act

Under the federal ESA, an endangered species is one that is in danger of extinction in all or a significant part of its range, and a threatened species is one that is likely to become endangered in the near future. The ESA is designed to preserve endangered and threatened species by protecting individuals of the species and their habitat and by implementing measures that promote their recovery. The ESA sets forth a procedure for listing species as threatened or endangered. Final listing decisions are made by USFWS or NMFS.

Once a species is listed, Section 7 of the act requires that federal agencies, in consultation with the USFWS or NMFS, ensure that their actions do not jeopardize the continued existence of the species or habitat critical for the survival of that species. The federal wildlife agencies are required to provide an opinion as to whether the federal action would jeopardize the species. The opinion must include reasonable and prudent alternatives to the action that would avoid jeopardizing the species' existence. Federal actions subject to Section 7 include issuance of federal permits such as the dredge and fill permit required under Section 404 of the federal Clean Water Act, which requires that the project proponent demonstrate that there is no feasible alternative consistent with the project goals that would not affect listed species. Mitigation of the proposed project is not considered until this hurdle is passed.

State agencies and private parties also are subject to the ESA. Section 9 of the ESA prohibits the "take" of endangered species and threatened species for which protective regulations have been adopted. Take has been broadly defined to include actions that harm or harass listed species or that cause a significant loss of their habitat. State agencies and private parties are generally required to obtain a permit from the USFWS or NMFS under Section 10(a) of the ESA before carrying out activities that may incidentally result in taking listed species. The permit normally contains conditions to avoid taking listed species and to compensate for habitat adversely impacted by the activities.

California Endangered Species Act

The California Endangered Species Act is similar to the federal ESA. Listing decisions are made by the California Fish and Game Commission.

All State lead agencies are required to consult with the Department of Fish and Game about projects that impact State listed species. DFG is required to render an opinion as to whether the proposed project jeopardizes a listed species and to offer alternatives to avoid jeopardy. State agencies must adopt reasonable alternatives unless there are overriding social or economic conditions that make such alternatives infeasible. For projects causing incidental take, DFG is required to specify reasonable and prudent measures to minimize take. Any take that results from activities that are carried out in compliance with these measures is not prohibited.

Many California species are both federally listed and State listed. CESA directs DFG to coordinate with the USFWS and NMFS in the consultation process so that consistent and compatible opinions or findings can be adopted by both federal and State agencies.

Natural Community Conservation Planning

Adopted in 1991, California's Natural Community Conservation Planning Act establishes a program to identify the habitat needs of species before they become listed as threatened or endangered, and to develop appropriate voluntary conservation methods compatible with development and growth. Participants in the program develop plans to protect certain habitat and will ultimately enter into agreements with DFG to ensure that the plans will be carried out. Plans must be created so that they are consistent with endangered species laws.

Dredge and Fill Permits

Section 404 of the federal Clean Water Act regulates the discharge of dredged and fill materials into waters of the United States, including wetlands. The term "discharge of dredged and fill material" has been defined broadly to include the construction of any structure involving rock, soil, or other construction material. No discharge may occur unless a permit is obtained from the USACE. Generally, the project proponent must agree to mitigate or have plans to mitigate environmental impacts caused by the project before a permit is issued. The EPA has the authority to veto permits issued by the Corps for projects that have unacceptable adverse effects on municipal water supplies, fisheries, wildlife, or recreational areas.

Section 404 allows the issuance of a general permit on a state, regional, or nationwide basis for certain categories of activities that will cause only minimal environmental effects. Such activities are permitted without the need of an individual permit application. Installation of a stream gaging station along a river levee is one example of an activity which falls within a nationwide permit.

The USACE also administers a permitting program under Section 10 of the 1899 Rivers and Harbors Act. Section 10 generally requires a permit for obstructions to navigable water. The scope of the permit under Section 10 is narrower than under Section 404 since the term "navigable waters" is more limited than "waters of the United States."

The majority of water development projects must comply with Section 404, Section 10, or both.

Public Interest Terms and Conditions

The Water Code authorizes the SWRCB to impose public interest terms and conditions to conserve the public interest, specifically the consideration of instream beneficial uses, when it issues permits to appropriate water. It also considers environmental impacts of approving water transfers under its jurisdiction. Frequently, it reserves jurisdiction to consider new instream uses and to modify permits accordingly.

Releases of Water for Fish

Fish and Game Code Section 5937 provides protection to fisheries by requiring that the owner of any dam allow sufficient water at all times to pass through the dam to keep in good condition any fisheries that may be planted or exist below the dam. In *California Trout, Inc. v. the State Water Resources Control Board* (1989), the court determined that Fish and Game Code sections 5937 and 5946 required the SWRCB to modify the permits and licenses issued to the City of Los Angeles to appropriate water from the streams feeding Mono Lake to ensure sufficient water flows for downstream fisheries. The SWRCB reconsidered Los Angeles' permits and licenses in light of Fish and Game Code Section 5937 and the public trust doctrine. In 1994, the SWRCB adopted D-1631, which requires Los Angeles to allow sufficient flows from the streams feeding Mono Lake to reach the lake to allow it to rise to the level of 6,391 feet in approximately twenty years.

Streambed Alteration Agreements

Fish and Game Code Sections 1601 and 1603 require that any governmental entity or private party altering a river, stream, lakebed, bottom, or channel enter into an agreement with DFG. When the project may substantially impact an existing fish or wildlife resource, DFG may require that the agreement include provisions designed to protect riparian habitat, fisheries, and wildlife. New water development projects and ongoing maintenance activities are often subject to these sections.

Migratory Bird Treaty Act

This act implements various treaties for the protection of migratory birds and prohibits the "taking" (broadly defined) of birds protected by those treaties without a permit. The Secretary of the Interior determines conditions under which a taking may occur, and criminal penalties are provided for unlawfully taking or transporting protected birds. Liability imposed by this act was one of several factors leading to the decision to close the San Luis Drain and Kesterson Reservoir.

Environmental Review and Mitigation

Another set of environmental statutes compels governmental agencies and private individuals to document and consider the environmental consequences of their actions. They define the procedures through which governmental agencies consider environmental factors in their decision-making process.

National Environmental Policy Act

NEPA directs federal agencies to prepare an environmental impact statement for all major federal actions which may have a significant effect on the human environment. It states that it is the goal of the federal government to use all practicable means, consistent with other considerations of national policy, to protect and enhance the quality of the environment. It is a procedural law requiring all federal agencies to consider the environmental impacts of their proposed actions during the planning and decision-making processes.

California Environmental Quality Act

CEQA, modeled after NEPA, requires California public agency decision-makers to document and consider the environmental impacts of their actions. It requires an agency to identify ways to avoid or reduce environmental damage, and to implement those measures where feasible. CEQA applies to all levels of California government, including the State, counties, cities, and local districts.

CEQA requires that a public agency carrying out a project with significant environmental effects prepare an environmental impact report. An EIR contains a description of the project; a discussion of the project's environmental impacts, mitigation measures, and alternatives; public comments; and the agency's responses to the comments. In other instances, a notice of exemption from the application of CEQA may also be appropriate.

NEPA does not generally require federal agencies to adopt mitigation measures or alternatives provided in the EIS. CEQA imposes substantive duties on all California governmental agencies that approve projects with significant environmental impacts to adopt feasible alternatives or mitigation measures that substantially lessen these impacts, unless there are overriding reasons. When a project is subject to both CEQA and NEPA, both laws encourage the agencies to cooperate in planning the project and to prepare joint environmental documents.

Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act expresses congressional policy to protect the quality of the aquatic environment as it affects the conservation, improvement, and enjoyment of fish and wildlife resources. Under this act, any federal agency that proposes to control or modify any body of water, or to issue a permit allowing control or modification of a body of water, must first consult with the USFWS and State wildlife officials. This requires coordination early in the project planning and environmental review processes.

Protection of Wild and Natural Areas

Water use and management are also limited by several statutes designed to set aside resources or areas to preserve their natural conditions. These statutes preclude many activities, including most water development projects, within the areas set aside.

Federal Wild and Scenic Rivers System

In 1968, Congress passed the National Wild and Scenic Rivers Act to preserve, in their free-flowing condition, rivers which possess "outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values." The act also states " . . . that the established national policy of dam and other construction at appropriate sections of rivers of the United States needs to be complemented by a policy that would preserve other selected rivers or sections thereof in their free-flowing condition to protect the water quality of such rivers and to fulfill other vital national conservation purposes."

The act prohibits federal agencies from constructing, authorizing, or funding the construction of water resources projects having a direct and adverse effect on the values for which a river was designated. This restriction also applies to rivers designated for potential addition to the National Wild and Scenic Rivers System. Included in the system are most rivers protected under California's State Wild and Scenic Rivers Act; these rivers were included in the national system upon California's petition on January 19, 1981. The West Walker and East Fork Carson Rivers are not included in the federal system.

California Wild and Scenic Rivers System

In 1972, the Legislature passed the California Wild and Scenic Rivers Act, declaring that specified rivers possess extraordinary scenic, recreational, fishery, or wildlife values, and should be preserved in a free-flowing state for the benefit of the people of California. It declared that such use of the rivers would be the highest and most beneficial use within the meaning of Article X, Section 2 of the California Constitution. The act prohibits construction of any dam, reservoir, diversion, or other water impoundment on a designated river. Diversions needed to supply domestic water to residents of counties through which the river flows may be authorized, if the Secretary for Resources determines that the diversion will not adversely affect the river's free-flowing character.

The major difference between the national and State acts is that if a river is designated wild and scenic under the State act, FERC can still issue a license to build a dam on that river, thus overriding the State system. (See Federal Power Act discussion above.) This difference explains why national wild and scenic designation is often sought.

National Wilderness Act

The Wilderness Act sets up a system to protect federal land designated by Congress as a "wilderness area" and preserve it in its natural condition. Wilderness is defined as undeveloped federal land retaining its primeval character and influence without permanent improvements or human habitation. Commercial enterprise, permanent roads, motor vehicles, aircraft landings, motorized equipment, or construction of structures or installations (such as dams, diversions, conveyance facilities, and gaging stations) are prohibited within designated wilderness areas.

Water Quality Protection

Water quality is an important aspect of water resource management. The SWRCB plays a central role in determining both water rights and regulating water quality. The Department of Health Services has regulatory oversight over drinking water quality, a program administered in coordination with county environmental health agencies. Discussed below are key State and federal laws governing water quality.

Porter-Cologne Water Quality Control Act

This act is California's comprehensive water quality control law and is a complete regulatory program designed to protect water quality and beneficial uses of the State's water. The act requires the adoption of water quality control plans by the State's nine RWQCBs for areas within their regions. These plans are subject to the approval of the SWRCB, and ultimately the federal EPA. The plans are to be reviewed and updated.

The primary method of implementing the plans is to require each discharger of waste that could impact the waters of the State to meet formal waste discharge requirements. Anyone discharging waste or proposing to discharge waste into the State's waters must file a "report of waste discharge" with the regional water quality control board within whose jurisdiction the discharge lies. Dischargers are subject to a wide variety of administrative, civil, and criminal actions for failing to file a report. After the report is filed, the regional board may issue waste discharge requirements that set conditions on the discharge. The waste discharge requirements must be consistent with the water quality control plan for the body of water and protect the beneficial uses of the receiving waters. The regional boards also implement Section 402 of the federal Clean Water Act, which allows the State to issue a single discharge permit for the purposes of both State and federal law.

Clean Water Act—National Pollutant Discharge Elimination System

Section 402 of the Clean Water Act established a permit system known as the National Pollutant Discharge Elimination System to regulate point sources of discharges in navigable waters of the United States. The EPA was given the authority to implement the NPDES, although the act also authorizes states to implement the act in lieu of the EPA, provided the state has sufficient authority.

In 1972, the Legislature amended the Porter-Cologne Act to give California the authority and ability to operate the NPDES permits program. Before a permit may be issued, Section 401 of the Clean Water Act requires that the regional water quality control board certify that the discharge will comply with applicable water quality standards. After making the certification, the regional board may issue the permit, satisfying both State and federal law. In 1987, Section 402 was amended to require the regulation of storm water runoff under the NPDES.

Safe Drinking Water Act

The SDWA, enacted in 1974 and significantly amended in 1986 and 1996, directed the EPA to set national standards for drinking water quality. It required the EPA to set maximum contaminant levels for a wide variety of constituents. Local water suppliers are required to monitor their water supplies to assure that regulatory standards are not exceeded.

The 1986 amendments set a timetable for the EPA to establish standards for specific contaminants and increased the range of contaminants local water suppliers were required to monitor to include contaminants that did not yet have an MCL established. The amendments included a wellhead protection program, a grant program for designating sole-source aquifers for special protection, and grant programs and technical and financial assistance to small systems and states.

The 1996 amendments added a provision requiring states to create their own revolving funds in order to be eligible to receive federal matching funds for loans and grants to public water systems. More details of the 1996 amendments are described in Chapter 2.

California Safe Drinking Water Act

In 1976, California enacted its own Safe Drinking Water Act, requiring the Department of Health Services to regulate drinking water, including: setting and enforcing federal and State drinking water standards; administering water quality testing programs; and administering permits for public water system operations. The federal Safe Drinking Water Act allows the State to enforce its own standards in lieu of the federal standards so long as they are at least as protective as the federal standards. Significant amendments to the California act in 1989 incorporated the new federal safe drinking water act requirements into California law, gave DHS discretion to set more stringent MCLs, and recommended public health levels for contaminants. DHS was authorized to consider the technical and economic feasibility of reducing contaminants in setting MCLs. The standards established by DHS are found in the California Code of Regulations, Title 22.

Historical Background—Bay-Delta Regulatory Actions

The SWRCB issued the first water rights permits to the USBR for operation of the CVP in 1958, and to the Department for operation of the SWP in 1967. In these and all succeeding permits issued for the CVP and SWP, the SWRCB reserved jurisdiction to reformulate or revise terms and conditions relative to salinity control, effect on vested rights, and fish and wildlife protection in the Delta. SWRCB has a dual role of issuing both water rights permits and regulating water quality.

Decision 1485

In 1976, SWRCB initiated proceedings leading to the adoption of D-1485 in 1978. D-1485 set forth conditions—including water quality standards, export limitations, and minimum flow rates—for SWP and CVP operations in the Delta and superseded all previous water rights decisions for the SWP and CVP operations in the Delta. Among beneficial uses to be protected by the decision were: municipal and industrial water supply, agriculture, and fish and wildlife.

In formulating D-1485, the SWRCB asserted that Delta water quality should be at least as good as it would have been if the SWP and CVP had not been constructed. In other words, both the SWP and the CVP were to be operated to meet "without project" conditions. D-1485 standards included different levels of protection to reflect variations in hydrologic conditions during different types of water years.

To help implement these water quality standards, D-1485 mandated an extensive monitoring program. It also called for special studies to provide critical data about major concerns in the Delta and Suisun Marsh for which information was insufficient. D-1485 included water quality standards for Suisun Marsh, as well as for the Delta, requiring the Department and USBR to develop a plan for the marsh that would ensure meeting long-term standards.

Recognizing that the complexities of project operations and water quality conditions would change over time, the SWRCB also specified that the Delta water right hearings would be reopened within ten years of the date of adoption of D-1485, depending upon changing conditions in the Bay-Delta region and the availability of new evidence on beneficial uses of water.

Racanelli Decision

Lawsuits by various interests challenged D-1485 and the decision was overturned by the trial court in 1984. Unlike its predecessor, D-1379, whose standards had been judicially stayed, D-1485 remained in effect. In 1986, the appellate court in the Racanelli Decision (named after Judge Racanelli who wrote the opinion) broadly interpreted the SWRCB's authority and obligation to establish water quality objectives, and its authority to set water rights permit terms and conditions that provide reasonable protection of beneficial uses of Delta water.

The court stated that SWRCB needed to separate its water quality planning and water rights functions. SWRCB needs to maintain a "global perspective" in identifying beneficial uses to be protected (not limited to water rights) and in allocating responsibility for implementing water quality objectives (not just to the SWP and CVP, nor only through the SWRCB's own water rights processes). The court recognized the SWRCB's authority to look to all water rights holders to implement water quality standards and advised SWRCB to consider the effects of all Delta and upstream water users in setting and implementing water quality standards in the Delta, as well as those of the SWP and the CVP.

SWRCB Bay-Delta Proceedings

Hearings to adopt a water quality control plan and water rights decision for the Bay-Delta estuary began in July 1987. Their purpose was to develop a Bay-Delta water quality control plan and to consider public interest issues related to Delta water rights, including implementation of water quality objectives. During the first phase of the proceedings, testimony was heard on issues pertaining to the reasonable and beneficial uses of the estuary's water. The second phase of the Bay-Delta hearings was to come up with a water quality control plan. SWRCB adopted a final plan in May 1991. The federal EPA rejected this plan in September 1991, setting the stage for preparation of federal water quality standards for the Bay-Delta.

With the adoption of the water quality control plan, the SWRCB began the EIR scoping phase and held several workshops during 1991 to receive testimony regarding planning activities, facilities development, negotiated settlements, and flow objectives.

Concurrently, under the broad authority of the ESA, the federal regulatory process was proceeding toward development of Delta standards and upstream measures applicable to the CVP and SWP for the protection of the threatened winter-run chinook salmon. In February 1993, the NMFS issued a long-term biological opinion governing operations of the CVP and SWP with Delta environmental regulations that, in certain months, were more restrictive than SWRCB's proposed measures. In March 1993, the USFWS listed the Delta smelt as a threatened species and shortly thereafter indicated that further restrictions of CVP and SWP operations would be required. In December 1993, EPA announced its proposed standards for the estuary in place of the SWRCB water quality standards that EPA had rejected in 1991. In addition, USFWS proposed to list the Sacramento splittail as a threatened species, and NMFS announced its decision to change the status of winter-run salmon from threatened to endangered.

The impending regulatory gridlock lead to the negotiation and signing of the June 1994 Framework Agreement for the Bay-Delta estuary. The Framework Agreement and subsequent Bay-Delta activities are described in Chapter 2.

To mitigate fish losses at Delta export facilities, the Department and USBR have entered into agreements with DFG. As part of the environmental review process for installing four additional pumps at SWP's Banks Pumping Plant in the Delta in 1992, DFG and the Department negotiated an agreement to preserve fish potentially affected by the operation of the pumps. This agreement, signed by the two departments in 1986, identifies the steps needed to offset adverse impacts of the Banks Pumping Plant on fisheries. It sets up a procedure to calculate direct fishery losses annually and requires the Department to pay for mitigation projects that would offset the losses. Losses of striped bass, chinook salmon, and steelhead are to be mitigated first. Mitigation of other species is to follow as impacts are identified and appropriate mitigation measures found. In recognition of the fact that direct losses today would probably be greater if fish populations had not been depleted by past operations, the Department also provided $15 million for a program to increase the probability of quickly demonstrated results. In 1996, the Department and DFG agreed to extend the period for expending the remainder of the $15 million to the year 2001.

Following negotiation of the agreement for Banks Pumping Plant, DFG negotiated a similar agreement with USBR for its CVP Tracy Pumping Plant.

Surface Water Management

The following sections are brief descriptions of major statutes affecting surface water management in California.

CVPIA

The Central Valley Project Improvement Act (Title 34 of PL 102-575) made significant changes to the CVP's legislative authorization, amending the project's purposes to place fish and wildlife mitigation and restoration on a par with water supply, and to place fish and wildlife enhancement on a par with power generation. Major provisions of the act are summarized below.

The act prohibits execution of new CVP water supply contracts for purposes other than fish and wildlife (with a few limited exceptions) until all environmental restoration actions specified in the act have been completed. Existing long-term water supply contracts are to be renewed for a 25-year term, with the possibility of subsequent 25-year renewals thereafter. Only interim contract renewals are allowed until the programmatic EIS required by the act is completed. Renewed contracts are to incorporate CVPIA's new requirements, such as restoration fund payments.

The act allows transfers of project water to users outside of the CVP service area, under numerous specified conditions. The conditions include a right of first refusal to a proposed transfer by existing CVP water users (under the same terms and conditions specified in the proposed transfer), and a requirement that proposed transfers of more than 20 percent of a contracting agency's project water supply be subject to review and approval by the contracting agency.

The act requires DOI to develop water conservation criteria, and to review conservation plans submitted by contracting agencies pursuant to Reclamation Reform Act requirements for conformance to the CVPIA criteria. Tiered pricing is to be included in CVP water supply contracts when they are renewed. Project water supply and repayment contractors' surface water delivery systems are to be equipped with water measurement devices.

The act directs DOI to develop a program, by October 1995, to make all reasonable efforts to double, by 2002, natural production (based on 1967-91 fishery population levels) of specified anadromous fish in the Central Valley, and to implement that program. (A portion of the San Joaquin River is exempted from this provision.) The act dedicates 800 taf/yr of CVP yield to fish and wildlife purposes, and authorizes DOI to acquire supplemental water for meeting the fish doubling goal. The act further requires that DOI provide an annual Trinity River instream flow of at least 340 taf through 1996, via releases from Lewiston Dam, with subsequent instream flow requirements to be determined by a USFWS instream flow study.

The act requires DOI to provide, from CVP supplies, firm water supplies (i.e., deliver water corresponding to existing non-firm supplies such as agricultural drainage) to specified federal, State, and private wildlife refuges in the Sacramento and San Joaquin Valleys. DOI is to acquire, from willing sellers, an additional increment of water supply for the wildlife areas, corresponding to their full habitat development needs. All of the supplemental water needs are to be met by 2002.

The act requires DOI to implement numerous specified environmental restoration actions, such as constructing a temperature control device at Shasta Dam, remedying fish passage problems at Red Bluff Diversion Dam, replenishing spawning gravel, and assisting in screening non-federal diversions. Costs of some of these restoration actions are allocated in part to the State of California. DOI is required to enter into a cost-sharing agreement with California for the environmental restoration actions whose costs are allocated in part to California.

The act requires DOI to prepare specified reports and studies, to implement a Central Valley fish and wildlife monitoring program, and to develop ecosystem and water operations models. Examples of reports to be prepared include a least-cost plan to replace the 800 taf/yr of project yield dedicated to environmental purposes, and an evaluation of water supply and development requirements for 120,000 acres of wetlands identified in a Central Valley Habitat Joint Venture report. DOI is also directed to prepare, by October 1995, a programmatic EIS analyzing impacts of CVPIA implementation.

The act authorizes DOI to carry out a land retirement program, and specifies categories of land that may be acquired. San Joaquin Valley drainage-impaired lands are among the authorized categories.

The act establishes a CVPIA restoration fund within the federal treasury, and directs DOI to collect mitigation and restoration payments from project water and power users. DOI is authorized to use appropriations from the fund to carry out the environmental restoration measures required by the act. Payments are capped at $6/af for agricultural water contractors and $12/af (1992 dollars) for municipal and industrial water contractors, but the caps are subject to adjustment for inflation. (An additional restoration payment is assessed against contractors in the Friant Division, in lieu of requiring Friant Dam releases for instream flows in the San Joaquin River between Gravelly Ford and the Mendota Pool.)

Regional and Local Water Agency Formation

In general, there are two methods in California for forming special districts which develop, control, or distribute water: enactment of a general act under which the districts may be formed as set forth in the act, and enactment of a special act creating the district and prescribing its powers. There are more than 40 different statutes under which local agencies may be so organized. In addition, there are a number of special act districts, such as the Metropolitan Water District of Southern California. The Department's Bulletin 155-94, *General Comparison of Water District Acts* (March 1994), presents a comparison of various water district acts in California.

In addition to public agencies, there are other entities that may provide water supply. Mutual water companies, for example, are private corporations that perform water supply and distribution functions similar to public water districts. Investor-owned utilities may also be involved in water supply activities, sometimes as an adjunct of hydroelectric power development.

Water Use Efficiency

Article X, Section 2 of the California Constitution prohibits the waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water. It also declares that the conservation and use of water "shall be exercised with a view to the reasonable and beneficial use thereof in the public interest and for the public welfare." Although provisions and requirements of the Constitution are self executing, the Constitution states that the Legislature may enact statutes to advance its policy. Water Code Section 275 directs the Department and SWRCB to "take all appropriate proceedings or actions before executive, legislative, or judicial agencies to prevent waste or unreasonable use of water." SWRCB's Water Right Decision 1600, directing the Imperial Irrigation District to adopt a water conservation plan, is an example of an action brought under Article X, Section 2. SWRCB's authority to order preparation of such a plan was upheld in 1990 by the courts in *Imperial Irrigation District v. State Water Resources Control Board.*

Urban Water Management Planning Act

Since 1983, this act has required urban water suppliers that serve more than 3,000 customers or more than 3,000 af/yr to prepare and adopt urban water conservation plans. The act authorizes the supplier to implement the water conservation program. The plans must contain several specified elements, including estimates of water use, identification of existing conservation measures, identification of alternative conservation measures, a schedule of implementation of actions proposed by the plan, and identification of the frequency and magnitude of water shortages. In 1991, the act was amended in response to the drought to require water suppliers to estimate water supplies available at the end of one, two, and three years, and to develop contingency plans for severe shortages. The act also requires water suppliers to review and update their plans at least once every five years.

Water Conservation in Landscaping Act

The Water Conservation in Landscaping Act required the Department, with the assistance of an advisory task force, to adopt a model water-efficient landscape ordinance. The model ordinance was adopted in August 1992, and has been codified in Title 23 of the California Code of Regulations. It establishes methods of conserving water through water budgeting plans, plant use, efficient irrigation, and auditing.

Cities and counties were required to review the model ordinance and adopt a water-efficient landscape ordinance by January 1, 1993, if they had not done so already. Alternatively, cities and counties could make a finding that such an ordinance is unnecessary due to climatic, geological, or topographic conditions, or water availability. If a city or county failed to adopt a water efficient landscape ordinance or make findings by January 31, 1993, the model ordinance became effective in that jurisdiction.

Agricultural Water Management Planning Act

Under this act, agricultural water suppliers supplying more than 50 taf of water annually were required to submit a report to the Department indicating whether a significant opportunity exists to conserve water or reduce the quantity of highly saline or toxic drainage water through improved irrigation water management. The act provided that agricultural water suppliers who indicated that they had an opportunity to conserve water or reduce the quantity of highly saline or toxic water should prepare a water management plan and submit it to the Department. The Department was required to review the plans and submit a report to the Legislature by January 1993.

Agricultural Water Suppliers Efficient Management Practices Act

The Agricultural Water Suppliers Efficient Management Practices Act, adopted in 1990, required that the Department establish an advisory committee to review efficient agricultural water management practices. Under the act, the Department was required to offer assistance to agricultural water suppliers seeking to improve the efficiency of their water management practices. The committee developed a Memorandum of Understanding to implement the practices, and to establish an Agricultural Water Management Council. The advisory committee adopted the MOU in October 1996. The MOU was declared in effect in May 1997 after 15 agricultural water suppliers, representing 2 million irrigated acres, had signed. The Council was established and held its first meeting in July 1997.

Agricultural Water Conservation and Management Act of 1992

This act gives any public agency that supplies water for agricultural use authority to institute water conservation or efficient management programs. The programs can include irrigation management services, providing information about crop water use, providing irrigation consulting services, improving the supplier's delivery system, providing technical and financial assistance to farmers, encouraging conservation through pricing of water, and monitoring.

Water Recycling Act of 1991

This act describes the environmental benefits and public safety of using recycled water as a reliable and cost-effective method of helping to meet California's water supply needs. It sets a statewide goal to recycle 700 taf/yr by the year 2000 and 1 maf/yr by 2010.

3

Water Supplies

This chapter reviews existing water supplies and updates information presented in Bulletin 160-93. Beginning with a brief overview of California's climate and hydrology, this chapter describes how water supplies are calculated and summarized within a water budget framework. A description of California's existing supplies—surface water, groundwater, recycled water, and desalted water—and how a portion of these supplies are reallocated through water marketing follows. Chapter 3 concludes with a review of water quality considerations that influence how the State's water supplies are used.

Climate and Hydrology

Much of California enjoys a Mediterranean-like climate with cool, wet winters and warm, dry summers. An atmospheric high pressure belt results in fair weather for much of the year with little precipitation during the summer. The high pressure belt shifts southward during the winter, placing the State under the influence of Pacific storms, bringing rain and snow. Most of California's moisture originates in the Pacific Ocean. As moisture-laden air moves over mountain barriers such as the Sierra Nevada, the air is lifted and cooled, dropping rain or snow on the western slopes. This mountain-induced (orographic) precipitation is very important for the State's water supply.

The SWP's California Aqueduct is the only conveyance facility that moves water from the Central Valley to Southern California.

Average annual statewide precipitation is about 23 inches, corresponding to a volume of nearly 200 maf over California's land surface. About 65 percent of this precipitation is consumed through evaporation and transpiration by trees and other plants. The remaining 35 percent comprises the State's

The Colorado River Region is California's driest region; the North Coast Region is its wettest.

average annual runoff of about 71 maf. Less than half this runoff is depleted by urban or agricultural use. Most of it maintains ecosystems in California's rivers, estuaries, and wetlands. Available surface water supply totals 78 maf when out-of-state supplies from the Colorado and Klamath Rivers are added.

Distribution of the State's water supplies varies geographically and seasonally. Water supplies also vary climatically through cycles of drought and flood.

Geographic Variability

Uneven distribution of water resources is part of the State's geography. More than 70 percent of California's 71 maf average annual runoff occurs in the northern part of the State; the North Coast Region accounts for 40 percent and the Sacramento River Region accounts for 32 percent. Figure 3-1 shows average annual rainfall and runoff in California by hydrologic region. About 75 percent of the State's urban and agricultural demands for water are south of Sacramento. The largest urban water use is in the South Coast Region where roughly half of California's population resides. The largest agricultural water use is in the San Joaquin River and Tulare Lake

FIGURE 3-1

Distribution of Average Annual Precipitation and Runoff

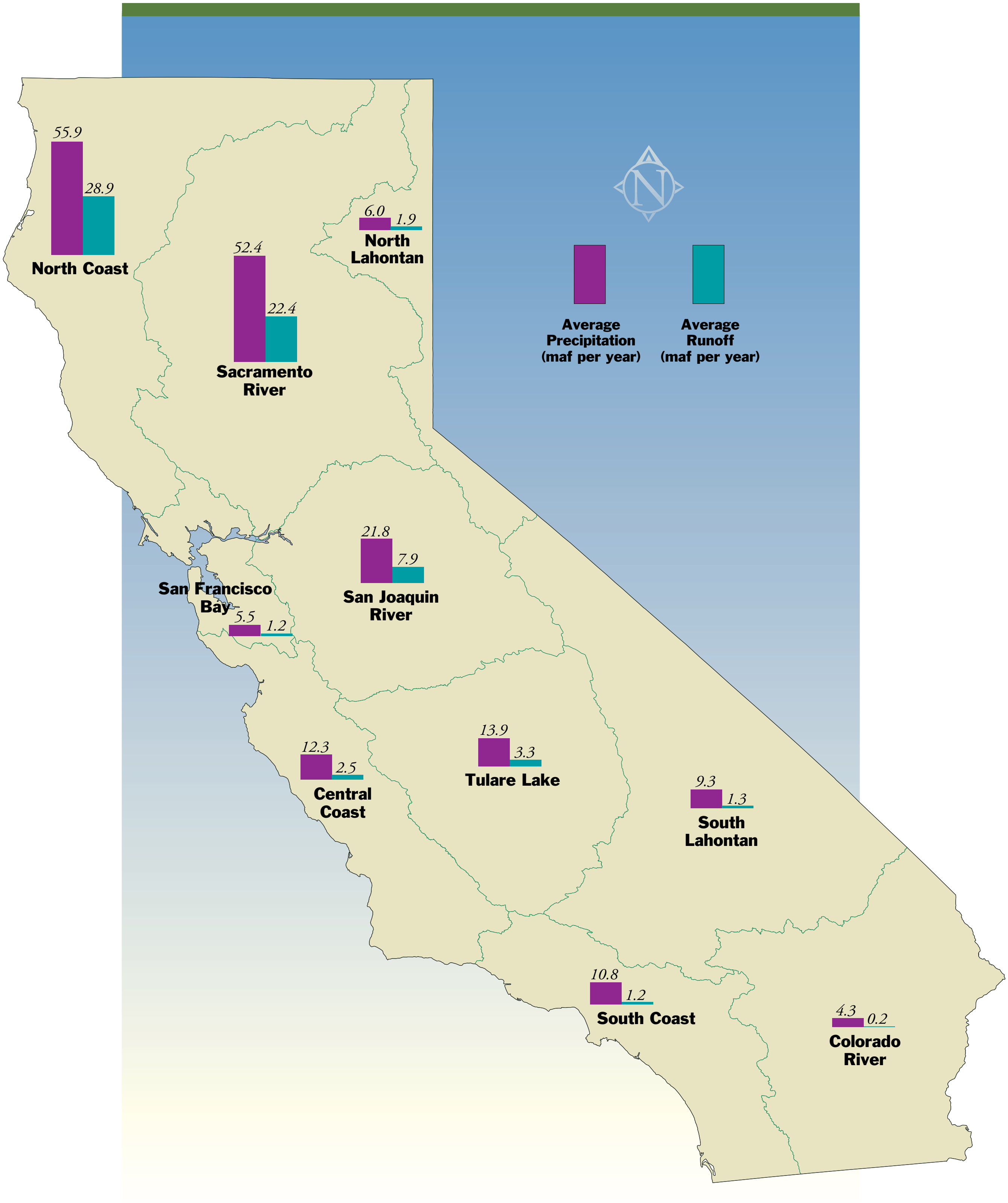
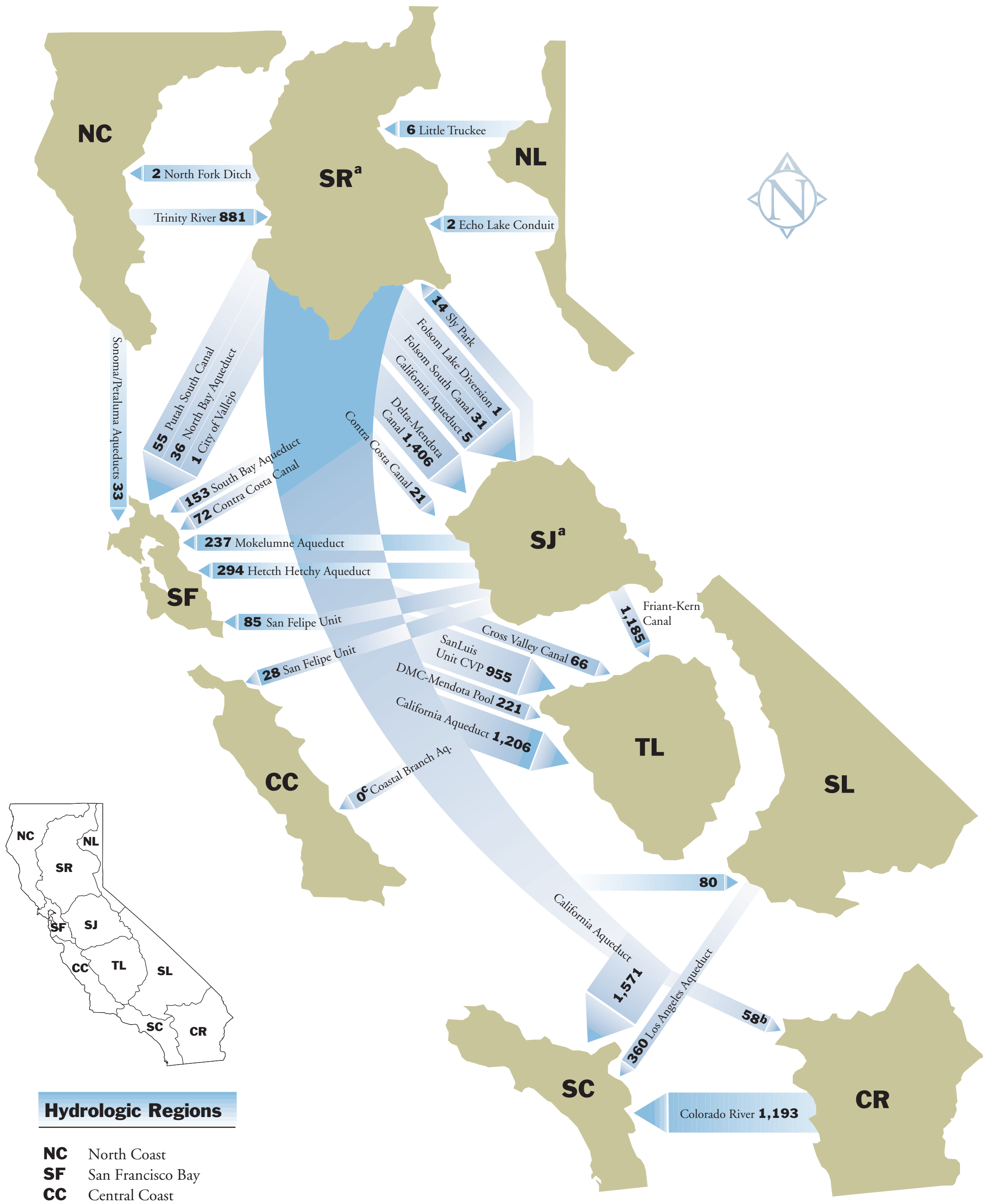


FIGURE 3-2

Regional Imports and Exports, 1995 Level of Development

1995 Level of Development (taf)



Hydrologic Regions

NC	North Coast
SF	San Francisco Bay
CC	Central Coast
SC	South Coast
SR	Sacramento River
SJ	San Joaquin River
TL	Tulare Lake
NL	North Lahontan
SL	South Lahontan
CR	Colorado River

[a] Exports from the Delta are taken from commingled waters originating in both the Sacramento and San Joaquin River Regions.

[b] Exchange

[c] Deliveries did not begin until 1997.

Spring snowmelt helps fill Sierra Nevada reservoirs. Every year, snowpack depth and water content are measured at selected sites throughout the Sierra as part of a cooperative snow surveys program. This information is used to forecast spring runoff, allowing reservoir operators to plan for the coming year.

regions. Fertile soils, a long, dry growing season, and water availability have combined to make these regions among the most agriculturally productive in the world. Wild and scenic river flows in the North Coast Region provide the largest environmental water use. Statewide water use is described in Chapter 4.

In response to the uneven geographic distribution of California's water resources, facilities have been constructed to convey water from one watershed or hydrologic region to another. Figure 3-2 shows larger exports and imports among the State's hydrologic regions.

Seasonal Variability

On average, 75 percent of the State's average annual precipitation of 23 inches falls between November and March, with half of it occurring between December and February. A shortfall of a few major storms during the winter usually results in a dry year; conversely, a few extra storms or an extended stormy period usually produces a wet year. An unusually persistent Pacific high pressure zone over California during December through February predisposes the year toward a dry year. Urban and agricultural water demands are highest during the summer and lowest during the winter, the inverse of statewide rainfall patterns. Figure 3-3 compares average monthly precipitation in the Sacramento River region with precipitation during extremely wet (1982-83) and dry (1923-24) years.

FIGURE 3-3

Northern Sierra Eight Station Precipitation Index

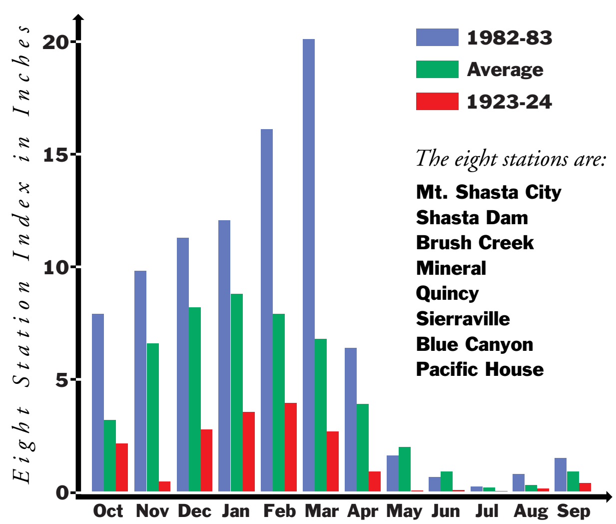
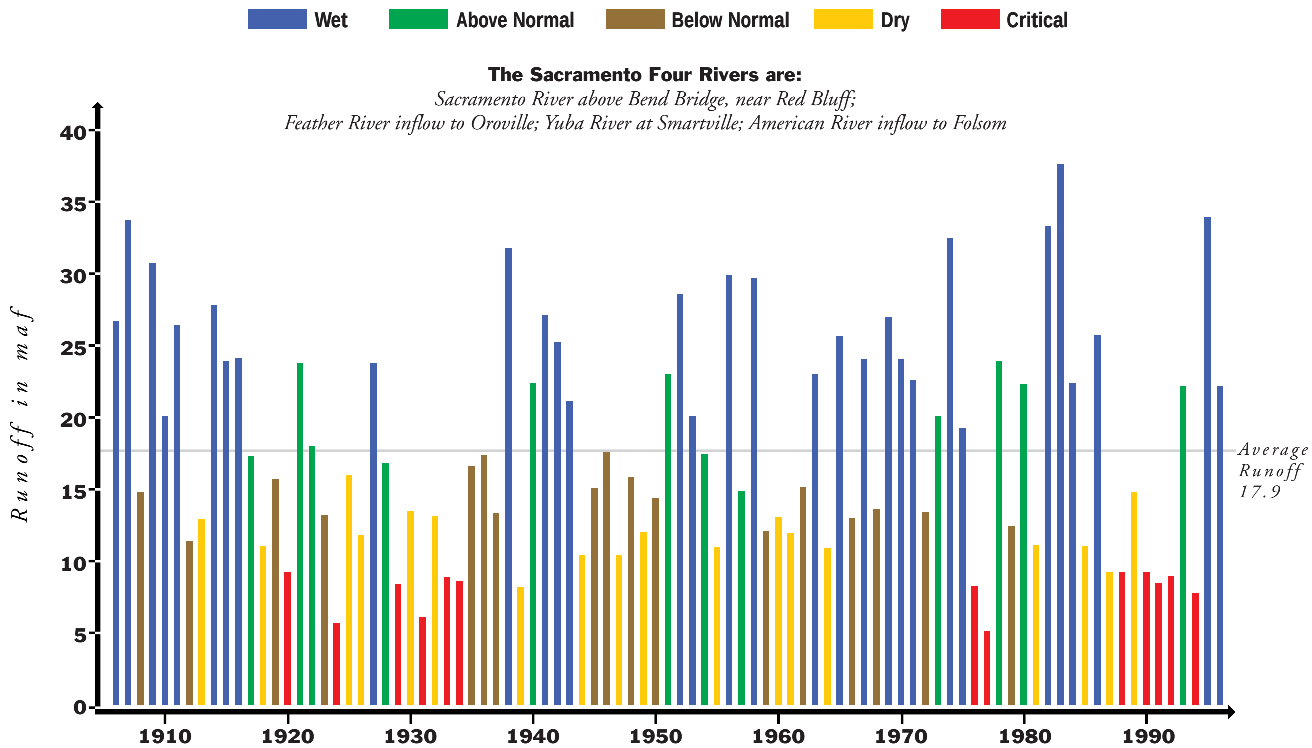


FIGURE 3-4

Sacramento Four Rivers Unimpaired Runoff

The WR 95-6 year types are:



Climatic Variability

California's water development has generally been dictated by extremes of droughts and floods. The six-year drought of 1929-34 established the criteria commonly used to plan storage capacity or water yield of large Northern California reservoirs.

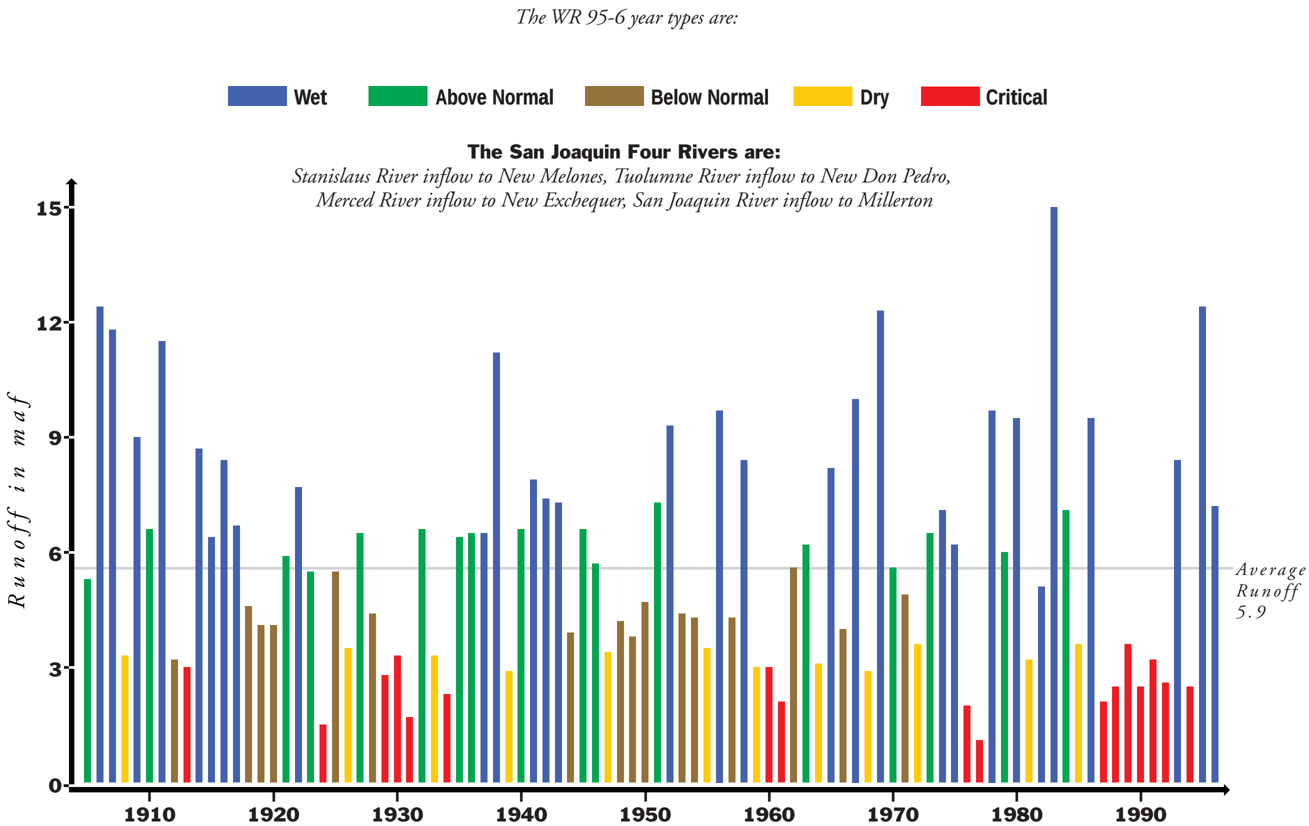
The influence of climatic variability on California's water supplies is much less predictable than the influences of geographic and seasonal variability, as evidenced by the recent historical record of precipitation and runoff. For example, the State's average annual runoff of 71 maf includes the all-time low of 15 maf in 1977 and the all-time high (exceeding 135 maf) in 1983. Floods and droughts occur often, sometimes in the same year. The January 1997 flood was followed by a record-setting dry period from February through June and the flooding of 1986 was followed by six years of drought (1987-92).

Figures 3-4 and 3-5 show the estimated annual unimpaired runoff from the Sacramento and San Joaquin River basins to illustrate climatic variability. Because these basins provide much of the State's water supply, their hydrologies are often used as indices of water year classification systems (see sidebar, page 3-8).

Droughts of Recent Record. Numerous multi-year droughts have occurred in California this century: 1912-13, 1918-20, 1922-24, 1929-34, 1947-50, 1959-61, 1976-77, and 1987-92. In order to provide water supply reliability, major reservoirs are designed to maintain and deliver carryover storage through several years of drought. The 1929-34 drought established the criteria commonly used to design the storage capacity and water yield of large Northern California reservoirs. Many reservoirs built since this drought were sized to maintain a reliable level of deliveries should a repeat of the 1929-34 hydrology occur. Even a single critical run-off year such as 1977 can be devastating to water users with limited storage reserves, who are more dependent

FIGURE 3-5

San Joaquin Four Rivers Unimpaired Runoff



on annual runoff. Table 3-1 compares the severity of recent droughts with the 1929-34 drought in the Sacramento Valley and San Joaquin Valley.

Groundwater supplies about 30 percent of California's urban and agricultural applied water use. In drought years when surface water supplies are reduced, groundwater supports an even greater percentage of use, resulting in declining groundwater levels in many areas. For example, during the first five years of the 1987-92 drought, groundwater extractions exceeded groundwater recharge by 11 maf in the San Joaquin Valley. Drawing down groundwater reserves in drought years is analogous to reservoir carryover storage operations.

TABLE 3-1

Severity of Extreme Droughts in the Sacramento and San Joaquin Valleys

Drought Period	*Sacramento Valley Runoff*		*San Joaquin Valley Runoff*	
	(maf/yr)	*(% Average 1906-96)*	*(maf/yr)*	*(% Average 1901-96)*
1929-34	9.8	55	3.3	57
1976-77	6.6	37	1.5	26
1987-92	10.0	56	2.8	47

An Example of Water Year Classifications

Water year classification systems provide a means to assess the amount of water originating in a basin. Because water year classification systems are useful in water planning and management, they have been developed for several hydrologic basins in California. The Sacramento Valley 40-30-30 Index and the San Joaquin Valley 60-20-20 Index were developed by SWRCB for the Sacramento and San Joaquin River hydrologic basins as part of SWRCB's Bay-Delta regulatory activities. Both systems define one "wet" classification, two "normal" classifications (above and below normal), and two "dry" classifications (dry and critical), for a total of five water year types.

The Sacramento Valley 40-30-30 Index is computed as a weighted average of the current water year's April-July unimpaired runoff forecast (40 percent), the current water year's October-March unimpaired runoff forecast (30 percent), and the previous water year's index (30 percent). A cap of 10 maf is put on the previous year's index to account for required flood control reservoir releases during wet years. Unimpaired runoff (calculated in the 40-30-30 Index as the sum of Sacramento River flow above Bend Bridge near Red Bluff, Feather River inflow to Oroville, Yuba River flow at Smartville, and American River inflow to Folsom) is the river production unaltered by water diversions, storage, exports, or imports. A water year with a 40-30-30 index equal to or greater than 9.2 maf is classified as "wet." A water year with an index equal to or less than 5.4 maf is classified as "critical." Unimpaired runoff from the Sacramento Valley, often referred to as the Sacramento River Index or the Four River Index, was the dominant water supply index used in SWRCB's 1978 Delta Plan and in D-1485. The SRI, while still used in SWRCB's Order WR 95-6 as a water supply index, is no longer employed to classify water years. By considering water availability from storage facilities as well as from seasonal runoff, the 40-30-30 Index provides a more representative characterization of water year types than does the SRI.

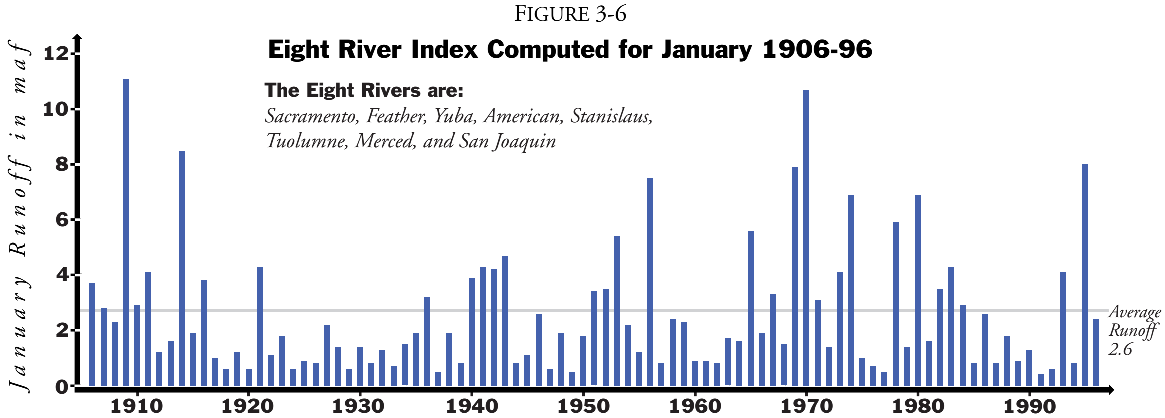
The San Joaquin Valley 60-20-20 Index is computed as a weighted average of the current water year's April-July unimpaired runoff forecast (60 percent), the current water year's October-March unimpaired runoff forecast (20 percent), and the previous water year's index (20 percent). A cap of 4.5 maf is placed on the previous year's index to account for required flood control reservoir releases during wet years. San Joaquin Valley unimpaired runoff is defined as the sum of inflows to New Melones Reservoir (from the Stanislaus River), Don Pedro Reservoir (from the Tuolumne River), New Exchequer Reservoir (from the Merced River), and Millerton Lake (from the San Joaquin River). A water year with a 60-20-20 index equal to or greater than 3.8 maf is classified as "wet." A water year with an index equal to or less than 2.1 maf is classified as "critical."

Although not used to classify water years, the Eight River Index is another important water supply index employed in Order WR 95-6. The Eight River Index, defined as the sum of the unimpaired runoff from the four Sacramento Valley Index rivers and the four San Joaquin Valley Index rivers, is used to define Delta outflow requirements and export restrictions. Key index months for triggering Delta requirements are December, January, and February. Figure 3-6 shows the Eight River Index computed for January from 1906-96.

Existing water year classification systems have been useful in planning and managing water supplies; however, they have also shown shortcomings during unusual hydrologic periods. The 1997 water year is one such example. Because of wet antecedent conditions and unusually high precipitation runoff in December and January, the water year was classified as "wet" in spite of a string of dry months that followed this unusually wet period. Water project operators were compelled to meet stringent instream flow and Delta requirements during the subsequent dry months to comply with the "wet" water year classification. Compliance was met through reservoir storage releases, as spring and summer runoff was significantly lower than is typical in wet years. Reservoir levels benefitted only marginally from the wet December and January, as flood control criteria limited the amount of water that could be stored.

FIGURE 3-6

Eight River Index Computed for January 1906-96



The Sacramento metropolitan area has one of the lowest flood protection levels in the nation, for a community of its size. Without interim reoperation of Folsom Dam, the community is estimated to have only a 1-in-60 year level of protection. (With reoperation, the level of protection is 1-in-77 years). This photo shows the American River in January 1997, and the high-density urban development adjacent to the levee.

Floods of Recent Record. Wet water years are not necessarily indicative of flood conditions. Although water year 1983 was the wettest in California this century, major flooding did not occur then. Table 3-2 shows estimated unimpaired runoff from a few of the State's larger floods since the 1950s. In January 1997, California confronted one of the largest and most extensive flood disasters in its history. Rivers across the State from the Oregon border to the southern Sierra reached flood stages. Flood volumes of some rivers exceeded channel capacities by as much as 700 percent. In many major river systems, flood control dams reduced peak flows by one-half or more. Even so, leveed flood control systems were overwhelmed in some areas. Flood damage costs are nearing $2 billion.

Pre-Nineteenth Century Climatic Variability. Precipitation and runoff records for some locations in California date back to the mid to late 1800s. Data for many other areas are sparse into the early 1900s. These data provide only a glimpse of the range of variability that has occurred. One approach to supplementing the existing climate record is to statistically reconstruct data through the study of tree rings. By properly selecting trees, data on the thickness of annual growth rings can be used to infer the wetness of the season. A 420-year reconstruction of Sacramento River runoff data from tree ring data was made for the Department in 1986 by the Laboratory for Tree Ring Research at the University of Arizona. The tree ring data suggested that the 1929-34 drought was the most severe in the 420-year reconstructed record from 1560 to 1980. The data also suggested that a few droughts prior to 1900 exceeded three years, and none lasted over six years, except for one eight-year period of less than average runoff from 1839-46. John Bidwell, an early pioneer who arrived in California in 1841, confirmed that 1841, 1843, and 1844 were extremely dry years in the Sacramento area. Similar tree ring studies, covering the period between 1550 and 1977, were also conducted for the Colorado and Santa Ynez Rivers. According to these studies, the most severe drought on the Colorado River occurred during 1580-1600, while the most severe drought on the Santa Ynez River occurred during 1621-37. Below average periods, very long wet periods, and

TABLE 3-2
Major Floods Since the 1950s

			Unimpaired Runoff	
River	*Location*	*Date*	*Max 1-Day (cfs)*	*3-day Volume (taf)*
Sacramento	Shasta Dam	Jan 1974	196,000	779
		Feb 1986	126,000	681
		Jan 1997	216,000	1,000
Feather	Oroville Dam	Dec 1964	179,000	984
		Feb 1986	217,000	1,113
		Jan 1997	298,000	1,392
Yuba	Marysville	Dec 1964	144,000	703
		Feb 1986	142,000	729
		Jan 1997	161,000	736
American	Folsom Dam	Dec 1964	183,000	835
		Feb 1986	171,000	988
		Jan 1997	249,000	977
Mokelumne	Camanche Dam	Dec 1964	36,000	171
		Feb 1986	28,000	149
		Jan 1997	76,000	233
Stanislaus	New Melones Dam	Dec 1964	44,000	198
		Feb 1986	40,000	246
		Jan 1997	73,000	298
Tuolumne	New Don Pedro Dam	Dec 1964	73,000	306
		Feb 1986	53,000	294
		Jan 1997	120,000	548
Merced	New Exchequer Dam	Dec 1964	33,000	136
		Feb 1986	30,000	164
		Jan 1997	67,000	262
San Joaquin	Friant Dam	Feb 1986	33,000	176
		Mar 1995	39,000	156
		Jan 1997	77,000	313
Truckee	Reno	Oct 1963	25,000	79
		Feb 1986	22,000	112
		Jan 1997	37,000	148
Cosumnes	Michigan Bar	Dec 1964	29,000	115
		Feb 1986	34,000	196
		Jan 1997	60,000	N/A
Eel	Scotia	Dec 1964	648,000	2,936
		Feb 1986	304,000	1,515
Santa Ynez	Lompoc[a]	Jan 1969	38,000	175
Salinas	Spreckles[a]	Feb 1969	65,000	252
		Mar 1983	60,000	314
		Mar 1995	64,000	241
Santa Clara	Saticoy	Feb 1969	92,000	270

[a] Impaired flows

short severe drought periods were also reconstructed in the studies.

A 1994 study of relict tree stumps rooted in present-day lakes, rivers, and marshes suggested that California sustained two "epic drought" periods, extending over more than three centuries. The first epic drought lasted more than two centuries before the year 1112; the second drought lasted more than 140 years before 1350. In this study, the researcher used drowned tree stumps rooted in Mono Lake, Tenaya Lake, West Walker River, and Osgood Swamp in the central Sierra. One conclusion that can be drawn from this study is that California is subject to droughts far more severe and far more prolonged than anything witnessed in the last 150 years of weather recording.

Future Climate Change. Much concern has been expressed about possible future climate change caused by burning fossil fuel and other modern human activities that increase carbon dioxide and other trace greenhouse gases in the atmosphere. World weather records indicate an overall warming trend during the last century, with a surge of warming prior to 1940 (which cannot be attributed to greenhouse gases) and a more recent rise during the 1980s. The extent to which this latest rise is real or an artifact of instrument location (heat island effect of growing cities) or a temporary anomaly is debated among climatologists. For now, most projections of climate change are derived from computer simulation studies and generally indicate a global average temperature rise of about 2 to 5°C over the next century, for a doubling of carbon dioxide content in the atmosphere. Figures for regional changes are less dependable because of regional weather influences not accounted for in the global models.

For California, if global warming occurs, the most likely impact would be a shift in runoff patterns. Warmer temperatures would mean higher snow levels during winter storms, more winter runoff, and less carryover storage into late spring and summer (assuming precipitation remains the same). There would be some loss in water supply yield if the shift in snowmelt runoff occurs.

When the climate was drier in the past, trees were growing in areas now submerged by alpine lakes such as Lake Tenaya. Dating these submerged stumps by radiocarbon and other techniques provides information about the dates and durations of previous drought periods.

Water Supply Calculation

Bulletin 160-98 calculates existing water supplies and demands, then balances forecasted future demand against supplies and future water management options. The balance, or water budget, with existing supply is presented on a statewide basis in Chapter 6 and on a regional basis in Chapters 7-9. The water budget with future water management options is presented in Chapter 10.

The following section defines and classifies water supplies, describes the method for calculating water supplies within the Bulletin 160 water budget framework, and quantifies statewide water supplies with existing facilities and programs. Two water supply scenarios—an average year and a drought year—are presented for a base year (1995) and a forecast year (2020) to illustrate existing and future water supply reliability.

Definition of Bulletin 160-98 Water Supplies

The Bulletin's water budgets do not account for the State's entire water supply and use. In fact, less than one-third of the State's precipitation is quantified in the water budgets.

As discussed in the previous section on climate and hydrology, precipitation provides California with about 200 maf of total water supply in average years. Of this renewable supply, about 65 percent is depleted through evaporation and transpiration by trees and other plants. This large volume of water (approximately 130 maf) is excluded from the Bulletin's water supply and water use calculations. The remaining 35 percent stays in the State's hydrologic system as runoff.

Over 30 percent of the State's runoff is not explicitly designated for urban, agricultural, or environmental uses. This water is depleted from the State's hydrologic system as outflow to the Pacific Ocean or other salt sinks. (Some of this non-designated runoff is captured by reservoirs, but is later released for flood control.) Similar to precipitation depletions by vegetation, non-designated runoff is excluded from the Bulletin 160 water supply and water use calculations.

The State's remaining runoff is available as renewable water supply for urban, agricultural, and environmental uses in the Bulletin's water budgets (Figure 3-7). In addition to this supply, water budgets include supplies not generated by intrastate precipitation. These supplies include imports from the Colorado and Klamath Rivers and new supplies generated by water recycling and desalting.

Classification of Water Supplies. Water supplies are classified into three broad groups to develop the

Key Water Supply and Water Use Definitions

Chapters 3 and 4 introduce California's water supplies and urban, agricultural and environmental water uses. Certain key concepts, defined below, provide a foundation for analyzing water supplies and water use.

Applied Water: The amount of water from any source needed to meet the demand of the user. It is the quantity of water delivered to any of the following locations:

- The intake to a city water system or factory.
- The farm headgate or other point of measurement.
- A managed wetland, either directly or by drainage flows.

For instream use, applied water is the quantity of stream flow dedicated to instream use (or reserved under the federal or State wild and scenic rivers acts) or to maintaining flow and water quality in the Bay-Delta pursuant to the SWRCB's Order WR 95-6.

Net Water: The amount of water needed in a water service area to meet all demands. It is the sum of evapotranspiration of applied water in an area, the irrecoverable losses from the distribution system, and agricultural return flow or treated urban wastewater leaving the area.

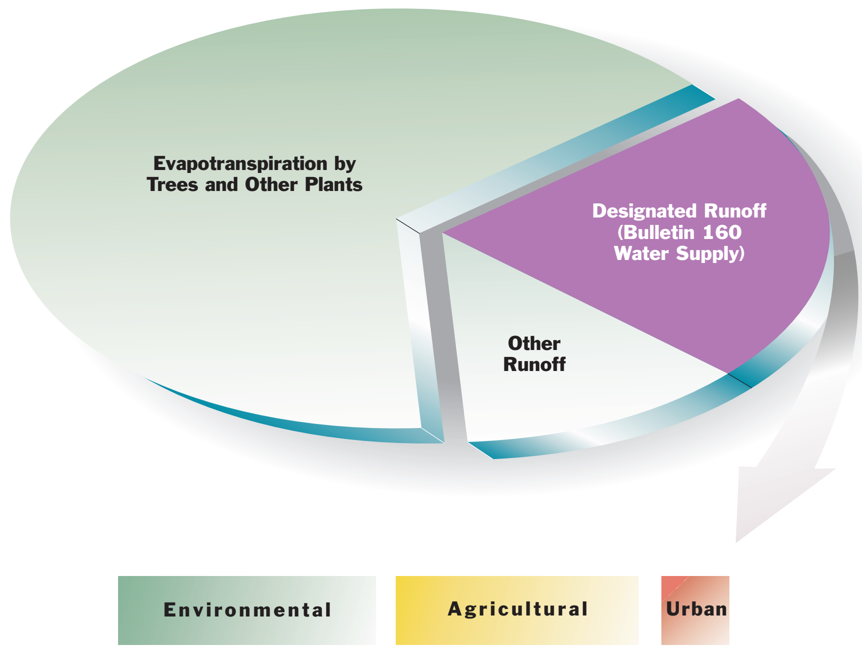
Irrecoverable Losses: The amount of water lost to a salt sink, lost by evapotranspiration, or lost by evaporation from a conveyance facility, drainage canal, or fringe area.

Evapotranspiration: ET is the amount of water transpired (given off), retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces.

Evapotranspiration of Applied Water: ETAW is the portion of the total ET which is provided by applied irrigation water.

Depletion: The amount of water consumed within a service area that is no longer available as a source of supply. For agricultural and certain environmental (i.e., wetlands) water use, depletion is the sum of irrecoverable losses and the ETAW due to crops, wetland vegetation, and flooded water surfaces. For urban water use, depletion is the ETAW due to landscaping and gardens, wastewater effluent that flows to a salt sink, and incidental ET losses. For environmental instream use, depletion is the amount of dedicated flow that proceeds to a salt sink.

FIGURE 3-7
Disposition of California's Average Annual Precipitation



Bulletin's water budgets: surface water, groundwater, and recycled/desalted water. Surface water includes developed supplies from the CVP, the SWP, the Colorado River, other federal projects, and local projects. Surface water also includes the supplies for required environmental flows. Required environmental flows are comprised of undeveloped supplies designated for wild and scenic rivers, supplies used for instream flow requirements, and supplies used for Bay-Delta water quality and outflow requirements. (Bulletin 160-98 assumes Bay-Delta requirements are in accordance with the SWRCB's Order WR 95-6.) Finally, surface water includes supplies available for reapplication downstream. Urban wastewater discharges and agricultural return flows, if beneficially used downstream, are examples of reapplied surface water.

Groundwater includes developed subsurface supplies and water reapplied through deep percolation. Bulletin 160-98 excludes long-term basin extractions in excess of long-term basin inflows in its definition of groundwater supply. This long-term average annual difference between extractions and recharge, defined in the Bulletin as overdraft, is not a sustainable source of water and is thus excluded from the base year and forecast year groundwater supply estimates. (In response to public comments on the Bulletin 160-93, Bulletin 160-98 is the first water plan update to exclude overdraft from the base year groundwater supply estimate.)

The Bulletin 160 definition of water supply from recycling and desalting does not include all water that is reclaimed and reused through treatment technologies. The recycled/desalted classification is limited to supplies that, if not recycled or desalted, would otherwise be depleted to a saline water body, such as the Pacific Ocean. This classification is limited to "new" supply that was previously unavailable for downstream reapplication. In California, this condition exists primarily in the Colorado River Region (which drains to the Salton Sea), parts of the coastal regions, and the westside of the San Joaquin Valley. In the Sacramento River, San Joaquin River, and Tulare Lake regions, almost all urban wastewater becomes available downstream for reapplication through river discharge or groundwater percolation. In these regions, recycling reduces applied water demand and provides water supply reliability and water quality benefits. However, recycling in these regions does not generate a "new" water supply.

Applied Water Methodology. Bulletin 160-98 water supplies are computed using applied water data. As defined in the sidebar on page 3-12, applied water refers to the amount of water from any source employed to meet the demand of the user. Previous editions of Bulletin 160 computed water supplies using net water data. Bulletin 160-98 switched from a net water methodology to an applied water methodology in response to public comments on Bulletin 160-93. Because applied water data are analogous to agency water delivery data, water supply data based on an applied water methodology are easier for local water agencies to review. Net water supply values are smaller than applied water supply values because they exclude that portion of demand met by reapplication of surface and groundwater supplies. Figures 3-8 through 3-10 illustrate applied water and net water methodologies for three different cases. Figure 3-8 shows how outflow in an inland area can be reapplied downstream; Figure 3-9 shows how outflow to a salt sink cannot be reapplied downstream. Figure 3-10 is similar to Figure 3-8 except that agricultural water use is more efficient. In addition to providing another example of applied and net water methodologies, Figure 3-10 also illustrates that, unless depletions are reduced, water conservation in an inland area does not generate new water.

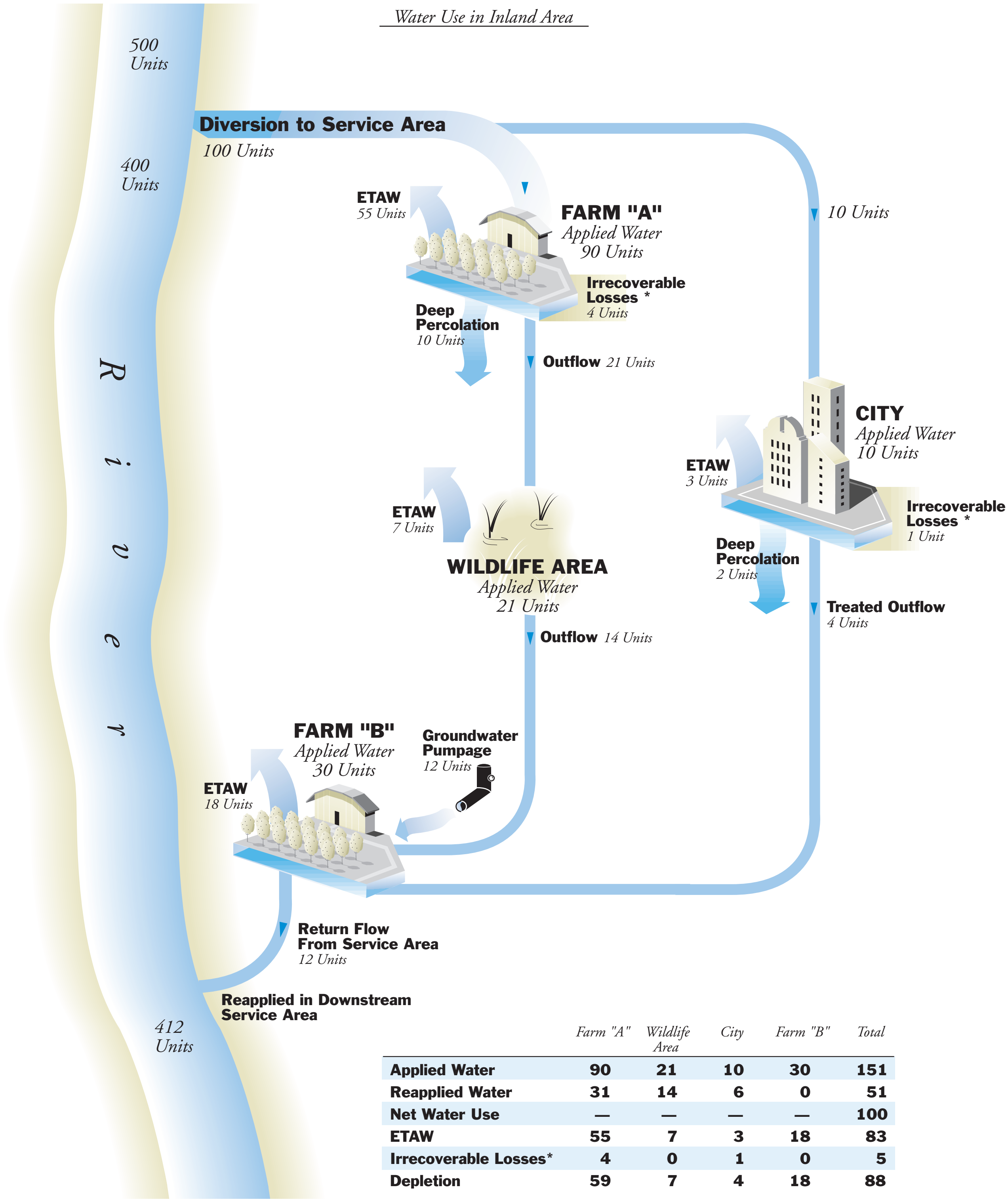
As suggested by Figures 3-8 through 3-10, reapplication can be a significant source of water in many hydrologic regions of California. An applied water budget explicitly accounts for this source. However, because of reapplication, applied water budgets do not translate directly into the supply of water needed to meet future demands. The approach used to compute the new water needed to meet future demands with applied water budgets is presented in Chapter 6.

Normalized Data. Water budget data used to represent the base planning year do not necessarily match the historical conditions observed in 1995.

Over 30 percent of the State's runoff is not explicitly designated for urban, agricultural, or environmental uses. This runoff flows to the Pacific Ocean or to inland drainage sinks.

FIGURE 3-8

Illustration of Applied and Net Water Methodologies: Inland Area



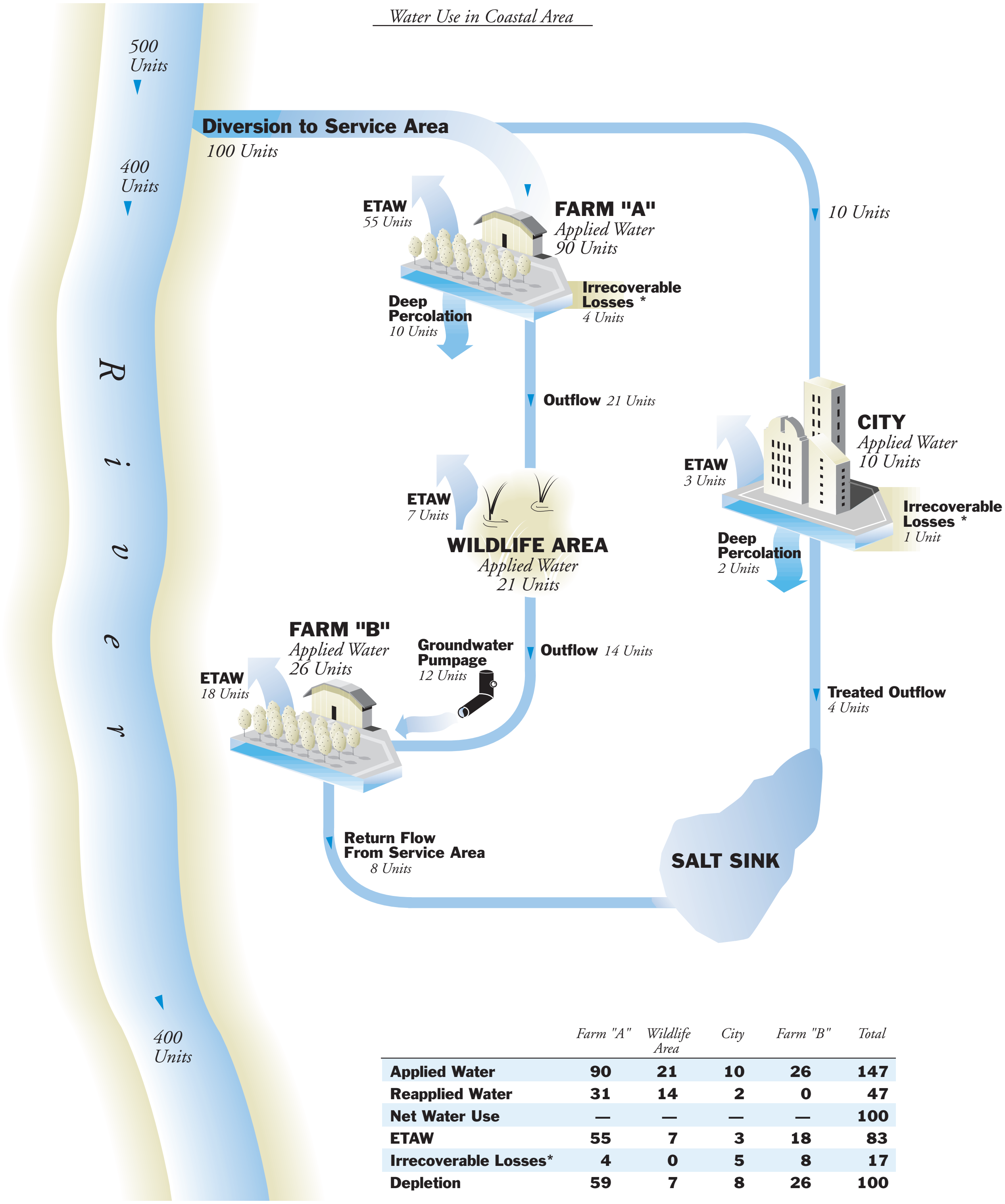
	Farm "A"	Wildlife Area	City	Farm "B"	Total
Applied Water	**90**	**21**	**10**	**30**	**151**
Reapplied Water	**31**	**14**	**6**	**0**	**51**
Net Water Use	**—**	**—**	**—**	**—**	**100**
ETAW	**55**	**7**	**3**	**18**	**83**
Irrecoverable Losses*	**4**	**0**	**1**	**0**	**5**
Depletion	**59**	**7**	**4**	**18**	**88**

ETAW = Evapotranspiration of Applied Water

* *Irrecoverable losses are losses from conveyance facilities due to evaporation, evapotranspiration, or deep percolation to a salt sink.*

FIGURE 3-9

Illustration of Applied and Net Water Methodologies: Coastal Area



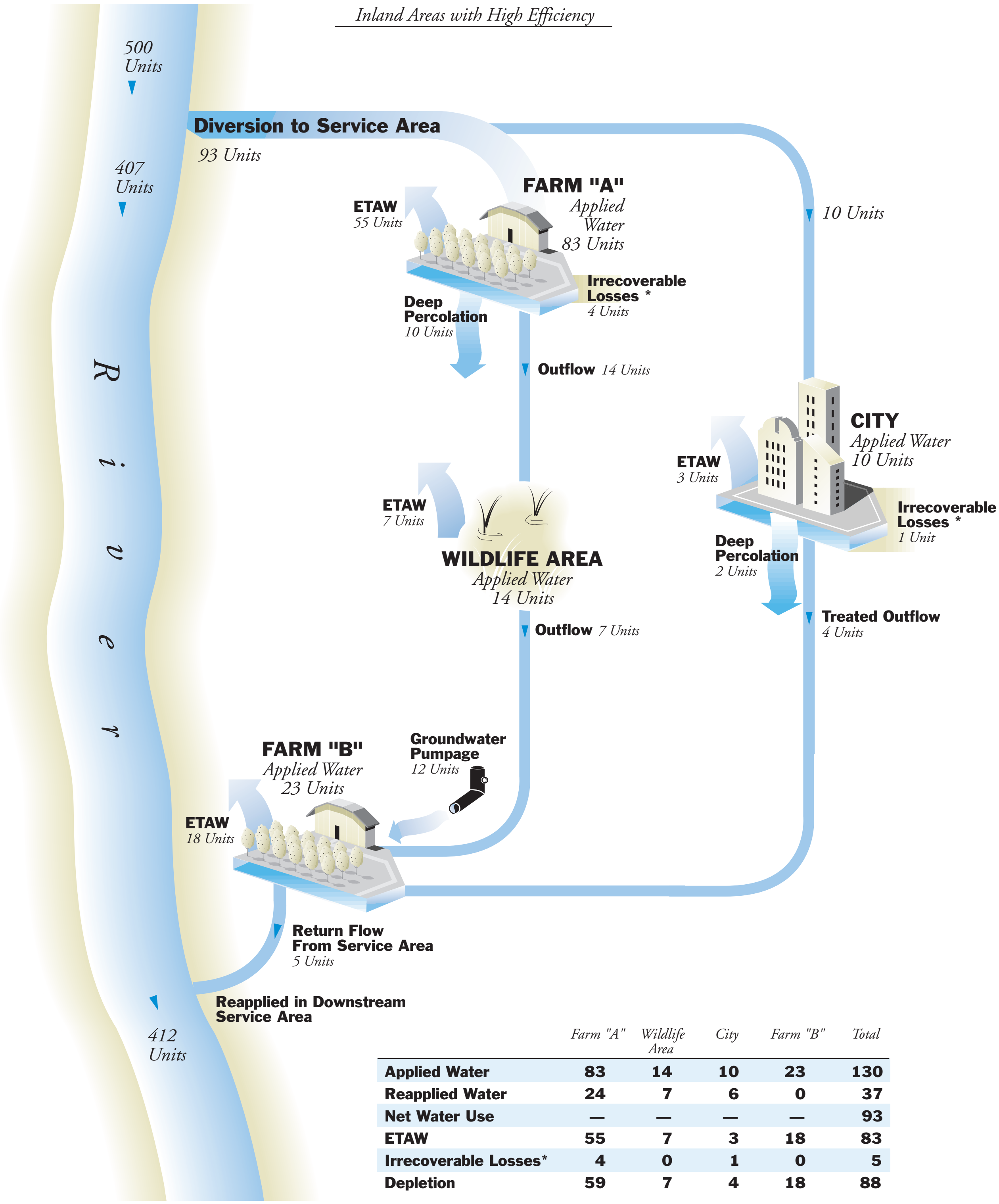
	Farm "A"	Wildlife Area	City	Farm "B"	Total
Applied Water	90	21	10	26	147
Reapplied Water	31	14	2	0	47
Net Water Use	—	—	—	—	100
ETAW	55	7	3	18	83
Irrecoverable Losses*	4	0	5	8	17
Depletion	59	7	8	26	100

ETAW = Evapotranspiration of Applied Water

* *Irrecoverable losses are losses from conveyance facilities due to evaporation, evapotranspiration, or deep percolation to a salt sink.*

FIGURE 3-10

Illustration of Applied and Net Water Methodologies: Inland Area with High Efficiency



	Farm "A"	Wildlife Area	City	Farm "B"	Total
Applied Water	83	14	10	23	130
Reapplied Water	24	7	6	0	37
Net Water Use	—	—	—	—	93
ETAW	55	7	3	18	83
Irrecoverable Losses*	4	0	1	0	5
Depletion	59	7	4	18	88

ETAW = Evapotranspiration of Applied Water

** Irrecoverable losses are losses from conveyance facilities due to evaporation, evapotranspiration, or deep percolation to a salt sink.*

Instead, Bulletin 160-98's base year applied water budget data are developed from "normalized" water supply, land use, and water use data. Through the normalizing process, year-to-year fluctuations caused by weather and market abnormalities are removed from the data. For example, water year 1998 would greatly underestimate average annual water use, as rainfall through May and early June provided the necessary moisture needed to meet crop and landscape water demands. In most years, much of California would require applied water supplies during May and early June.

On the supply side, normalized water project delivery values are computed by averaging historical delivery data. Normalized "average year" project supplies are typically computed from 3 to 5 recent non-deficient water years. Normalized "drought year" project supplies are computed by averaging historical delivery data from 1990 and 1991. A notable exception to the above procedure is the development of normalized CVP and SWP project deliveries. Supplies from these projects are developed from operations studies rather than from historical data (See sidebar). Operations studies provide an average project delivery capability over a multi-year sequence of hydrology under SWRCB's WR 95-6 Bay-Delta standards. The following section on water supply scenarios describes how other water supply data are normalized.

On the demand side, base year urban per capita water use data are normalized to account for factors such as residual effects of the 1987-92 drought. In any given year, urban landscape and agricultural irrigation requirements will vary with precipitation, temperature, and other factors. Base year water use data are normalized to represent ETAW requirements under average and drought year water supply conditions. Land use data are also normalized. The Department collects land use data through periodic surveys; however, the entire State is not surveyed in any given year (such as 1995). To arrive at an estimate of historical statewide land use for a specific year, additional sources of data are consulted to interpolate between surveys. After a statewide historical land use base is constructed, it is evaluated to determine if it was influenced by abnormal weather or crop market conditions and is normalized to remove such influences. (See Chapter 4 for further discussion on the development of Bulletin 160-98 water and land use data.)

Normalizing allows Bulletin 160-98 to define an existing level of development (i.e., the 1995 base year) that is compatible with a forecasted level of development (i.e., the 2020 forecast year). Future year shortage calculations implicitly rely on a comparison between future water use and existing water supply, as water supplies do not change significantly (without implementation of new facilities and programs) over the planning horizon. Therefore, the normalizing procedure is necessary to provide an appropriate future year shortage calculation. Normalizing also permits more than one water supply condition to be evaluated for a given level of development. If historical data were used to define the base year, only one specific hydrologic condition would be represented. (Historical data for 1995 would represent a wet year.) But through normalizing, a base level of development can be evaluated under a range of hydrologic conditions. The following section discusses how Bulletin 160-98 develops average and drought year water supply scenarios for its water budget analysis.

Water Supply Scenarios

California is subject to a wide range of hydrologic conditions and water supply variability. Knowledge of water supplies under a range of hydrologic conditions is necessary to evaluate reliability needs that water managers must meet. Two water supply scenarios–average year conditions and drought year conditions–were selected from among a spectrum of possible water supply conditions to represent variability in the regional and statewide water budgets.

Average Year Scenario. The average year supply scenario represents the average annual supply of a system over a long planning horizon. As discussed in the sidebar, average year supplies from the CVP and SWP are defined by operations studies for a base (1995) level of development and for a future (2020) level of development. Project delivery capabilities are defined over a 73-year hydrologic sequence. For other water supply projects, historical data are normalized to represent average year conditions. For required environmental flows, average year supply is estimated for each of its components. Wild and scenic river flow is calculated from long-term average unimpaired flow data. Instream flow requirements are defined for an average year under specific agreements, water rights, court decisions, and congressional directives. Bay-Delta outflow requirements are estimated from operations studies.

Drought Year Scenario. For many local water agencies, and especially urban agencies, drought year water supply is the critical factor in planning for water

Operations Studies

Computer simulations, also known as operations studies, are performed to estimate the delivery capabilities of the CVP and SWP under average year and drought year conditions. Two widely used computer models for conducting CVP/SWP operations studies are the Department's DWRSIM and USBR's PROSIM. Most Bulletin 160-98 studies were performed with DWRSIM.

DWRSIM is designed to simulate the monthly operation of the CVP and SWP system of reservoirs and conveyance facilities under different hydrologic sequences. These hydrologic sequences are typically based on a 73-year record of historical hydrology from 1922 through 1994. DWRSIM simulates the availability, storage, release, use, and export of water in the Sacramento and San Joaquin River systems, the Delta, and the aqueduct and reservoir systems south of the Delta. The model provides numerical output on parameters such as reservoir storage and releases, Delta inflows, exports, and outflows. The model operates the CVP and SWP system to provide the maximum water withdrawal from the Delta allowed by regulatory constraints, up to the total water demand. Additional system operational objectives (e.g., reservoir carryover storage), physical constraints (e.g., reservoir and pumping plant capacities), and institutional agreements (e.g., Coordinated Operation Agreement) also affect the simulated operation.

In considering the results of a project operations study, it is important to note that conditions in a specific model year do not match those observed in the actual year. Simulated hydrology deviates from historical hydrology because the 73-year sequence is normalized to reflect existing or forecasted future land development and consumptive use conditions. Project deliveries and reservoir operations deviate from historical conditions because they are optimized for a specific level of demand over the entire hydrologic sequence. The results should be interpreted as average project delivery capability over a 73-year sequence of hydrology rather than in water years 1922 through 1994. Project deliveries over this long sequence of hydrology provide an indication of the system's average performance, as well as the performance over a wide range of wet and dry years.

An example of the use of operations studies is provided later in this chapter to describe how operations studies evaluated CVP/SWP delivery impacts associated with the SWRCB's Order WR 95-6 Delta standards.

supply reliability. Traditional drought planning often uses a design drought hydrology to characterize project operations under future conditions. For a planning region with the size and hydrologic complexity of California, selecting an appropriate statewide design drought presents a challenge. The 1990-91 water years were selected to represent the drought year supply scenario for Bulletin 160-98. (The 1990-91 water years were also used to represent the drought year scenario in Bulletin 160-93.)

The 1990-91 drought year scenario has a recurrence interval of about 20 years, or a 5 percent probability of occurring in any given year. This is typical of the drought level used by many local agencies for routine water supply planning. For extreme events such as the 1976-77 drought, many agencies would implement shortage contingency measures such as mandatory rationing. Another important consideration in selecting water years 1990-91 was that, because of their recent occurrence, local agency water demand and supply data were readily available.

The statewide occurrence of dry conditions during the 1990-91 water years was another key consideration in selecting them as a representative drought. Because of the size of California, droughts may or may not occur simultaneously throughout the entire State. Figure 3-11 illustrates the statewide occurrence of dry conditions in water year 1990. The figure also shows that, two years later, dry conditions persisted in Northern California, but not in Southern California.

Defining a representative drought in Southern California is complicated by the region's access to imported supplies from the Colorado River. The Colorado River watershed is large (about 244,000 square miles, or roughly 10 times the size of the Sacramento River watershed) and experiences hydrologic conditions different than California's. As a result, Southern California's water supply may be buffered from the effects of severe drought in Northern California. Figure 3-12 presents Colorado River unimpaired flow at the Lee Ferry interstate compact measurement point to illustrate the river basin's hydrology.

Other Drought-Related Considerations. During low runoff years such as 1990 and 1991, carryover storage in surface water reservoirs is an important source of water supply. At the beginning of an extended dry period, the drought's duration is unknown. Therefore, to manage deficiencies imposed on water users, water may be released from storage based upon a predetermined risk analysis procedure. As the drought continues, the procedure may impose progressively larger deficiencies.

Carryover storage was used to supplement water

FIGURE 3-11

Statewide Distribution of Precipitation for Water Years 1990 and 1992

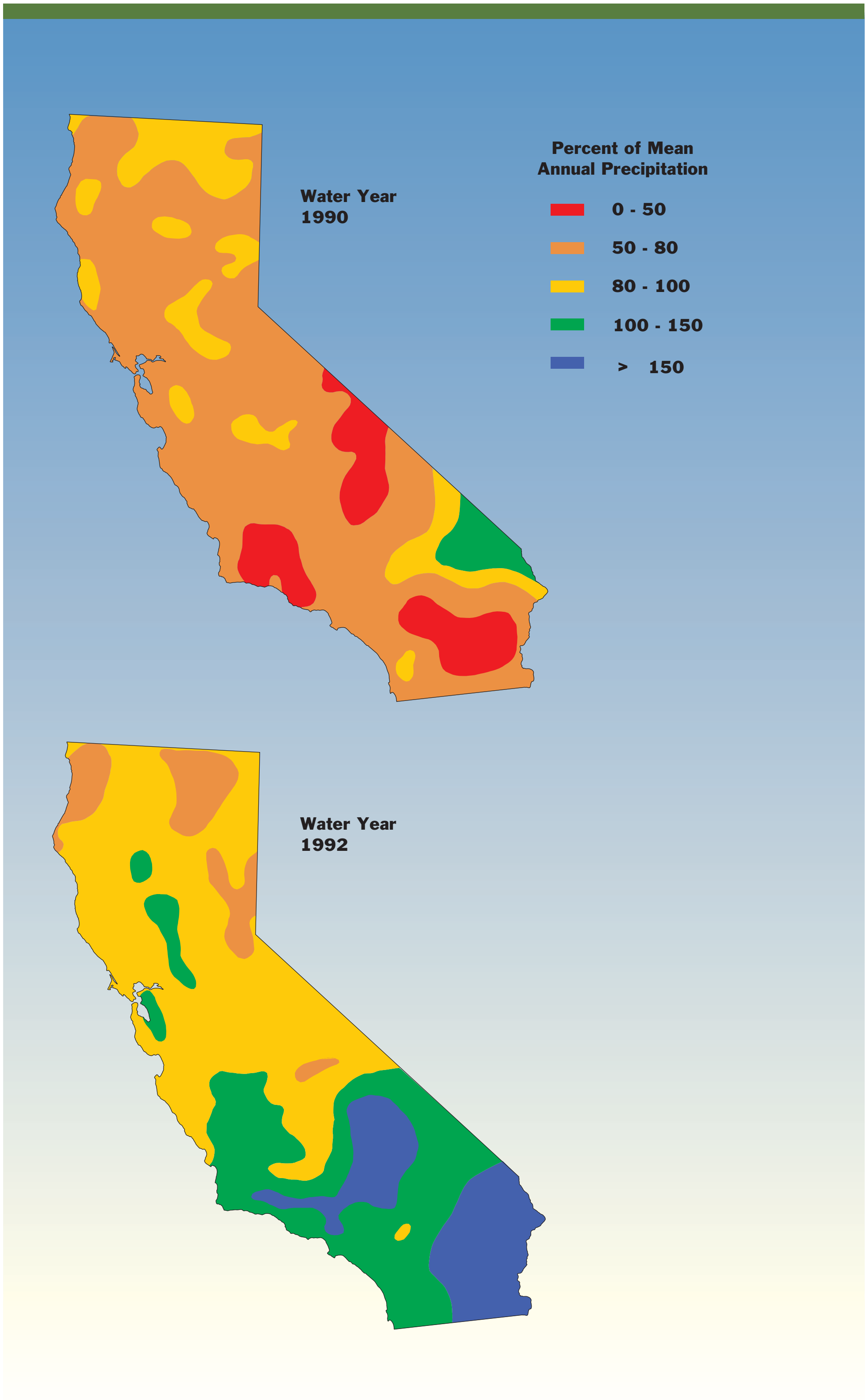
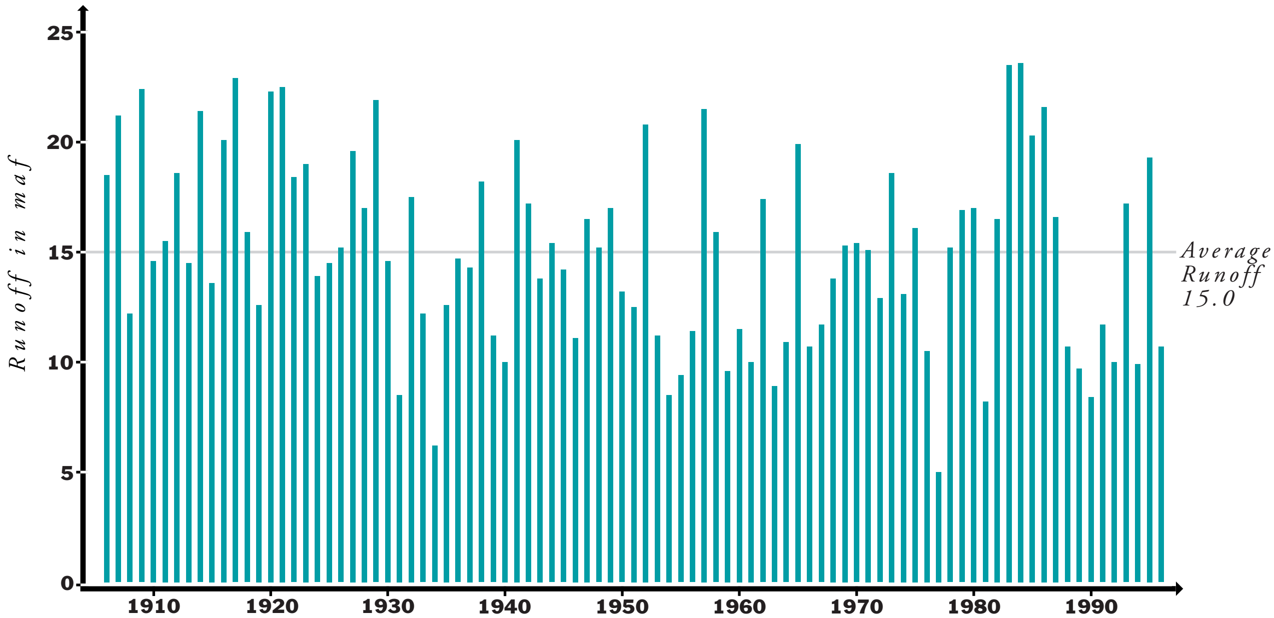


FIGURE 3-12

Colorado River Unimpaired Runoff at Lee Ferry Compact Point



deliveries during the low runoff years of the 1987-92 drought, minimizing the initial impacts of the drought on many water users. To illustrate the use of carryover storage for supplementing water project deliveries, actual CVP and SWP deliveries during the 1987-92 drought are shown in Figure 3-13. (The Bulletin's drought year water supplies from these projects are based on normalized operations studies data, not the actual delivery data shown in Figure 3-13.) Although the drought lasted six years, neither project imposed delivery deficiencies during the first three years of the drought. During the final three years, however, both projects imposed significant deficiencies.

Figure 3-14 shows how Shasta, Oroville, New Melones, and Cachuma Reservoirs were actually operated during the 1987-92 drought. Data for Cachuma

FIGURE 3-13

CVP and SWP Deliveries During 1987-92 Drought

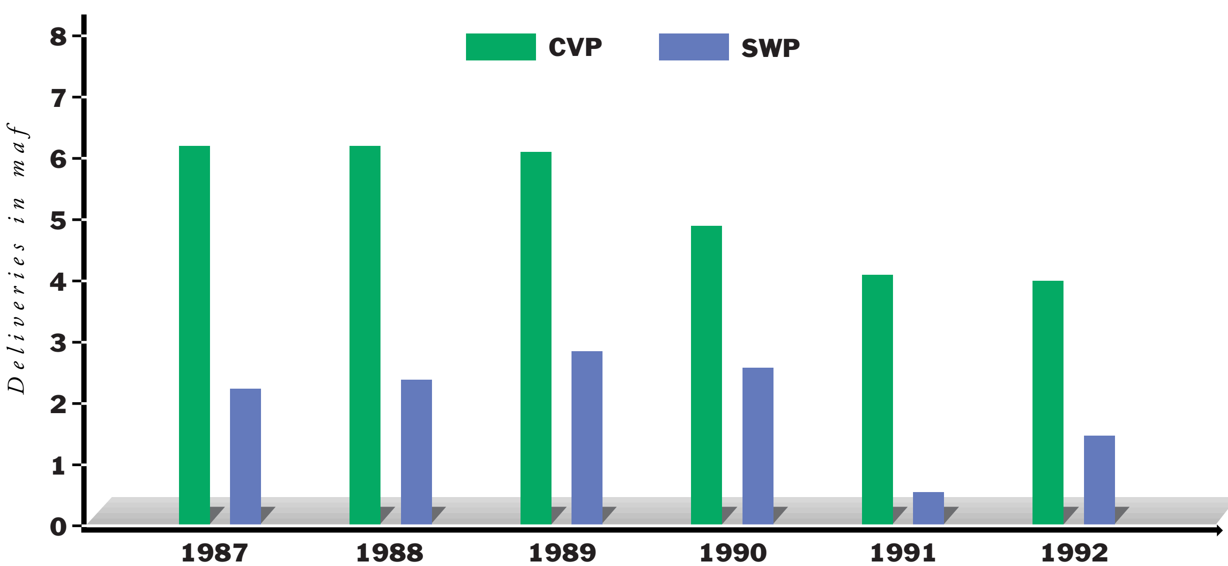
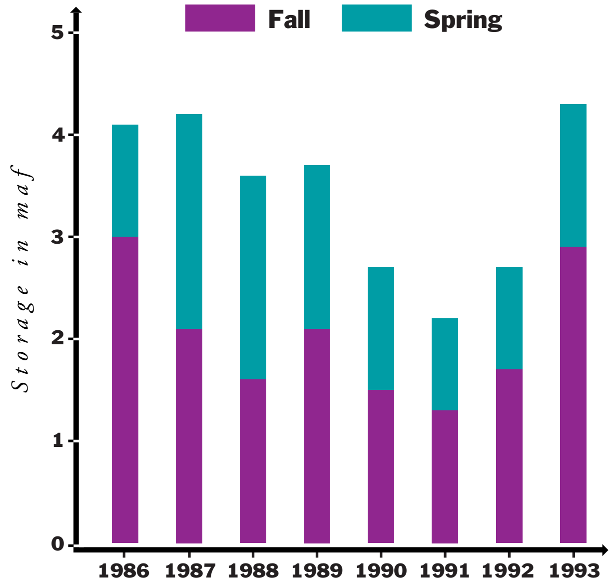


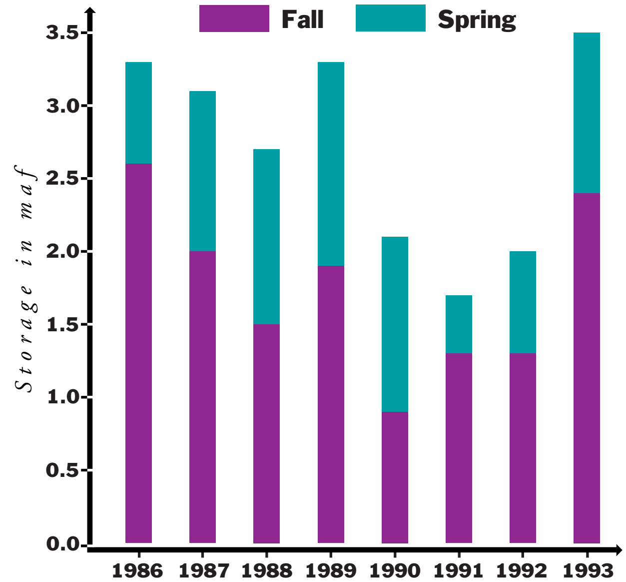
FIGURE 3-14

Selected Reservoir Storage During 1987-92 Drought

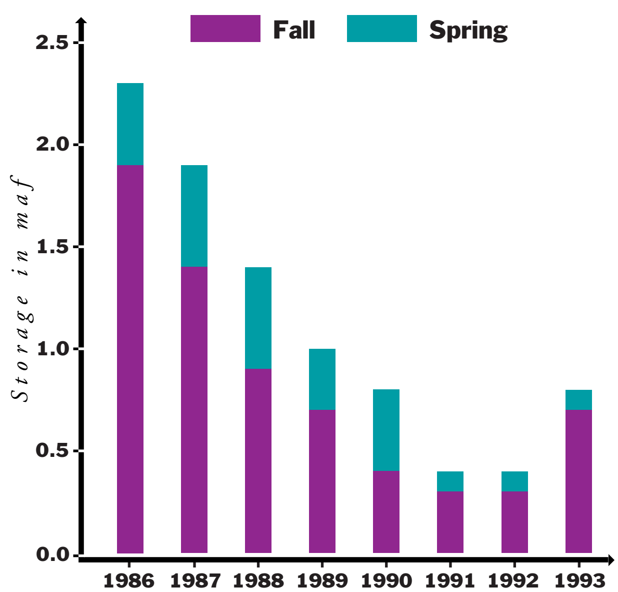
SHASTA



OROVILLE



NEW MELONES



CACHUMA

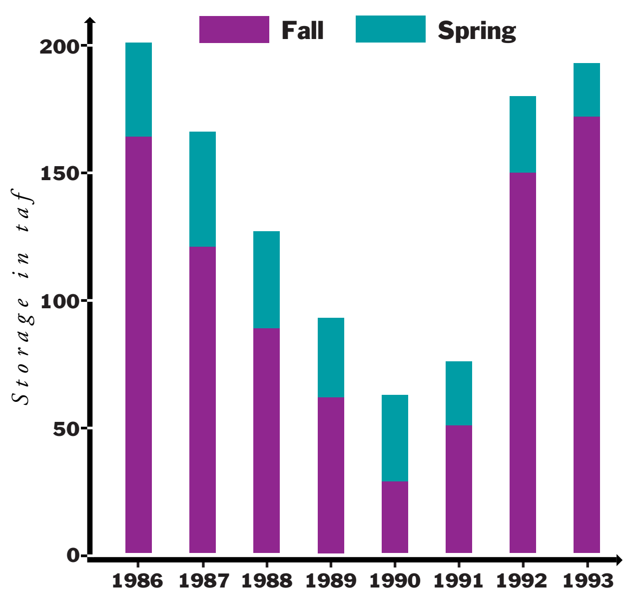


TABLE 3-3
California Water Supplies with Existing Facilities and Programs[a] (taf)

Supply	*1995*		*2020*	
	Average	*Drought*	*Average*	*Drought*
Surface				
CVP	7,004	4,821	7,347	4,889
SWP	3,126	2,060	3,439	2,394
Other Federal Projects	910	694	912	683
Colorado River	5,176	5,227	4,400	4,400
Local	11,054	8,484	11,073	8,739
Required Environmental Flow	31,372	16,643	31,372	16,643
Reapplied	6,441	5,596	6,449	5,575
Groundwater[b]	12,493	15,784	12,678	16,010
Recycled and Desalted	323	333	415	416
Total (rounded)	**77,900**	**59,640**	**78,080**	**59,750**

[a] Bulletin 160-98 presents water supply data as applied water, rather than net water. This distinction is explained in a previous section. Past editions of Bulletin 160 presented water supply data in terms of net supplies.

[b] Excludes groundwater overdraft

are shown to illustrate drought impacts to a Southern California reservoir not hydrologically connected to Central Valley supplies.

California Water Supplies with Existing Facilities and Programs

Table 3-3 shows California's estimated water supply, for average and drought years under 1995 and 2020 levels of development, with existing facilities and programs. Facility operations in the Delta are assumed to be in accordance with SWRCB's Order WR 95-6.

The State's 1995-level average year water supply is about 77.9 maf, including about 31.4 maf of dedicated flows for environmental uses. As previously discussed, this supply is based on an applied water methodology and therefore includes considerable amounts of reapplication within hydrologic regions. Even with a reduction in Colorado River supplies to California's 4.4 maf basic apportionment, annual average statewide supply is projected to increase about 0.2 maf by 2020 without implementation of new water supply options. While the expected increase in average year water supplies is due mainly to higher CVP and SWP deliveries (in response to higher 2020-level demands), new water production will also result from groundwater and recycling facilities currently under construction.

The State's 1995-level drought year water supply is about 59.6 maf, of which about 16.6 maf is dedicated for environmental uses. Annual drought year supply is expected to increase slightly by 2020 without implementation of new water supply options. The expected increase comes from higher CVP and SWP deliveries and new production from surface, groundwater, and recycling facilities currently under construction.

The following section describes the State's major surface water development projects. In response to public comments on Bulletin 160-93, the description of surface water projects was expanded to provide more detail on the larger local agency projects. A discussion on reservoir and river operations follows. The section

O'Neill Forebay with San Luis Reservoir in the background. These are joint facilities of the CVP and SWP.

concludes by addressing surface water supply impacts associated with recent events and the effects of changes in reservoir operations on supplies.

Surface Water Supplies

Surface Water Development Projects

This section describes California's largest surface water development projects, including the CVP, SWP, Colorado River facilities, and Los Angeles Aqueduct. Descriptions of smaller surface water development projects are provided in Chapters 7-9. See Chapter 1 for a location map of these larger facilities.

Central Valley Project. In 1921, California began planning a water project to serve the Central Valley. The Legislature authorized the State Central Valley Project in 1933. Because California was unable to sell the bonds needed to finance the project during the

Auburn Dam—Planned, But Not Constructed

Auburn Dam was authorized as a CVP facility by Congress in 1965 to provide greater flood control and water supply on the American River. Foundation preparation and related earthwork for a dam to impound 2.3 maf were halted by seismic safety concerns after a 1975 Oroville earthquake. The dam's design was changed in 1980 from a concrete arch to a gravity structure. The proposed dam has been a source of controversy between proponents of downstream flood control and water supply benefits and those who wish to preserve the American River Canyon. As originally planned, a multipurpose Auburn Reservoir could have provided more than 300 taf/yr of new water supply to the CVP, as well as substantial flood control and power benefits. Recent reviews of American River hydrology have emphasized the flood control potential of a dam at Auburn.

Much of the Sacramento metropolitan area is threatened by flooding from the American and Sacramento Rivers. The 100-year floodplain covers over 100,000 acres and contains over 400,000 residents, 160,000 homes and structures, and over $37 billion in developed property. When Folsom Dam was completed in 1955, the facility was estimated to provide Sacramento with 250-year level of flood protection. This estimate was revised downward to a 60-year level of protection (77-year level with Folsom reoperation for additional flood control space) after the storms of 1986 and 1997.

Given the area's low level of flood protection (one of the lowest in the nation for a metropolitan area of its size), USACE has evaluated many alternatives to providing additional flood protection. Three recent alternatives include the Folsom modification plan, the Folsom stepped release plan, and the detention dam plan. The Folsom modification plan would increase maximum flood storage in Folsom from 400 taf to 720 taf, lower the main spillway by 15 feet, enlarge 8 river outlets, and make levee improvements along the American and Sacramento Rivers. The Folsom stepped release plan would increase Folsom's flood storage to 670 taf, lower the main spillway by 15 feet, enlarge 8 river outlets, and make levee improvements to increase maximum reservoir releases to 180,000 cfs. The detention dam plan would construct a 508-foot-high flood detention facility on the North Fork of the American River near Auburn, make levee improvements along the American and Sacramento Rivers, and return the maximum flood storage in Folsom Reservoir to 400 taf.

USACE completed an EIR/EIS in 1992 and a supplemental EIR/EIS in March 1996, addressing flood control alternatives for the Sacramento area. Both identified the detention dam as the national economic development plan, i.e., the plan that would maximize net national economic benefit. In 1995, the Reclamation Board voted for a preferred plan from among the three alternatives and endorsed the detention dam plan. The Sacramento Area Flood Control Agency also voted for the detention dam as the locally preferred plan.

In its Resolution No. 95-17, the Reclamation Board stated that it " . . . believes the Folsom Modification Plan provides an inadequate level of flood protection for the Sacramento area, and would reduce water-supply capacity and hydropower benefits at Folsom Reservoir . . ." and that " . . .the Board believes the Stepped Release Plan would place undue reliance on the levees of the lower American River, would reduce water supply capacity and hydropower benefits at Folsom Reservoir, and . . . would be significantly more expensive for State and local interests . . . ." Regarding the detention dam plan, the resolution states " . . . the Board believes that the Detention Dam Plan . . . represents the NED Plan for the American River flood plain. The Board recommends that the Corps pursue Congressional authorization of this plan." In spite of support from USACE, the Reclamation Board and SAFCA, the detention dam was not authorized in the Water Resources Development Act of 1996.

In 1998, the Reclamation Board reaffirmed its support for an Auburn Dam, stating in Resolution No. 98-04 that "the best long-term engineering solution to reliably provide greater than 1-in-200 year flood protection is to develop additional flood detention storage at Auburn which, with a capacity of 894,000 acre-feet would provide a 1-in-400 year level of protection".

As Bulletin 160-98 is being written, competing proposals for American River flood control measures are being heard by congressional authorizing committees.

TABLE 3-4

Major Central Valley Project Reservoirs

Reservoir	*Capacity (taf)*	*Year Completed*	*Stream*
Shasta	4,552	1945	Sacramento River
Trinity	2,448	1962	Trinity River
New Melones	2,420	1979	Stanislaus River
Folsom	977	1956	American River
San Luis (Federal Share)	966	1967	Offstream
Millerton	520	1947	San Joaquin River
Whiskeytown	241	1963	Clear Creek

Great Depression, USBR stepped in to begin project construction. Initial congressional authorization for the CVP covered facilities such as Shasta and Friant Dams, Tracy Pumping Plant, and the Contra Costa, Delta-Mendota, and Friant-Kern Canals. Later authorizations included Folsom Dam (1949), Trinity River Division (1955), Sacramento Valley Canals (1959), San Luis Unit (1960), New Melones Dam (1962), Auburn Dam (1965), and the San Felipe Division (1967).

The USBR's CVP is the largest water storage and delivery system in California, covering 29 of the State's 58 counties. The project's features include 18 federal reservoirs and 4 additional reservoirs jointly owned with the SWP. The keystone of the CVP is the 4.55 maf Lake Shasta, the largest reservoir in California. CVP reservoirs provide a total storage capacity of over 12 maf, nearly 30 percent of the total surface storage in California, and deliver about 7 maf annually for agricultural (6.2 maf), urban (0.5 maf), and wildlife refuge use (0.3 maf). Table 3-4 shows major CVP reservoirs.

Shasta and Keswick Reservoirs regulate CVP releases into the Sacramento River. Red Bluff Diversion Dam on the Sacramento River diverts water to the Tehama-Colusa and Corning Canals. At the Delta, CVP water is exported at Rock Slough into the Contra Costa Canal and at Tracy Pumping Plant on Old River to the Delta-Mendota Canal. During the winter, water is conveyed via the Delta-Mendota Canal to San Luis

Floodflows on the American River in 1986 breached the cofferdam that USBR had constructed when it began its initial work at the Auburn damsite. This flood event produced record flows in the American River through metropolitan Sacramento.

FIGURE 3-15

Major Central Valley Project Facilities

Reservoir for later delivery to the San Luis and San Felipe Units of the project. A portion of the Delta-Mendota Canal export is placed back into the San Joaquin River at Mendota Pool to serve, by exchange, water users with long-standing historical rights to the use of San Joaquin River flow. This exchange enabled the CVP to build Friant Dam (Millerton Lake), northeast of Fresno, which diverts a major portion of San Joaquin River flows through the Friant-Kern and Madera Canals. Figure 3-15 is a map of CVP facilities.

The CVP supplies water to more than 250 long-term water contractors in the service areas shown in Figure 3-16. The majority of CVP water goes to agricultural water users. Large urban centers receiving CVP water include Redding, Sacramento, Folsom, Tracy, most of Santa Clara County, northeastern Contra Costa County, and Fresno. Collectively, the contracts call for a maximum annual delivery of 9.3 maf, including delivery of 1.7 maf of Friant Division supply when available in wet years. Of the 9.3 maf total annual contractual delivery, 4.8 maf is classified as project water and 4.5 maf is classified as water right settlement (also called base supply or prior rights) water. About 90 percent of south-of-Delta contractual delivery is for agricultural and urban uses; the remaining 10 percent is for wildlife refuges. Figure 3-17 shows actual CVP water deliveries since 1960. (The Bulletin's CVP supplies are based on normalized data, not the actual delivery data shown in Figure 3-17.)

Water right settlement water is water covered in agreements with water rights holders whose diversions existed before the project was constructed. Project reservoirs altered natural river flow upon which these pre-project diverters had relied, so contracts were negotiated to agree on the quantities of diversions that could be made without any payment to the United States. CVP base supply and settlement contractors on the upper Sacramento River receive their supply (about 2.3 maf/yr) from natural flow and storage regulated at Shasta Dam. Settlement contractors on the San Joaquin River (called exchange contractors) receive Delta water from Northern California which is diverted at Tracy Pumping Plant, stored in San Luis Reservoir and/or pumped directly via the Delta-Mendota Canal.

Courtesy of USBR

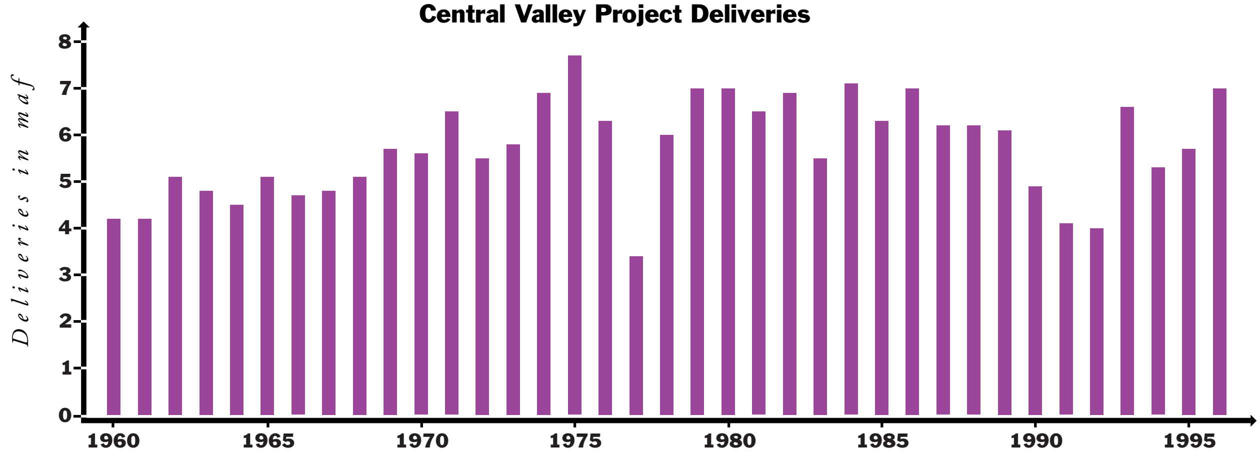
Friant Dam, a 319-foot high concrete gravity dam, controls runoff from about 1,630 square miles of the San Joaquin River's drainage basin. The Friant-Kern Canal is in the foreground.

FIGURE 3-16

Central Valley Project Service Areas

FIGURE 3-17

Central Valley Project Deliveries



The capability of the CVP to meet full water supply requests by its south-of-Delta contractors in a given year depends on rainfall, snowpack, runoff, carryover storage, pumping capacity from the Delta, and regulatory constraints on CVP operation. Figure 3-18 shows existing (1995 level) and future (2020 level) CVP south-of-Delta delivery capability, as estimated by operations studies, under SWRCB Order WR 95-6. The figure shows that existing CVP facilities have a 20 percent chance of making full deliveries under both demand levels.

State Water Project. It was evident soon after World War II that local and federal water development could not keep pace with California's rapidly growing population. Planning for the multipurpose SWP began in the late 1940s, and accelerated in the early 1950s. Voters authorized SWP construction in 1960 by ratifying the Burns-Porter Act. The majority of existing project facilities were constructed in the 1960s and 1970s. Future SWP facilities were to be added as water demands increased, to meet the project's initial contractual entitlement of 4.2 maf/yr.

SWP facilities include 20 dams, 662 miles of aqueduct, and 26 power and pumping plants. SWP reservoirs are listed in Table 3-5. Major facilities include the multipurpose Oroville Dam and Reservoir on the Feather River, the Edmund G. Brown California

FIGURE 3-18

1995 and 2020 Level Central Valley Project Delivery Capability South of Delta with Existing Facilities

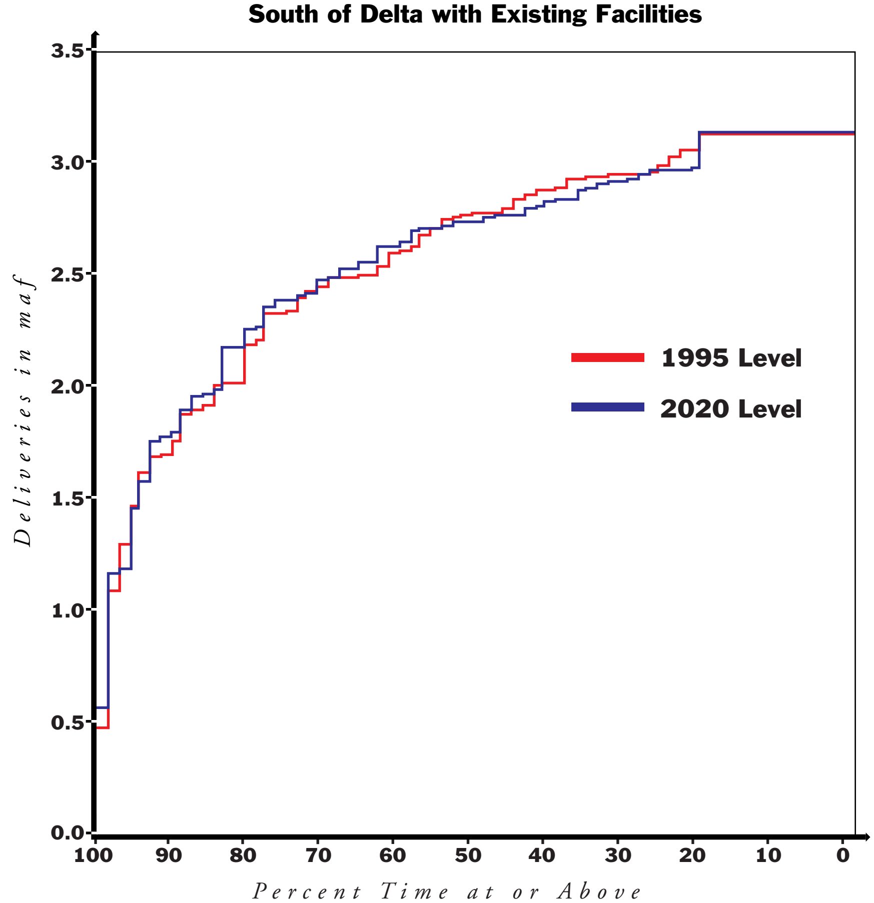


TABLE 3-5
Major State Water Project Reservoirs

Reservoir	*Capacity (taf)*	*Year Completed*	*Stream*
Oroville	3,538	1968	Feather River
San Luis (State share)	1,062	1967	Offstream
Castaic	324	1973	Offstream
Pyramid	171	1973	Offstream
Perris	131	1973	Offstream
Davis	84	1966	Big Grizzly Creek
Del Valle	77	1968	Arroyo Valle Creek
Silverwood	75	1971	Offstream
Frenchman	55	1961	Last Chance Creek
Antelope	23	1964	Indian Creek

Aqueduct, South Bay Aqueduct, North Bay Aqueduct, and a share of the State-federal San Luis Reservoir. With a storage capacity of 3.5 maf, Lake Oroville is the second largest reservoir in California after Lake Shasta. Lake Oroville stores winter and spring flows of the upper Feather River. Water released from Lake Oroville travels down the Feather and Sacramento Rivers to the Delta. There, some of the water flows to the ocean to meet mandated Delta water quality criteria, and some of the water is delivered through project facilities to the Bay Area, Central Coast, San Joaquin Valley and Southern California.

Water is diverted from the California Aqueduct into the South Bay Aqueduct, which extends into Santa Clara County. A separate Delta diversion supplies the North Bay Aqueduct, which serves areas in Napa and Solano Counties. Maximum capacity of the California Aqueduct is 10,300 cfs at the Delta and 4,480 cfs over the Tehachapis to the South Coast Region. The Department has just completed construction of the extension of the Coastal Branch of the California Aqueduct, which extends about 115 miles from the main aqueduct to serve parts of San Luis Obispo and Santa Barbara Counties. Figure 3-19 is a map of major SWP facilities.

The service area of the 29 SWP contracting agencies is shown in Figure 3-20. Initial project contracts were signed for an eventual annual delivery of 4.2 maf. Of this annual entitlement, about 2.5 maf was to serve Southern California and about 1.3 maf was to serve

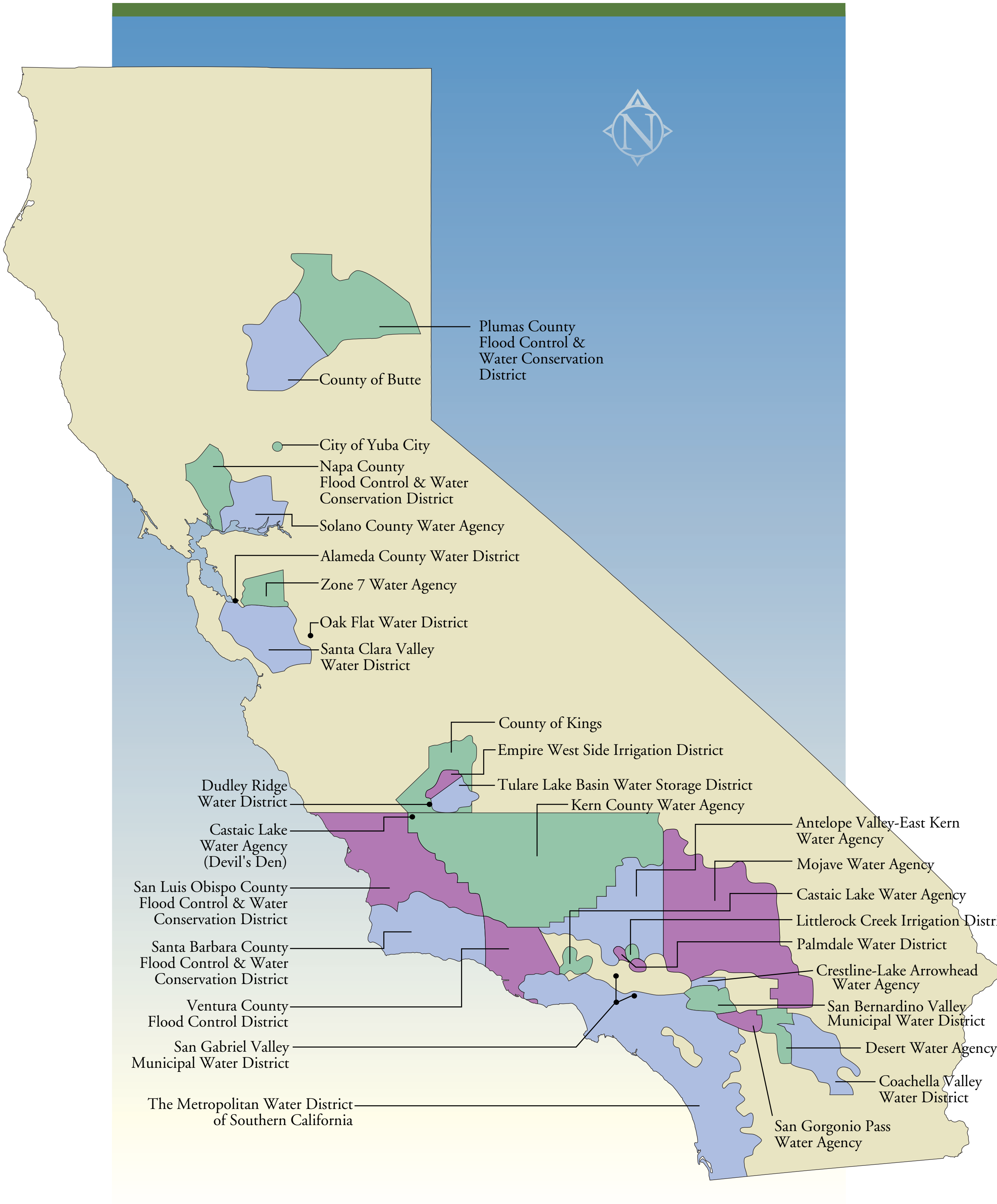
The Department's expansion of the Coastal Branch included construction of new pumping plants, such as the Bluestone Pumping Plant.

FIGURE 3-19

Major State Water Project Facilities

FIGURE 3-20

State Water Project Service Areas



the San Joaquin Valley. The remaining 0.4 maf annual entitlement was to serve the Feather River area and the San Francisco Bay and Central Coast regions. (As discussed in Chapter 2, 45 taf of annual entitlement belonging to two project contractors in the San Joaquin Valley was subsequently retired as part of the Monterey Agreement.) Figure 3-21 shows actual SWP water deliveries since the beginning of entitlement deliveries in 1967. (The Bulletin's SWP supplies are based on normalized data, not the actual delivery data shown in Figure 3-21.) Except during very wet years and during drought years, San Joaquin Valley use of SWP supply has been near full contract amounts since about 1980. Southern California use of SWP supply has reached about 60 percent of full entitlement.

The ability of the SWP to deliver full water supply requests by its contractors in a given year depends on rainfall, snowpack, runoff, carryover storage, pumping capacity from the Delta, and regulatory constraints on SWP operation. The calculated average annual delivery during a repeat of the 1929-34 drought is about 2.1 maf. About half of this water would come from Lake Oroville and the rest from surplus flow in the Delta, some of which is stored in San Luis Reservoir. Figure 3-22 shows existing (1995 level) and future (2020 level) SWP delivery capability, as estimated by operations studies, under SWRCB Order WR 95-6. The figure shows that existing SWP facilities have a 65 percent chance of making full deliveries under 1995 level demands and have an 85 percent chance of delivering 2.0 maf to project contractors in any given year. The figure also shows that under a 2020 level demand scenario, existing SWP facilities have less than a 25 percent chance of making full deliveries.

FIGURE 3-21

State Water Project Deliveries

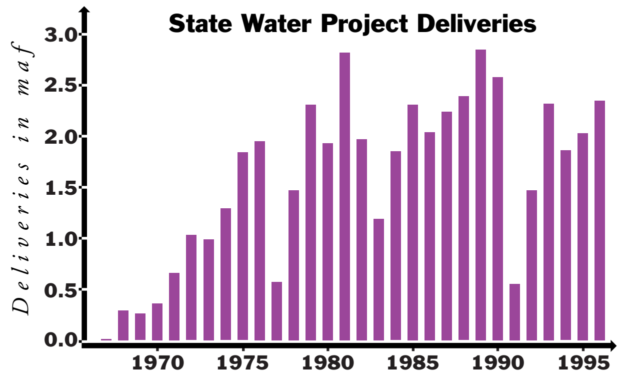
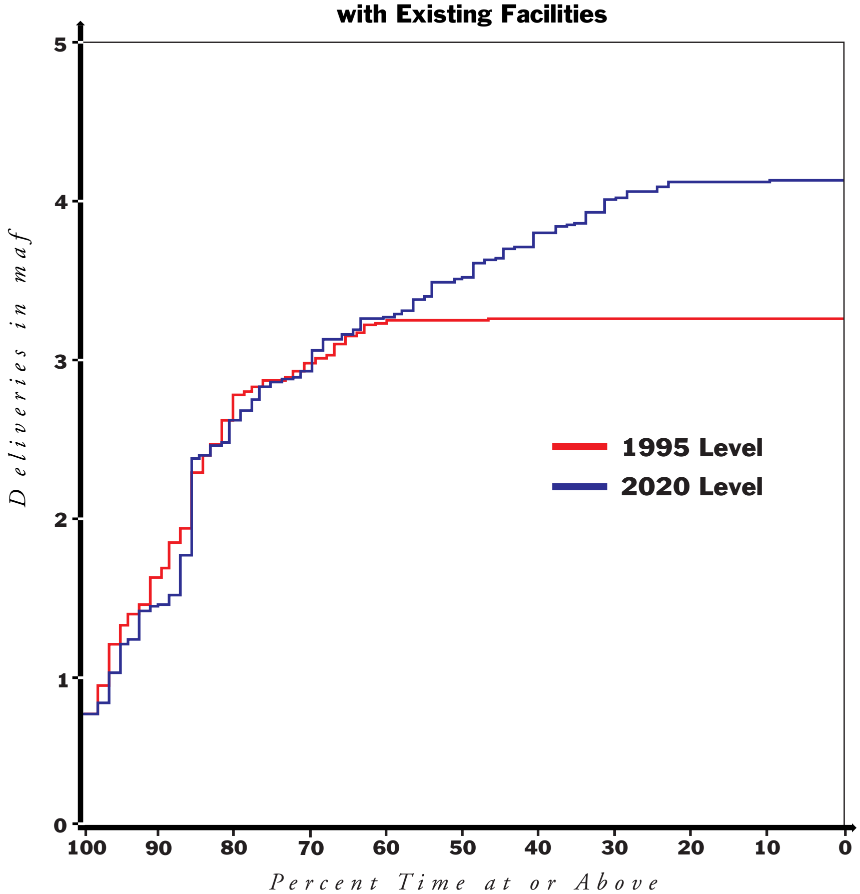


FIGURE 3-22

1995 and 2020 State Water Project Delivery Capability with Existing Facilities



Colorado River. The Colorado River is an interstate and international river. Its mean annual unimpaired flow is about 15 maf. The river, which has is headwaters in Wyoming's Green River Basin, crosses through parts of seven states before flowing into Mexico and terminating at the Gulf of California. The Colorado River watershed is depicted in Figure 3-23.

Nearly 60 maf of surface water storage has been developed on the river and its tributaries, resulting in a ratio of storage to average annual river flow of about 4 to 1—comparable to the ratio found on Putah Creek at Lake Berryessa—but much higher than the ratio found on

FIGURE 3-23

Colorado River Watershed in United States

most of California's rivers. The two largest reservoirs are the 24 maf Lake Powell (impounded by Glen Canyon Dam) and the 26 maf Lake Mead (impounded by Hoover Dam). Three major structures divert water from the Colorado River to California. Parker Dam impounds Lake Havasu, which supplies water for MWDSC's Colorado River Aqueduct on the California side of the stateline and for the Central Arizona Project on the Arizona side of the stateline. Palo Verde Diversion Dam supplies water to Palo Verde Irrigation District's canal system. Imperial Dam diverts water to the All American Canal (and to California users of USBR's Yuma Project) on the California side of the stateline and to Arizona Yuma Project users on the Arizona side of the stateline. An off-stream storage reservoir, Senator Wash Reservoir, is used to adjust releases from Parker Dam and to meet downstream demands. The Colorado River service area is shown in Figure 3-24.

Three major facilities—USBR's All American Canal, MWDSC's Colorado River Aqueduct, and Palo Verde Irrigation District's main canal—convey water from the Colorado River to California users. Construction of the All American Canal was authorized in the

The 82-mile All American Canal transports water from Imperial Dam on the Colorado River to Imperial Irrigation District's service area. In an outstanding engineering feat, the canal system and district distribution system operate entirely on gravity flow.

FIGURE 3-24

Colorado River Service Areas

Colorado River Reservoir Operations

Operation of lower Colorado River reservoirs is controlled by USBR, which serves as the watermaster for the river. USBR is responsible for maintaining an accounting of consumptive use of the basin states' allocations, and for ensuring that Mexican treaty requirements are met with respect to the quantity of flows and salinity concentration of water delivered to Mexico.

The 1968 Colorado River Basin Project Act directed DOI to develop criteria for long-range operation of the major federal reservoirs on the river and its tributaries. USBR conducts a formal review of the long-range operating criteria every five years. The act further requires DOI to prepare an annual operating plan for the river, in consultation with representatives from the basin states. Some river operating criteria have already been established in the statutes comprising the law of the river (see Chapter 9 for more detail). For example, USBR is required to equalize, to the extent practicable, storage in Lake Mead and Lake Powell. (Lake Powell in essence serves as the bank account that guarantees annual delivery of 7.5 maf from the Upper Basin to the Lower Basin, plus water to satisfy Mexican treaty obligations. The actual statutory guarantee is 75 maf every 10 years, plus one-half of the Mexican treaty water requirements.)

Current federal operating criteria for the reservoirs have focused on balancing the conservation of water and avoiding downstream flood damage. As consumptive use of water in the Lower Basin has reached the annual 7.5 maf basic apportionment, there has been increasing interest in operating the river more efficiently from a water supply standpoint. Proposals discussed among Colorado River water users have included a variety of surplus and shortage operating criteria, banking programs, and augmentation of the river's base flow. In order to be implemented, any changes in operating criteria formally recommended by the Colorado River Board would have to be acceptable to the other basin states and to the federal government.

Based on the amount of water in the reservoir system, USBR declared a surplus condition on the river in 1996, 1997, and 1998, allowing California to continue diverting more than its basic apportionment. In 1997 and 1998, flood control releases were made from Lake Mead.

1928 Boulder Canyon Project Act. Work on the canal began in the 1930s, with water deliveries beginning in 1940. Colorado River water diverted at Imperial Dam flows by gravity through the All American Canal and the Coachella Canal to the Imperial and Coachella Valleys. The All American Canal has a maximum capacity of 15,200 cfs in the reach immediately downstream from Imperial Dam. The main branch of the All American Canal extends 82 miles from Imperial Dam to the western portion of Imperial Irrigation District's distribution system. The Coachella Canal branches off from the main canal and extends 121 miles northward, to terminate in Coachella Valley Water District's Lake Cahuilla.

In 1933, MWDSC started constructing its Colorado River Aqueduct to divert Colorado River water from Lake Havasu to the South Coast Region. Completed in 1941, the 242-mile long aqueduct had a design capacity of 1.2 maf/yr, although MWDSC has been able to deliver as much as 1.3 maf/yr. Facilities associated with the aqueduct include five major pumping plants and Lake Mathews, the aqueduct's terminal reservoir in Riverside County. The San Diego Aqueduct, constructed by the federal government, interconnects with the Colorado River Aqueduct in Riverside County. Delivery of Colorado River Aqueduct water to San Diego County began in 1947. Colorado River operations are described in the sidebar.

California's basic apportionment of Colorado River supplies is a consumptive use of 4.4 maf/yr, plus half of any excess or surplus water. Apportionment of Colorado River supplies is discussed in detail in Chapter 9. California has been able to use as much as 5.4 maf of Colorado River supplies annually because neither the Upper Basin states nor Arizona and Nevada were using their full apportionments, and because of wet hydrologic conditions.

Klamath Project. The USBR's Klamath Project straddles the California-Oregon stateline near Klamath Falls, Oregon, and provides water supplies to users in both states. The project, authorized in 1905 by the Reclamation Act of 1902, transfers water between the Lost River (which naturally flowed into Tule Lake and occasionally into the Klamath River) and the Klamath River. Project works were constructed to drain and reclaim lakebed lands of Lower Klamath and Tule Lakes and to provide irrigation supplies to lands within the project area totaling about 230,000 acres. Major storage facilities of the Klamath Project are given in Table 3-6.

The Klamath Project includes 185 miles of main canal, 532 miles of laterals, 37 pumping plants, and 728 miles of drains. Project agricultural water use has historically averaged about 400 taf/yr. The project also serves water to adjacent national wildlife refuges.

Other Federal Projects. In addition to the CVP,

TABLE 3-6

Major Reservoirs of USBR's Klamath Project

Reservoir	*Capacity (taf)*	*Year Completed*	*Stream*
Upper Klamath	873	1921	Klamath River
Clear	527	1910	Lost River
Gerber	94	1925	Miller Creek

Colorado River facilities, and the Klamath Project, USBR has constructed several other reclamation projects in California (Table 3-7). These reclamation projects and other facilities constructed by USACE provide important flood control and recreation benefits.

Los Angeles Aqueduct. In 1913, the City of Los Angeles began importing water from the Owens Valley through the first pipeline of the Los Angeles Aqueduct. The original aqueduct reach was 233 miles long, had 142 tunnels, and crossed 9 major canyons to deliver water to Los Angeles using only gravity. In 1940, the aqueduct was extended north to tap Mono Basin water at Lee Vining Creek, increasing its length to 338 miles. The extension included an 11-mile tunnel drilled through the Mono Craters.

To keep pace with the city's growing population, a second pipeline of the LAA was completed in 1970 to import additional water from the southern Owens Valley at Haiwee Reservoir. The second pipeline increased the aqueduct's annual delivery capacity from 330 taf to 550 taf. In dry years, the aqueduct was to be maintained at full capacity through groundwater pumping in the Owens Valley. Pumped groundwater is also used to meet in-valley uses. In addition to the two aqueduct pipelines, the system includes eight reservoirs and eleven powerplants. The largest reservoirs are shown in Table 3-8.

The delivery capability of LADWP's aqueduct system has been affected by judicial and regulatory actions intended to restore environmental resources in the Mono Lake Basin and in the Owens River Valley. In 1979, the National Audubon Society, the Mono Lake Committee, and others filed the first in a series of lawsuits which challenged the project's water diversions from the Mono Basin. In 1989 and 1990, the El Dorado County Superior Court entered preliminary injunctions which required the project to reduce diversions to restore and maintain the water level of Mono Lake at 6,377 feet. The injunctions also established minimum fishery flows in all four Mono Basin streams from which project diversions are made.

In 1994, SWRCB's Decision 1631 specified minimum fishery flows on the four Mono Basin streams. The order also established water diversion criteria to protect wildlife and other environmental resources in the Mono Basin. The water diversion criteria prohibited export of water from the Mono Basin until the water level of Mono Lake reached 6,377 feet, and restricted Basin exports until the water level of Mono Lake rose to an elevation of 6,391 feet (estimated to take approximately 20 years). Once the water level of 6,391 feet is reached, the

TABLE 3-7

Other USBR Projects in California[a]

Reservoir	*Project*	*Capacity (taf)*	*Year Completed*	*Stream*
Berryessa	Solano	1,600	1957	Putah Creek
Tahoe[b,c]	Newlands	745	1913	Truckee River
Casitas	Ventura River	254	1959	Ventura River
Twitchell	Santa Maria	240	1958	Cuyama River
Stampede[b]	Washoe	227	1970	Little Truckee River
Cachuma	Cachuma	190	1953	Santa Ynez River
East Park	Orland	51	1910	Stony Creek
Stony Gorge	Orland	50	1928	Stony Creek
Boca[b]	Truckee Storage	41	1937	Little Truckee River
Prosser Creek[b]	Washoe	30	1962	Prosser Creek

[a] Does not include CVP or Colorado River projects.

[b] Lands served by this reservoir are located in Nevada.

[c] USBR controls the dam under easement from Sierra Pacific Power Company.

LAA will be able to export approximately 31 taf/yr from the Mono Basin.

Longstanding litigation between Inyo County and the City of Los Angeles over environmental effects of Owens Valley groundwater pumping ended in June 1997, allowing implementation of water management and environmental mitigation actions. (See Chapter 9 for additional details.) A key environmental restoration effort is rewatering the lower Owens River in a 60-mile stretch from the aqueduct intake south of Big Pine to just north of Owens Dry Lake. The effort calls for providing continuous river flows of about 40 cfs (with seasonal habitat flows up to about 200 cfs), establishing 1,825 acres of wetlands, and establishing and maintaining off-river lakes and ponds. (Most of the instream flows will be pumped back out of the river and into the LAA from a point just north of Owens Dry Lake. Between 6 and 9 cfs will be allowed to flow past the pumpback station to sustain a 325 acre wetland in the Owens Lake delta.) Providing the base flow of 40 cfs and river channel restoration must begin no later than 2003.

As discussed in Chapter 9, the Great Basin Unified Air Pollution Control District issued an order to LADWP in July 1997 requiring 50 taf of water per year to control dust from the Owens Dry Lake. Two potential sources of water identified by the GBUAPCD include aquifers under the lakebed and the Los Angeles Aqueduct. As described in Chapter 9, LADWP and GBUAPCD have developed a draft agreement for dust control measures.

As Mono Lake's level rises as a result of SWRCB's Decision 1631, some of the lakeshore tufa formations will be submerged.

Tuolumne River Development. The Tuolumne River, which begins at Lyell Glacier in Yosemite National Park and extends 163 miles to its confluence with the San Joaquin River west of Modesto, is the largest of the San Joaquin River tributaries. It produces an average annual runoff of about 1.9 maf of which 1.2 maf comes from snowmelt between April and July. Total reservoir capacity on the river is 2.8 maf, almost 1.5 times its average annual runoff. Of this total, over 0.34 maf is reserved for flood control. Table 3-9 lists major reservoirs on the Tuolumne River system.

The oldest dam on the Tuolumne River is La Grange Dam, about 2.5 miles downstream of New

TABLE 3-8

Major Reservoirs in the Los Angeles Aqueduct System

Reservoir	*Capacity (taf)*	*Year Completed*	*Stream*
Crowley	183	1941	Owens River
Grant	47	1940	Rush Creek
Haiwee	39	1913	Rose Valley Creek
Bouquet	34	1934	Bouquet Creek
Tinemaha	6	1929	Owens River

TABLE 3-9

Major Reservoirs in the Tuolumne River Basin

Reservoir	*Capacity (taf)*	*Year Completed*	*Owner*	*Stream*
New Don Pedro	2,030	1971	Modesto ID/Turlock ID	Tuolumne River
Hetch Hetchy	360	1923	San Francisco PUC	Tuolumne River
Lake Lloyd	268	1956	San Francisco PUC	Cherry Creek
Turlock	49	1915	Turlock ID	Offstream
Modesto	29	1911	Modesto ID	Offstream
Eleanor	26	1918	San Francisco PUC	Eleanor Creek

Don Pedro Dam. The 131-foot high La Grange Dam was completed in 1894; it serves as a diversion dam to divert river flows into Modesto ID's and Turlock ID's canals. In 1923, Modesto and Turlock Irrigation Districts completed the old Don Pedro concrete dam with a capacity of about 290 taf. The New Don Pedro Dam, capacity 2.03 maf, was completed in 1971 as a joint project of the two irrigation districts and the City and County of San Francisco.

In its early years, the City of San Francisco's water supply came from local creeks and springs. This was soon inadequate and, in 1862, water from the peninsula was drawn from Pilarcitos Creek (in San Mateo County) via a tunnel and redwood flume. In the 1870s, San Andreas and Crystal Springs Reservoirs were added and, with later improvements, increased the city's water supply greatly. About the turn of the century, the Spring Valley Water Company, the city's main water purveyor, turned its attention to the East Bay area and Alameda Creek. It constructed the Sunol Aqueduct in 1900 and completed Calaveras Dam in 1925. (The 215-foot high dam was the highest earth-fill dam in the world at the time.)

San Francisco's Pulgas Water Temple marks the original terminus of the Hetch Hetchy Aqueduct at Upper Crystal Springs Reservoir.

Concern about adequate water supply led to a series of studies and the choice in 1901 of the Tuolumne River as the city's next major source of supply. The centerpiece was to be a dam at Hetch Hetchy Valley in northern Yosemite Park. Authorization was secured in the 1913 Raker Act and work soon began on the construction of O'Shaughnessy Dam and the Hetch Hetchy Aqueduct. A dam at Lake Eleanor was built in 1918 to supply hydroelectric power for Hetch Hetchy construction. O'Shaughnessy Dam was completed in 1923 and the San Joaquin Valley pipeline and Coast Range tunnel were finished to deliver the first water to the San Francisco peninsula in 1934. Cherry Valley Dam (Lake Lloyd) was completed in 1956, which added further regulated storage to help satisfy irrigation district prior water rights below Hetch Hetchy.

The capacity of the current Hetch Hetchy Aqueduct system's San Joaquin pipeline is about 330 taf/yr. Average and drought year delivery capability of the system is 294 taf and 270 taf, respectively.

Two major San Joaquin Valley water agencies, Turlock and Modesto Irrigation Districts, have water rights on the Tuolumne River that are senior to those of San Francisco. Annual diversions by these irrigation districts average between 0.9 maf and 1.1 maf. As shown in Table 3-9, each of the irrigation districts uses an offstream regulatory reservoir to manage the distribution of the water diverted from the river.

Mokelumne Aqueduct. The Mokelumne River, one of the smaller Sierra Nevada rivers, has an average annual runoff of 740 taf. It is a snowmelt stream, with over 60 percent of its runoff occurring during April through July. The Mokelumne River has about 840 taf of storage capacity, approximately 1.1 times its average annual runoff. The largest reservoir is Camanche,

TABLE 3-10

Mokelumne Aqueduct System Reservoirs

Reservoir	*Capacity (taf)*	*Year Completed*	*Stream*
Camanche	417	1963	Mokelumne River
Pardee	198	1929	Mokelumne River

Hydraulic mining in the 1860s in the Michigan Bar District. Hydraulic mining was widely blamed for worsening flooding in Sacramento Valley towns because sediments washed into streams and rivers, raising their beds and reducing their capacity.

Courtesy of California State Library

which can hold 417 taf. Total flood control space on the Mokelumne River system is 200 taf. In addition to EBMUD's facilities on the river (Table 3-10), there is 220 taf of storage (owned by PG&E) and diversion works for two irrigation districts—Jackson Valley and Woodbridge Irrigation Districts.

In the 1920s, as the Hetch Hetchy Project for the San Francisco peninsula was under way, East Bay cities also turned to the Sierra Nevada for more water, specifically to the Mokelumne River. EBMUD completed Pardee Dam and the Mokelumne Aqueduct from Pardee Reservoir to the East Bay in 1929. The downstream Camanche Reservoir was completed in 1963. With the addition of a third pipeline in 1965, Mokelumne Aqueduct capacity was increased from 224 taf/yr to 364 taf/yr. Drought year supplies are not always adequate to sustain full aqueduct capacity diversions.

Yuba and Bear Rivers Development. The Yuba and Bear Rivers drain the west slope of the Sierra Nevada between the Feather River Basin on the north and the American River Basin on the south. The Yuba and Bear River Basins include portions of Yuba, Sutter, Placer, Nevada, Sierra, Butte, and Plumas Counties. Elevations range from 60 feet near Marysville to over 9,000 feet along the Sierra Nevada crest. The basins produce an average annual runoff of about 2.4 maf, 45 percent of which is derived from snowmelt from April through July. Runoff from the 1,700 square mile area drains westerly to the confluence with the Feather River, south of Marysville. Total reservoir capacity on the rivers is more than 1.6 maf, or approximately two-thirds of the average annual runoff. Surface water development provides municipal, irrigation, power generation, and environmental supplies to more than one dozen water purveyors, and serves the Cities of Marysville, Grass Valley, Nevada City, and many smaller communities.

The basins contain numerous lakes and reservoirs, including many small mountain lakes in the headwaters area. The larger reservoirs are listed in Table 3-11. New Bullards Bar, a concrete arch dam 645 feet high impounding a 966 taf reservoir, is located on the North Fork Yuba River about 30 miles northeast of Marysville. The facility was built for irrigation, power generation, recreation, fish and wildlife enhancement, and flood control. Seasonal flood control storage capacity is 170 taf. Englebright Dam (which impounds Englebright Reservoir) was constructed in 1941 by the California Debris Commission as a debris storage project. The dam, along with Daguerre Point Dam and channel training walls farther downstream, was designed to control movement of hydraulic mining debris along the lower Yuba River. Up to that time, mining debris was filling the downstream channels, creating flooding and navigation problems. Currently, PG&E and YCWA pay the federal government to use Englebright's storage to generate hydroelectric power at two powerplants.

Water from the Yuba and Bear Rivers is exported to the Feather and American River Basins via diversion works. Water is transferred to the Feather River basin (from Slate Creek to Sly Creek Reservoir) by Oroville-Wyandotte Irrigation District. Water is transferred to

TABLE 3-11

Major Reservoirs on the Yuba and Bear River Systems

Reservoir	*Capacity (taf)*	*Year Completed*	*Owner*	*Stream*
New Bullards Bar	966	1970	YCWA	NF Yuba River
Camp Far West	103	1963	South Sutter WD	Bear River
Lake Spaulding	75	1913	PG&E	SF Yuba River
Englebright	70	1941	USACE	Yuba River
Bowman	69	1927	Nevada ID	Canyon Creek
Jackson Meadows	69	1965	Nevada ID	MF Yuba River
Rollins	66	1965	Nevada ID	Bear River
Collins	57	1963	Browns Valley ID	Dry Creek
Scotts Flat	49	1948	Nevada ID	Deer Creek

the American River Basin (from Rollins Reservoir to Folsom Lake) by PG&E and Nevada Irrigation District. PG&E also diverts water for power generation from the American River Basin to the Bear River, which is subsequently returned to the North Fork American River and Folsom Lake.

Reservoir and River Operations

Most large reservoirs in California are multipurpose impoundments designed to provide water supply storage, electric power, flood control, recreation, water quality, and downstream fishery needs. Often, large reservoirs would not be economically feasible as single purpose projects. Multipurpose designs maximize the beneficial uses of large reservoir sites and provide regional water supply benefits.

Water Supply Operations. Water supply needs dictate many operating criteria of multipurpose reservoirs. Sufficient water must be provided for existing water rights, instream requirements for fish and water quality (including temperature control), downstream water demands, and, in the case of Shasta Reservoir, minimum flows or depths in the Sacramento River for navigation. The generation of hydroelectric power is, for the most part, an ancillary purpose. However, where there is capacity and an afterbay to re-regulate flow, reservoirs may be operated to meet peaking power needs. Lake recreation is an important element of the local economy at many reservoirs. High reservoir levels often are maintained into the summer to maximize local recreation.

Urban and agricultural water demands are highest during the summer and lowest during the winter, the inverse of natural runoff patterns. Environmental water demands can follow a different pattern. Water needs for flooding refuge and duck club lands tend to peak in the late fall. Anadromous fishery (primarily salmon) demands are highest in the fall to attract spawning fish and again in the spring to move the newly hatched smolts and fry downstream to the ocean. Demands for groundwater recharge can be scheduled any time of the year when water spreading capacity is available. Reservoir operators must balance these varying water demands against other considerations that affect reservoir and river use, such as flood control operating criteria and fishery temperature needs.

Flood Control Operations. Multipurpose reservoirs incorporating formal flood control functions are common on California's major rivers. Table 3-12 shows the principal Central Valley storage facilities that incorporate flood control. Most of the reservoirs shown were constructed by federal agencies under authorizations that allowed a large share of costs allocated to flood control to be treated as non-reimbursable and be absorbed by the federal government. Table 3-12 also includes several non-federal projects where part of the costs allocated to flood control were paid by the federal government under federal flood control law (or specific legislation). The share of flood control costs that must be borne by non-federal interests has gradually increased in recent years. Under the Water Resources Development Act of 1996, that non-federal share is now up to 35 percent.

Typically, flood control operations are integrated with those for other project purposes through the concept of "joint use" sharing of a portion of a reservoir's storage capacity. The usual climate patterns in California result in flood control needs being greatest in midwinter and least in the summer. Through joint use, substantial reservoir storage space is maintained empty to help control floods during the period of highest risk. As the year progresses and flooding risk diminishes,

TABLE 3-12

Federal Flood Control Storage in Major Central Valley Reservoirs

Reservoir	*Stream*	*Storage (taf)*	*Maximum Flood Control Space (taf)*	*Owner*
Shasta	Sacramento River	4,552	1,300	USBR
Oroville	Feather River	3,538	750	DWR
New Melones	Stanislaus River	2,420	450	USBR
New Don Pedro	Tuolumne River	2,030	340	Modesto ID/Turlock ID
McClure	Merced River	1,025	350[a]	Merced ID
Pine Flat	Kings River	1,000	475[a]	USACE
Folsom	American River	977	400[b]	USBR
New Bullards Bar	Yuba River	966	170	YCWA
Isabella	Kern River	568	398[a]	USACE
Millerton	San Joaquin River	520	170[a]	USBR
Camanche	Mokelumne River	417	200[a]	EBMUD
New Hogan	Calaveras River	317	165	USACE
Indian Valley	Cache Creek	301	40	YCFCWCD
Eastman	Chowchilla River	150	45	USACE
Black Butte	Stony Creek	144	137[a]	USACE
Kaweah	Kaweah River	143	142	USACE
Hensley	Fresno River	90	65	USACE
Success	Tule River	82	75	USACE
Farmington	Littlejohns Creek	52	52	USACE

[a] Maximum flood control space may vary depending on transferable upstream storage space and/or snowpack

[b] Does not include 270 taf reoperation for SAFCA

the flood reservation is reduced, allowing the storage to be used for water supply or other project purposes. The allocation of joint use storage is controlled by formal operating procedures, as discussed in the sidebar.

Flood control operating criteria are individually crafted to reflect the specific conditions at each reservoir. For example, reservoirs on the east side of the San Joaquin Valley are subject to high late spring snowmelt runoff from the high Sierra; their flood reservations must be maintained longer than those for areas where late spring snowmelt is not a factor.

Temperature Control Operations. Downstream water temperature has become an important criterion in establishing river and reservoir operations for the protection of salmon and other anadromous fish. For example, in 1990 and 1991 SWRCB established temperature standards in portions of the Sacramento and Trinity Rivers through its Orders WR 90-5 and 91-01. On the Sacramento River below Keswick Dam, these orders include a daily average water temperature objective of 56^0 F during critical periods when high temperatures could be detrimental to survival of eggs and pre-emergent fry. Through reservoir releases, the CVP attempts to maintain this temperature within the winter-run chinook salmon spawning grounds below Keswick Dam from April through September.

As another example of temperature control operations, NMFS issued a long-term winter-run chinook salmon biological opinion in 1993 that required the CVP to maintain a minimum Shasta Lake September storage of at least 1.9 maf, except in the driest years. Higher storage levels are required in Shasta Reservoir to ensure that cold water is available for reservoir releases. Before USBR constructed the temperature control device, water of sufficiently low temperature could be provided during critical periods only by bypassing Shasta Dam's powerplant, causing an annual revenue loss to the CVP of $10 to $20 million. The TCD, constructed at a cost of about $83 million, has multi-level intakes, allowing temperature- selective reservoir releases without having to bypass the powerplant. Some dams, such as the Department's Oroville Dam, were constructed with the ability to make temperature-selective reservoir releases, as shown in the photo.

In certain cases, temperature control capability can be provided by a temperature control curtain. This technology has been used successfully to provide selective withdrawal and to control reservoir mixing

Federal Flood Control Operating Criteria

For federal projects, or as a condition of federal cost sharing on other projects, USACE prescribes rules for operating reservoir space dedicated to flood control. Figure 3-25, a flood control operating diagram for Lake Oroville, illustrates the nature of those operating criteria.

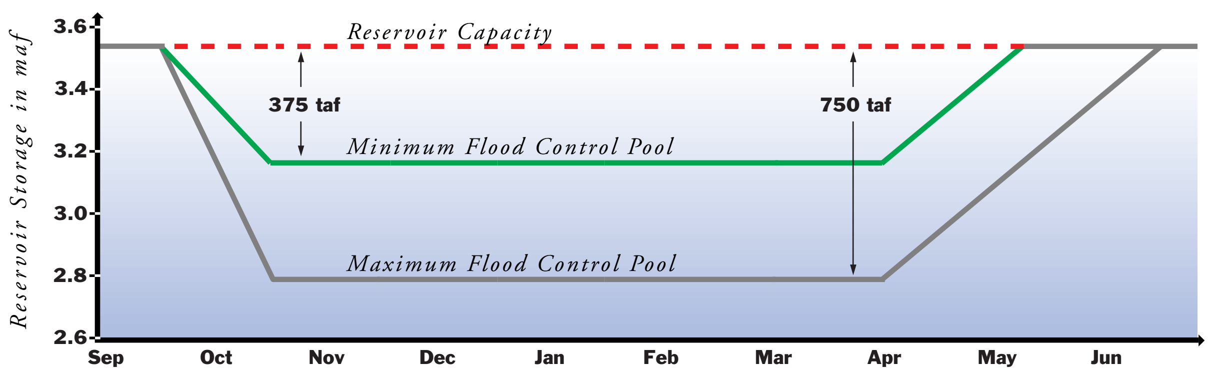
By mid-October each year, Lake Oroville storage must be reduced to a specified level within the range shown, creating an initial flood control reservation of at least 375 taf. The allowable level within the range is recalculated each day, using an index that reflects the wetness of the watershed and the likelihood of heavy runoff from any incoming storms. As a wet season such as 1997-98 progresses, the allowable storage tends to coincide with the "maximum flood control pool" line at the bottom of the flood diagram, which represents a flood reservation of 750 taf.

When high inflows occur, water is temporarily held in the flood reservation as necessary to maintain reservoir releases within prescribed limits that are designed to prevent downstream damage. The downstream flow limits set by the USACE for Lake Oroville are 150,000 cfs north of Honcut Creek, 180,000 cfs above the mouth of the Yuba River, and 320,000 cfs south of the Bear River.

While water is being stored to maintain releases within target levels, reservoir storage may exceed the level allowable under the flood operating criteria, a condition known as "encroachment" into the required flood reservation. The USACE criteria recognize that such encroachment will occur and establish release criteria for such conditions. Reservoir operators must balance the conflicting objectives of controlling the current flood event and preparing for a possible future one; the encroachment will be eliminated when downstream conditions permit.

FIGURE 3-25

Lake Oroville Flood Control Operating Diagram



at USBR's Lewiston and Whiskeytown Reservoirs. The four curtains constructed at the two reservoirs have reduced the temperature of Trinity River diversions into the upper Sacramento River by about 5^0 F. See Chapter 5 for more detailed discussion of temperature control technology.

Delta Operations. Because both the CVP and SWP export water from the Delta, a need for coordinated project operations exists. The Coordinated Operation Agreement between the Department and USBR differentiates between storage withdrawals and unstored flows in the Delta. Storage withdrawals belong to the project that makes the reservoir release. Unstored flows that are available for export are shared between the projects—55 percent to the CVP and 45 percent to the SWP. The COA also specifies how the projects are to share the responsibility of satisfying Sacramento River in-basin demands and Delta requirements

This sloping intake structure at Oroville Reservoir allows for temperature-selective releases of water through Hyatt Pump Generating Plant. Shutters underneath the trashrack structure are lowered into position with the gantry crane shown.

when there are no surplus flows. Under "balanced" conditions when storage withdrawals are being made, responsibility is allocated 75 percent to the CVP and 25 percent to the SWP. The sharing of responsibility for satisfying new Delta export restrictions under Order WR 95-6 is not specified under the present COA.

Environmental needs in the Delta, especially for threatened and endangered fisheries, exert a strong influence on export pumping and other water project operations. Starting in the 1970s, project exports were reduced during May and June to improve juvenile striped bass survival in the Delta. In the last decade, requirements to protect ESA listed fish species have led to new Delta environmental criteria and more export constraints. Travel time to the Delta is a consideration in operating SWP and CVP reservoirs to meet regulatory requirements. Sometimes, a rapid change in salinity conditions calls for additional release of water. Of the major Sacramento River region reservoirs, Folsom gives the quickest response (about a day), while it takes 3 days for Oroville releases and 5 days for water at Keswick Dam (from Shasta releases or Trinity River imports) to reach the Delta. Reservoir releases from New Melones on the San Joaquin River reach the Delta in about 1.5 days.

Stanislaus River releases from USBR's New Melones Reservoir must meet prior water rights and provide CVP water supply. Also, some water is dedicated to maintaining dissolved oxygen levels in the Stanislaus River and to diluting salts in the lower San Joaquin River. New Melones must make spring pulse flow releases to meet Delta fishery requirements. Except during flood control operations, releases are maintained below 1,500 cfs to avoid seepage effects on adjacent orchard lands.

Impacts of Recent Events on Surface Water Supplies

As discussed in Chapter 2, several key events in California water have occurred since the last update of Bulletin 160. Events of particular importance to surface water supply availability include CVPIA implementation, the 1993 winter-run chinook salmon biological opinion, the Monterey Agreement, and the Bay-Delta Accord. The Department's DWRSIM computer model was used to evaluate the Bay-Delta Accord's impact on CVP and SWP operations under base year (1995) and future year (2020) conditions. A similar operations study, assuming D-1485 Delta standards and base year conditions, was conducted to compare delivery capability of the projects with the new Delta criteria. The 73-year simulations (1922-94) show how the CVP and SWP would operate at current and future levels of demand and upstream development if the historical hydrology sequence were to repeat.

Based on these operations studies, Figures 3-26 and 3-27 show that delivery capabilities of the CVP (south

FIGURE 3-26

1995 Level Central Valley Project Delivery Capability South of Delta Under D-1485 and WR 95-6

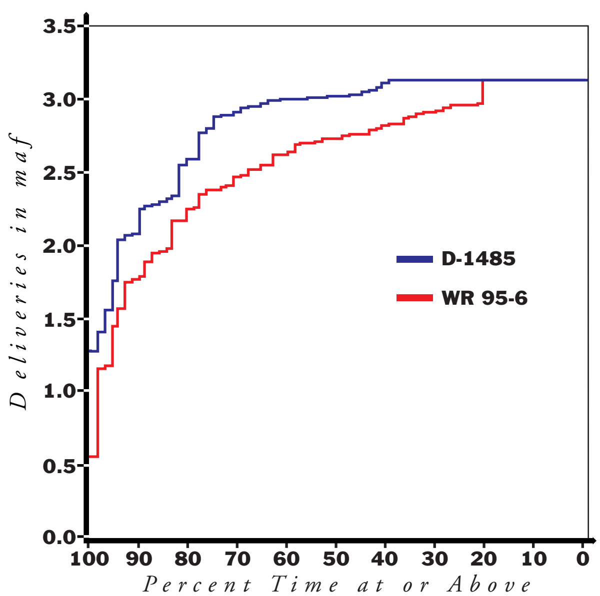
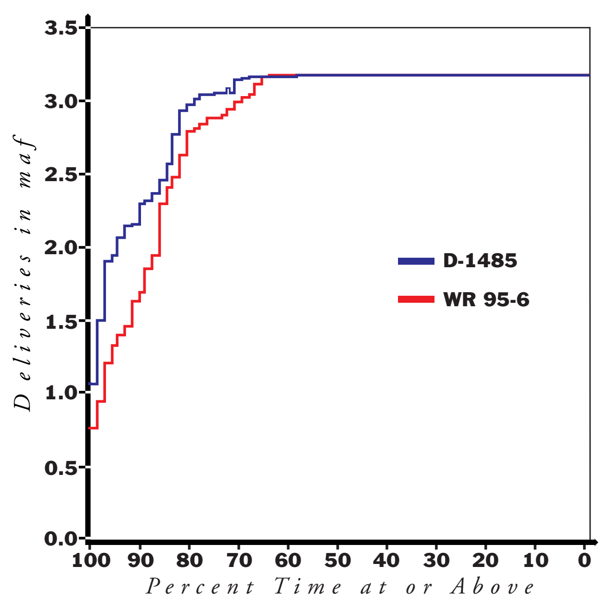


FIGURE 3-27

1995 Level State Water Project Delivery Capability Under D-1485 and WR 95-6



of the Delta) and SWP were significantly reduced from the prior Delta operating criteria to the current criteria. Under D-1485 and 1995 level demands, the CVP had a 40 percent chance of making full deliveries and a 95 percent chance of delivering 2.0 maf in any given year. Under WR 95-6 with identical demands, the CVP has a 20 percent chance of making full deliveries and an 80 percent chance of delivering 2.0 maf in any given year. Under D-1485 and 1995 level demands, the SWP had a 70 percent chance of making full deliveries and a 95 percent chance of delivering 2.0 maf in any given year. Under WR 95-6 with identical demands, the SWP has a 65 percent chance of making full deliveries and an 85 percent chance of delivering 2.0 maf in any given year.

The gated inlet structure to the SWP's Clifton Court Forebay in the Southern Delta.

Together, the operations studies indicate the combined 1995 level export capability of the CVP and SWP declined by about 300 taf/yr on average and by about 850 taf/yr during 1929-34 drought conditions. (These operations studies do not account for Delta export curtailments due to concerns for authorized take of ESA listed species. Reduction in exports due to take limits could be significant, especially during drought periods, when the projects are unable to export significant unstored flows or reservoir releases providing required instream flows.) Table 3-13 summarizes key changes in Delta standards, as modeled in operations studies, from Bulletin 160-93 to Bulletin 160-98.

Impacts of Reservoir Reoperation on Surface Water Supplies

California's large multipurpose reservoirs have been constructed to provide a certain mix of project benefits established during their planning periods. A change in a reservoir's operation rules (to increase one type of benefit) requires careful analysis of how the change may affect the project's ability to accomplish other purposes.

Providing additional winter flood control in a reservoir, for example, reduces the probability that it will refill after the flood season. Temporary increases in winter flood control space have been suggested at some of the San Joaquin River region foothill reservoirs in the wake of the 1997 flood. However, the value of water supply in this region is high, and these proposals would have significant costs and water supply impacts. At USBR's Folsom Reservoir, the local flood control agency has negotiated an agreement with USBR for an additional 270 taf of winter flood control space. The agreement requires the flood control agency to provide a substitute water supply, under specified conditions, if the flood control reservation results in a loss of supply to USBR. The payback provision of this agreement was triggered by the 1997 flood. See Chapter 8 for details.

Conversely, Chapters 7-9 discuss several flood control reservoirs being studied for reoperation to provide some water supply benefits. Many of these reservoirs are smaller, single-purpose flood detention impoundments on streams with relatively low average annual runoff. In many cases, physical changes to the existing dams, such as raising their spillways, would be needed as part of a reoperation for water supply. Often, the goal at existing detention dams is to operate the reservoir to enhance groundwater recharge, because maintaining year-round conservation storage on a stream with relatively low average runoff would not be economical.

Providing higher reservoir minimum storage requirements, another example of reservoir reoperation, results in lower delivery potential during dry periods. The increase in required Shasta Reservoir storage to maintain cool water for the winter-run salmon has reduced CVP water supply potential during drought periods. Current minimum storage target levels are about 1.9 maf, except in critical years when the target is allowed to drop to 1.2 maf. (Shasta storage dropped under 0.6 maf in the 1976-77 drought and dropped to 1.3 maf during the 1987-92 drought.) Providing higher reservoir carryover also reduces electrical energy generation, which is often replaced with electricity generated from fossil fuel burning generation plants.

TABLE 3-13

Major Changes in Delta Criteria from D-1485 to WR 95-6

Criteria	*Change*
Water Year Classification	from SRI to 40-30-30 Index
Sacramento River Flows	higher Sept.-Dec. Rio Vista flows
San Joaquin River Flows	new minimum flows and pulse flows
Vernalis Salinity Requirement	more restrictive during irrigation season, less restrictive other months
Delta Outflow	outflow required to maintain 2 ppt salinity during Feb.-June
Export Limits	35%-65% export-to-Delta inflow ratio, Apr.-May export-to-SJR inflow ratio
Delta Cross Channel Operations	additional closures required

Groundwater Supplies

In an average year, about 30 percent of California's urban and agricultural applied water is provided by groundwater extraction. In drought years when surface supplies are reduced, groundwater supports an even larger percentage of use. The amount of water stored in California's aquifers is far greater than that stored in the State's surface water reservoirs, although only a portion of California's groundwater resources can be economically and practically extracted for use.

In evaluating California water supplies, an important difference between surface water and groundwater must be accounted for—the availability of data quantifying the resource. Surface water reservoirs are constructed to provide known storage capacities, reservoir inflows and releases can be measured, and stream gages provide direct measurements of flows in surface water systems. Groundwater basins have relatively indeterminate dimensions, inflow (e.g., recharge) to an entire basin cannot be directly measured, and total basin extractions and natural outflow are seldom directly measured. In addition to physical differences between surface water and groundwater systems, statutory differences in the administration of the resources also affect data availability. Entities who construct surface water reservoirs must have State water rights for the facility, and all but the smallest dams are regulated by the State's dam safety program. These requirements help define and quantify the resource. In contrast, groundwater may be managed by local agencies (as described later in this section), but there are no statewide requirements that require quantification of the resource. Much of California's groundwater production is self-supplied, and is not managed or quantified by local agencies.

Groundwater is often the only local source of supply for desert communities.

The following description of groundwater supplies is presented in a more general manner than was used for surface water supplies, reflecting the difference in data availability. Much of the groundwater information in this section is based on calculations, rather than on direct measurement. Estimating overdraft in a basin, for example, relies on interpretation of measured data (water levels in wells) and interpretation of calculated information (extractions from the basin). The ability to assess statewide groundwater resources would benefit greatly from additional data collection and better access to existing data.

Base Year Supplies

Table 3-14 summarizes estimated 1995 level groundwater supplies. The data represent current levels of groundwater production, and not necessarily the maximum potential of statewide groundwater supplies. The data include water reapplied through deep percolation and exclude groundwater overdraft.

To help put this information in perspective, the sidebar illustrates typical groundwater production conditions in three hydrologic regions that rely heavily on groundwater because their local surface water supplies do not fully support existing development. These regions—the San Joaquin, Tulare Lake, and Central Coast regions—all have alluvial aquifer systems that support significant groundwater development, as

TABLE 3-14

Estimated 1995 Level Groundwater Supplies by Hydrologic Region (taf)

Region	*Average*	*Drought*
North Coast	263	294
San Francisco Bay	68	92
Central Coast	1,045	1,142
South Coast	1,177	1,371
Sacramento River	2,672	3,218
San Joaquin River	2,195	2,900
Tulare Lake	4,340	5,970
North Lahontan	157	187
South Lahontan	239	273
Colorado River	337	337
Total (rounded)	**12,490**	**15,780**

suggested by the information presented in the sidebar. (The data shown are typical of wells used for agricultural or municipal production. A well used to supply an individual residence would have a much smaller capacity. Over 90 percent of the groundwater use in each of these regions is for agricultural use.) In contrast, aquifer systems in fractured rock, such as those used to supply small communities in the Sierra Nevada foothills, can generally support only limited groundwater development.

In these hydrologic regions water users frequently take advantage of surface water available in wet years to recharge groundwater basins. In drought years when surface water is not available, water users increase groundwater pumping. For example, Friant-Kern CVP contractors maximize groundwater recharge with less expensive Class II supplies (wet weather water) when they are available. Member agencies of KCWA have developed extensive recharge facilities along the Kern River channel to take advantage of wet year flows.

Groundwater Basin Yield

Historically, the term safe yield has been used in an attempt to describe the available supply from a groundwater basin. Safe yield is defined in the Department's Bulletin 118-80, *Groundwater Basins in California*, as "the maximum quantity of water that can be continuously withdrawn from a groundwater basin without adverse effect." Adverse effect in this context can include depletion of the groundwater reserves (groundwater level decline), intrusion of water of undesirable quality, impacts to existing water rights, higher extraction costs, subsidence, depletion of streamflow, and environmental impacts. Historically, additional extraction from a groundwater basin above the safe yield value has been called overdraft. Overdraft is defined in Bulletin 118-80 as "the condition of a groundwater basin where the amount of water withdrawn exceeds the amount of water replenishing the basin over a period of time."

Typical Groundwater Production Conditions

The Department collects data from a statewide network of wells to monitor long-term changes in groundwater levels. The network includes local agency wells and privately-owned wells. These data were combined with Bulletin 160 water use information to prepare the tabulation on typical groundwater production conditions shown below. Long-term water level data can show the effects of increased groundwater extraction in drought years; it can also show the effects of changing water management practices in a basin.

Local conditions within the tabulated basins may deviate greatly from the typical conditions shown below. In the Tulare Lake Region, for example, some groundwater production is occurring from wells with pumping lifts of over 800 feet.

Basin	*Extraction (taf/yr)*	*Well Yields (gpm)*	*Pumping Lifts (feet)*
San Joaquin River Region			
Madera	570	750-2,000	160
Merced	560	1,500-1,900	110
Delta Mendota	510	800-2,000	35-150
Turlock	450	1,000-2,000	90
Chowchilla	260	1,500-1,900	110
Modesto	230	1,000-2,000	90
Tulare Lake Region			
Kings	1,790	500-1,500	150
Kern	1,400	1,500-2,500	200-250
Kaweah	760	1,000-2,000	125-250
Tulare Lake	670	300-1,000	270
Tule	660	NA	150-200
Westside	210	800-1,500	200-800
Pleasant Valley	100	NA	350
Central Coast Region			
Salinas Valley	550	1,000-4,000	180
Pajaro Valley	60	500	10-300

Quantifying either overdraft or safe yield is inherently complex. For example, estimates of safe yield of a basin often change over time, as more development occurs in a basin and extractions increase. The observed effects of these extractions can cause water managers to revise—either upward or downward—safe yield estimates based on an earlier level of development. The safe yield definition is limited because it tends to imply a fixed quantity of water that can be extracted on an annual basis without regard to how the overall supply might be enhanced through basin management. This update of the *California Water Plan* uses perennial yield rather than safe yield to define long-term groundwater basin yield.

Perennial Yield. Perennial yield is the amount of groundwater that can be extracted without lowering groundwater levels over the long-term. Perennial yield in basins where there is hydraulic connection between surface water and groundwater depends, in part, on the amount of extraction that occurs. Perennial yield can increase as extraction increases, as long as the annual amount of recharge equals or exceeds the amount of extraction. Extraction at a level that exceeds the perennial yield for a short period may not result in an overdraft condition. In basins with an adequate groundwater supply, increased extraction may establish a new hydrologic equilibrium with a new perennial yield. The establishment of a new and higher perennial yield requires that adequate recharge from some surface supply be induced, which may impact downstream users of that supply.

In Bulletin 160-98, perennial yield is estimated as the amount of groundwater extraction that has taken place, or could take place, over a long period of time under average hydrologic conditions without lowering groundwater levels. Existing basin water management programs (1995 level of development) were evaluated in the development of perennial yield estimates.

Overdraft. Additional annual extraction from a groundwater basin over a long period of time above the annual perennial yield is defined as overdraft in Bulletin 160-98. In wet years, recharge in developed groundwater basins tends to exceed extractions. Conversely, in dry years, groundwater basin recharge tends to be less than groundwater basin extraction. By definition, overdraft is not a measure of these annual fluctuations in groundwater storage volume. Instead, overdraft is a measure of the long-term trend associated with these annual fluctuations. The period of record used to evaluate overdraft must be long enough to produce data that, when averaged, approximate long-term average hydrologic conditions for the basin. Table 3-15

TABLE 3-15

1995 and 2020 Level Overdraft by Hydrologic Region (taf)

	1995		*2020*	
Region	***Average***	***Drought***	***Average***	***Drought***
North Coast	0	0	0	0
San Francisco Bay	0	0	0	0
Central Coast	214	214	102	102
South Coast	0	0	0	0
Sacramento River	33	33	85	85
San Joaquin River	239	239	63	63
Tulare Lake	820	820	670	670
North Lahontan	0	0	0	0
South Lahontan	89	89	89	89
Colorado River	69	69	61	61
Total (rounded)	**1,460**	**1,460**	**1,070**	**1,070**

shows the Department's estimates of 1995 and 2020-level groundwater overdraft by hydrologic region. Within some regions overdraft occurs in well-defined subareas, while additional groundwater development potential may exist in other subareas.

For the 1995 base year, Bulletin 160-98 estimates a statewide increase in groundwater overdraft (160 taf) above the 1990 base year reported in Bulletin 160-93. Most of the statewide increase in overdraft occurred in the San Joaquin and Tulare Lake regions, two regions where surface water supplies have been reduced in recent years by Delta export restrictions, CVPIA implementation, and ESA requirements. CVP contractors who rely on Delta exports for their surface water supply have experienced supply deficiencies of up to 50 percent subsequent to implementation of export limitations and CVPIA requirements. Many of these contractors have turned to groundwater pumping for additional water supplies. This long-term increase in groundwater extractions exacerbated a short-term decline in water levels as a result of the 1987-92 drought.

As shown in Table 3-15, groundwater overdraft is expected to decline from 1.5 maf to 1.1 maf statewide by 2020. Overdraft in the Central Coast Region is expected to decline as demand shifts from groundwater to imported SWP supplies, provided through the recently completed Coastal Branch of the California Aqueduct. The reduction in irrigated acreage in drainage problem areas on the west side of the San Joaquin Valley, as described in the 1990 report of the San Joaquin Valley Interagency Drainage Program, is expected to reduce groundwater demands in the San Joaquin River and Tulare Lake regions by 2020. (A discussion on the San Joaquin Valley Interagency Drainage Program is provided in Chapter 4.) Some increases in groundwater overdraft are expected in Sacramento, Placer and El Dorado Counties of the Sacramento River Region.

The Central Coast hydrologic region includes, in addition to the Salinas and Pajaro Valley Basins, several small basins with limited storage capacity. During drought periods, water levels in these basins may decline to a point where groundwater is not usable. However, during wet periods, most of these basins recover, thus making application of overdraft or perennial yield concepts difficult. The Department is currently evaluating Central Coast Region groundwater use to better estimate overdraft, but this evaluation will not be completed in time for Bulletin 160-98. Parts of the Central Coast have received CVP water through the San Felipe Tunnel since 1986; other parts are now able to receive SWP water through the Coastal Branch of the California Aqueduct. These imported supplies should help reduce overdraft in the region.

Groundwater Management Programs

Groundwater basin management may be implemented to achieve a variety of objectives, including limiting groundwater overdraft or well interference, preventing seawater intrusion, controlling land subsidence, or managing migration of contaminants of concern. Because no two groundwater basins are identical, local agency groundwater basin management programs differ in purpose and scope. Typical local groundwater management strategies include monitoring groundwater levels and extractions; cooperative arrangements among pumpers to minimize or eliminate problem conditions; and, where applicable, conjunctive use. Groundwater management options include AB 3030 plans (Water Code Section 10750, et seq.), local ordinances, and legislative authorization for individual special districts. Rights to use groundwater also may be adjudicated by court action.

Reasons for Basin Management. Overdraft in a basin, or intensive local pumping in one part of a basin, can cause problems in addition to those associated with insufficient water quantity. Some of the most common undesirable impacts are land subsidence and seawater intrusion (or migration of poorer quality water).

Land subsidence caused by groundwater withdrawal has occurred in parts of the Central and Santa Clara Valleys and in localized areas of the south coastal plain. An important groundwater management goal in developed areas is the prevention or reduction of land subsidence. Land subsidence can impact infrastructure, roads, buildings, wells, canals, stream channels, flood control structures (such as levees), and low-lying coastal or floodplain areas. Actions to monitor and manage subsidence may include monitoring changes in groundwater levels, precisely surveying land surface elevations at periodic intervals to detect changes, installing extensometers to measure the change in thickness of sediments between the land surface and fixed points below the surface, recording the amount of groundwater extracted, recharging the aquifer to control subsidence, and determining when extraction must be decreased or stopped. These management actions could be coordinated with groundwater/land subsidence modeling to predict future land subsidence under various water management scenarios.

Land Subsidence in the San Joaquin Valley

San Joaquin Valley land subsidence was observed as early as the 1920s. The rate of subsidence increased significantly in the post-WWII era as groundwater extraction increased. Subsidence was especially noticeable along parts of the west side of the valley, where land that had been used for grazing or dry farming was converted to irrigated agriculture. By 1970, 5,200 square miles in the valley had subsided more than 1 foot. Between 1920 and 1970, a maximum of 28 feet of subsidence was measured at one location southwest of Mendota. In the years since 1970, the rate of subsidence has declined because surface water was imported to the area. An increase in subsidence occurred during the 1976-77 and 1987-92 droughts, when groundwater extraction increased due to reductions in SWP and CVP supplies. Recent increases in subsidence are the result of increased groundwater extractions to compensate for water supply deficiencies caused by Bay-Delta export restrictions, ESA requirements, and CVPIA.

The Department monitors subsidence along the California Aqueduct, maintaining seven compaction recorders and performing periodic precise leveling along the aqueduct. The data indicate, for example, that a 68-mile reach of the aqueduct near Mendota subsided 2 feet between 1970 and 1994. Over the same time period, the aqueduct subsided approximately 2 feet along a 29-mile reach near Lost Hills, and up to 1 foot in a 9-mile reach near the Kern Lake Bed. At the time of the aqueduct's design, the potential for San Joaquin Valley subsidence was recognized, and measures were taken to compensate for some of its impacts. Canal sections in subsidence-prone areas were designed with extra freeboard, and structures crossing the canal (such as bridges) were designed to allow them to be raised later. Even so, continued subsidence along the aqueduct alignment creates the need for canal lining repairs and reduces the canal's capacity in places.

One area of particular concern is the west side of the San Joaquin Valley, where infrastructure affected by subsidence includes state highways, county roads, and water conveyance and distribution facilities. The sidebar provides an overview of subsidence in the area.

Seawater intrusion was recognized as a water management problem in California's coastal areas as early as the 1950s (see sidebar), affecting both urban and agricultural water agencies. Overextraction from basins near the coast induces seawater intrusion into the aquifer where the extraction occurred and leads to the expansion of areas of degraded water quality, as pumpers relocate wells to take advantage of better quality water in deeper aquifers or in aquifers farther inland. Typically, seawater intrusion in larger basins occurs in areas where surface water supplies are limited, relative to the extent of water demands. In this case, a new supply of surface water must be provided to the area as part of controlling seawater intrusion, if existing land use patterns (either urban or irrigated agriculture) are to continue. Examples of areas which have experienced seawater intrusion problems include some of the managed basins in the highly urbanized South Coast Region, small basins serving individual communities in the Central Coast Region, and the Salinas Valley (a highly productive agricultural area). Imported supplies from the SWP have helped local agencies manage seawater intrusion in the South Coast Region; local agencies are also increasingly turning to recycled water supplies to help manage intrusion. Examples of local agency efforts to control seawater intrusion are described in Chapter 7.

Local Agency Groundwater Management Programs. The 1992 enactment of AB 3030 (Water Code Section 10750, et seq.) provided broad general authority for local agencies to adopt groundwater management plans pursuant to specified procedures, and to impose assessments to cover the cost of implementing the plans. To date, about 150 local agencies have adopted AB 3030 groundwater management plans. Under other groundwater management authorities, there are 7 agencies with AB 255 plans and over 50 agencies with some other form of statutory authority.

While the number of agencies adopting AB 3030 plans increases every year, quantifying the statewide number of adopted plans is somewhat uncertain; there is no requirement in the statute that agencies adopting plans file copies of those plans with the Department or SWRCB. A tabulation of agencies with AB 3030 plans, together with agencies managing groundwater under some other authority, can be found in the Department's 1998 report to the Legislature on the number of local agencies having some form of management authority.

Special Powers Agencies and Local Ordinances. The California Legislature may create special powers agencies, such as the Fox Canyon Groundwater Management District, or may amend the statutory authority of an existing agency to allow it to manage groundwater. Generally, these agencies are governed by a board of directors that may be appointed or elected.

The *Baldwin v. County of Tehama* decision

Seawater Intrusion in Orange County

Orange County Water District was formed in 1933 to protect and manage the groundwater basin that underlies the northwest half of the county. Groundwater supplies about 75 percent of OCWD's total water demand. As the county developed, increased groundwater extractions resulted in a gradual lowering of the water table. By 1956, years of heavy pumping to sustain the region's agricultural economy had lowered the water table below sea level, and saltwater from the ocean had encroached as far as 5 miles inland. The area of seawater intrusion is primarily along 4 miles of coast between Newport Beach and Huntington Beach known as the Talbert Gap.

To prevent further seawater intrusion, OCWD operates a hydraulic barrier. A series of 23 multi-point injection wells 4 miles inland delivers fresh water into the underground aquifer to form a water mound, blocking further passage of seawater. Water supply for the Talbert Barrier is produced at OCWD's Water Factory 21. The supply is a blend of recycled water and groundwater pumped from a deep aquifer zone that is not subject to seawater intrusion. The first blended recycled water from the plant was injected into the barrier in October 1976.

Water Factory 21 recycles about 10 mgd and, with the deep well water used for blending, produces about 15 mgd. OCWD has applied for and has received a permit to modify the treatment process to allow for injection of 100 percent recycled water, eliminating the use of deep well water for blending. The plant's current treatment includes chemical clarification, recarbonation, multi-media filtration, granular activated carbon, reverse osmosis, chlorination, and blending. The blended injection water has a total dissolved solids content of 500 mg/L or lower, and meets DHS primary and secondary drinking water standards.

confirmed the right of cities and counties to adopt local regulations concerning groundwater. Moreover, the *Baldwin* decision confirmed that Tehama County has general police power to regulate groundwater and water transfers, and that counties are free to adopt local ordinances that do not conflict with State legislative mandates. The following counties have ordinances regulating groundwater: Butte, Glenn, Imperial, San Benito, San Joaquin, Tuolumne, and Tehama. At least three other counties (Shasta, Sutter, and Yolo) have developed ordinances, or are in the process of developing ordinances, to regulate indirect transfers of groundwater resulting from groundwater substitution programs.

Basin Adjudication. In California's adjudicated groundwater basins, groundwater extraction is regulated or administered by a court-appointed watermaster. The court retains jurisdiction over the judgment, so parties can appeal to the court to resolve disputes related to their adjudicated rights. The groundwater that each well owner may extract is determined by the court decision as administered by the watermaster. While each court decision may be different, the common goal is to avoid groundwater overdraft. Table 3-16 shows a list of adjudicated basins. Also see Figure 3-28.

While not listed in Table 3-16, groundwater and surface water have also been adjudicated in the Santa Margarita River Watershed in Riverside and San Diego Counties. Water users are required by the court decision to report to the court-appointed watermaster the amount of groundwater they extract from the aquifer and the amount of surface water they divert from the river, canals, or ditches. However, groundwater extraction is not limited by the decision.

Water Marketing

In recent years, water marketing has received increasing attention as a tool for addressing statewide imbalances between water supply and water use. Experience with water markets during and since the 1987-92 drought bolstered interest in utilizing marketing as a local and statewide water supply augmentation option. While water marketing does allow water agencies to purchase additional water supply reliability during both average and drought years, water marketing does not create new water. Therefore, water markets alone cannot meet California's long-term water supply needs. A discussion on the use of marketing to meet future statewide water needs is provided in Chapter 6.

Definition of Water Marketing

In this update of the *California Water Plan,* water marketing may include:

- A permanent sale of a water right by the water right holder.
- A lease from the water right holder (who retains the water right), allowing the lessee to use the water under specified conditions over a specified period of time.
- A sale or lease of a contractual right to water supply. Under this arrangement, the ability of the holder to transfer a contractual water right is usually con-

FIGURE 3-28

Adjudicated Groundwater Basins

TABLE 3-16
California Adjudicated Groundwater Basins and Watermasters

County	*Basin*	*Watermaster*
Los Angeles	Central West Coast Upper Los Angeles River Area Raymond Main San Gabriel[a] Puente	DWR DWR Superior Court appointee Raymond Basin Management Board Nine-member board Three appointees
Kern	Cummings Tehachapi	Tehachapi-Cummings Water District Tehachapi-Cummings Water District
San Bernardino	Warren Valley San Bernardino Basin Area Cucamonga Mojave Basin Area	Hi-Desert Water District One representative each from Western Municipal Water District of Riverside County and San Bernardino Valley Municipal Water District Cucamonga County Water District and San Antonio Water Company Mojave Water Agency
Riverside and San Bernardino	Chino	Nine-member board
Riverside and San Diego	Santa Margarita River Watershed	District Court appointee
Siskiyou	Scott River Stream System	Two irrigation districts
Ventura	Santa Paula	Three-person Technical Advisory Committee

[a] The watermaster for Main San Gabriel Basin has returned to court and obtained approval of regulations to control extraction for protecting groundwater quality.

tingent upon receiving approval from the supplier. An example of this type of arrangement is a sale or lease by a water agency that receives its supply from the CVP, SWP, or other water wholesaler.

Water marketing is not an actual statewide source of water, but rather is a means to reallocate existing supplies. Therefore, marketing is not explicitly itemized as a source of water supply from existing facilities and programs in the Bulletin 160 water budgets. (Water marketing agreements in place by 1995 are considered to be existing programs and are implicitly part of the water budgets.) Water marketing is identified as a potential water supply augmentation option in the Bulletin 160 water budgets (see Chapter 6). Potential water marketing options have several characteristics that must be captured in the water budgets incorporating supplies from future management options. For example, through changes in place of use, water marketing options can reallocate supplies from one hydrologic region to another. And through changes in type of use, water marketing options can reallocate supplies from one water use sector to another. Finally, for a given place and type of use, water marketing options can reallocate supplies between average years and drought years.

A transfer of water through a local exchange is not defined as water marketing in this update of Bulletin 160. Water exchanges between individual water users within a water district are common in drought years, and such transfers are becoming increasingly common, even in average years. Water exchanges between users within a district normally do not require approval from the SWRCB because a change in the place of use, purpose of use, or point of diversion does not occur.

Water banking, where water is physically banked or stored without a change in ownership, is also not defined as water marketing in this Bulletin. For example, Warren Act contracts, where local agencies contract with USBR for storage or conveyance of non-project water in federal facilities, only involve the rental of facilities for storage or conveyance. On the other hand, if a water banking agreement does involve a change in ownership, it is defined as water marketing in this Bulletin. For example, an agreement between MWDSC and Semitropic Water Storage District allows MWDSC access to 35 percent of SWSD's groundwater storage capacity. According to the agreement, MWDSC may store a portion of its SWP entitlement water for later withdrawal and delivery to its service area. Alternatively, SWSD could exchange a portion of its SWP entitlement water for MWDSC's stored water.

Short-Term Agreements

Short-term agreements have made up the majority of water marketing arrangements in recent years. Short-term agreements (less than one year) can be an effective means of alleviating the most severe drought year impacts. Short-term agreements can be executed on the spot market; however, water purveyors are increasingly interested in negotiating longer-term agreements for drought year transfers. In such future agreements, specific water supply conditions may be the triggers to determine whether water would be transferred in a specific year.

Two examples of programs for acquiring water through short-term agreements are the Drought Water Bank and the CVPIA interim water acquisition program. These programs are discussed below. Beyond these programs, data on short-term water marketing arrangements are difficult to locate and verify. Agreements executed for less than one year do not need SWRCB approval (unless there is a change in place of use or point of diversion) and thus are not tracked by outside entities. Data are also difficult to evaluate, as it is often difficult to distinguish between exchanges and marketing arrangements.

Drought Water Bank. In 1991, after four consecutive years of drought, the Governor signed an executive order establishing a Drought Action Team. The first emergency drought water bank was created in response to the team's recommendations. The Department operated the DWB in coordination with other agencies, including USBR, SWRCB, DFG, and local governments. DWB's primary role was to purchase water from willing sellers and sell it to entities with critical needs. Sellers made water available to DWB by fallowing farmland, releasing surplus reservoir storage, and by substituting groundwater for surface supplies.

During 1991, the DWB purchased about 820 taf of water under more than 300 short-term agreements. About half of that water came from fallowing agreements. About 30 percent came from groundwater substitution arrangements made with participating farmers and water districts. The remainder of the water came from reservoir storage.

The 1991 DWB experience and contracts provided a basis for administration of the 1992 DWB. In 1992, the Department purchased about 190 taf of water, with 80 percent from groundwater substitution contracts and 20 percent from reservoir storage. No land fallowing contracts were executed. These conditions allowed the 1992 DWB to operate at a significantly reduced cost for water. As with the 1991 DWB, the 1992 DWB was able to acquire sufficient water to meet the critical needs of all participants.

Drawing on the 1991 and 1992 DWB experiences, the Department completed a programmatic environmental impact report that evaluated different types of water marketing. The final EIR, released in 1993, covered future drought water bank programs intended to meet water demands during drought periods over the next 5 to 10 years, on an as-needed basis. The program is a water purchase and allocation program whereby the Department will purchase water from willing sellers and market the water to buyers under specific critical needs allocation guidelines.

The DWB program would be implemented as needed for a particular year upon an executive order of the Governor, a decision by the Secretary for Resources, or upon a finding by the Department's Director that drought or other unanticipated conditions exist that would significantly curtail water deliveries. The program would continue to operate until water supplies returned to noncritical levels.

In 1994, the Department reactivated the DWB and also initiated a short-term water purchase program for SWP contractors. More than 170 taf of water was delivered to cities and farms throughout the State. About 115 taf was delivered from the DWB and 58 taf was delivered from the short-term water purchase program. A comparison of the three DWBs is shown in Table 3-17.

The Department began to organize a 1995 DWB in September 1994, anticipating another drought year. By mid-November, water agencies had signed contracts with the Department to purchase water from DWB for critical needs. The Department established DWB in an inactive status, with the intent of activating it if 1995 precipitation was below normal. While in inactive

TABLE 3-17

Drought Water Bank Purchases and Allocations (taf)

	1991	*1992*	*1994*[a]
Supply			
Purchases	821	193	222
Delta and instream fish requirements	(165)	(34)	(48)
Net supply	**656**	**159**	**174**
Allocation			
Urban	307	39	24
Agricultural	83	95	150
Environmental	—	25	—
SWP Carryover	266	—	—
Total Allocation	**656**	**159**	**174**
Selling Price ($/af)[b]	**175**	**72**	**68**

[a] Includes deliveries for the SWP.

[b] Price to buyers south of the Delta at Banks Pumping Plant. Includes the cost of the water, adjustments for carriage losses and administrative charges. Does not include transportation charges which have ranged from $15 to $200 /af, depending on the point of delivery and other factors.

status, DWB purchased options on 29 taf of water from five willing sellers. As a result of an abundance of precipitation and snowpack throughout California in 1995, the DWB was not activated and the Department did not exercise the acquired options.

Despite the success of the DWB, it is a contingency or drought management supply option. The program does not provide a permanent water supply. Based upon past experience, future State-operated DWBs might be able to reallocate about 250 taf/yr of supplies during droughts. Future ESA listings and other actions that would reduce the ability to convey water through the Delta could reduce the amount of water available from the DWB.

CVP Interim Water Acquisition Program. Short-term water marketing arrangements have provided supplies to meet CVPIA fish and wildlife water requirements. An interim water acquisition program was established to acquire water while long-term planning for supplemental fishery water acquisition and refuge water supply acquisition continued. The program, a joint effort by USBR and USFWS, was to be in place from October 1995 through February 1998, as initially envisioned in its environmental documentation. A 1995 environmental assessment and finding of no significant impact for the interim program addressed the regional impacts associated with four categories of water acquisition. The four categories were:

- Acquisition of up to 13.1 taf/yr of water for wildlife refuges in the Sacramento Valley;
- Acquisition of up to 45 cfs of water on Battle Creek for spawning and migration of winter- and spring-run chinook salmon and steelhead trout;
- Acquisition of up to 52.4 taf/yr of water for wildlife refuges within the San Joaquin Valley; and
- Acquisition of up to 100 taf/yr of water on each of the Stanislaus, Tuolumne, and Merced Rivers to meet instream flows for anadromous fish and to help meet Bay-Delta flow and water quality requirements on the San Joaquin River.

Table 3-18 summarizes water purchases made under the program.

Long-Term Agreements

Table 3-19 presents several long-term agreements completed in recent years. Long-term agreements currently being negotiated are presented as future water management options and are discussed in Chapter 6.

One of the terms in the SWP's Monterey Agreement was that agricultural contractors would make 130 taf of SWP annual entitlement available through permanent sale to urban contractors (on a willing buyer-willing seller basis). In 1997, KCWA concluded sale of 25 taf to MWA. KCWA is also in the process of selling up to 7 taf of annual entitlement to Zone 7 WA. Entitlement transfers among CVP contractors are also taking place. In 1997, USBR completed an environmental assessment for a proposed long-term, 25-year transfer of 25 taf/yr of water from

TABLE 3-18

CVP Interim Water Acquisition Program Purchases

Seller	*Water Purchases (taf)* 1995	1996	1997	*Purpose*
Pacific Gas and Electric	8.4	12.3	9.2	Battle Creek instream flow
Oakdale & South San Joaquin IDs	—	—	50.0	Stanislaus and lower San Joaquin River instream flows
Modesto ID	—	—	5.0	Tuolumne and lower San Joaquin River instream flows
Merced ID	—	16.2	45.3	Merced and lower San Joaquin River instream flows
SJR Exchange Contractors	25.0	30.3	40.0	Level 4 refuge supply; lower San Joaquin River instream flows
Semitropic WSD	5.2	4.3	—	Level 4 refuge supply
Yuba County WA	—	—	25.0	Level 4 refuge supply
Corning, Proberta, & Thomes Creek WDs	—	—	4.8	Level 4 refuge supply
Total	**38.6**	**63.1**	**179.3**	

Westside Water District to the CCWD.

Banking project water outside of an SWP contractor's service area for later use within its service area is also provided for in the Monterey Agreement. Semitropic WSD has developed a groundwater storage program with 1 maf of storage capacity. Under this program, an SWP contractor may negotiate an agreement with SWSD to deliver SWP water to SWSD for in-lieu groundwater recharge. At the contractor's request, groundwater would be extracted and delivered to the California Aqueduct, or otherwise exchanged for entitlement. Currently, MWDSC and SCVWD each have long-term agreements with SWSD for 350 taf of storage, Alameda County Water District has an agreement for 50 taf and Z7WA has an agreement for 43 taf.

In addition to the MWDSC-IID water conservation agreement shown in Table 3-19 (described in Chapter 9), MWDSC has executed an agreement for groundwater banking in Arizona. Under an existing agreement between MWDSC and the Central Arizona Water Conservation District, MWDSC can store a limited amount of unused Colorado River water in Arizona for future use. The Southern Nevada Water Authority is also participating in the program. The agreement stipulates that MWDSC and SNWA can store up to 300 taf in central Arizona any time before 2001. To date, MWDSC has placed 89 taf of water in storage and SNWA has placed 50 taf of water in storage for a total of 139 taf. About 90 percent of the stored water can be recovered, contingent upon the declaration of surplus conditions on the Colorado River. When

TABLE 3-19

Recently Completed Long-Term Water Marketing Agreements

Participants	*Region(s)*
Westside Water District, Colusa County Water District	Sacramento River
Semitropic Water Storage District, Santa Clara Valley Water District	Tulare Lake, San Francisco Bay
Semitropic Water Storage District, Alameda County Water District	Tulare Lake, San Francisco Bay
Semitropic Water Storage District, Zone 7 Water Agency	Tulare Lake, San Francisco Bay
Semitropic Water Storage District, Metropolitan Water District of Southern California	Tulare Lake, South Coast
Kern County Water Agency, Mojave Water Agency	Tulare Lake, South Lahontan
Arvin-Edison Water Storage District, Metropolitan Water District of Southern California	Tulare Lake, South Coast
Mojave Water Agency, Solano County Water Agency	South Lahontan, San Francisco Bay
Imperial Irrigation District, Metropolitan Water District of Southern California	Colorado River, South Coast

MWDSC is able to draw on this source, it can divert up to a maximum of 15 taf in any one month. The stored water would be made available to MWDSC by Arizona foregoing the use of part of its normal supply from the Central Arizona Project. MWDSC plans to recover the stored water at times in the future when its Colorado River Aqueduct diversions may be limited.

Water Recycling and Desalting Supplies

Water recycling is the intentional treatment and management of wastewater to produce water suitable for reuse. Several factors affect the amount of wastewater treatment plant effluent that local agencies are able to recycle, including the size of the available market and the seasonality of demands. Local agencies must plan their facilities based on the amount of treatment plant effluent available and the range of expected service area demands. In areas where irrigation uses constitute the majority of recycled water demands, winter and summer demands may vary greatly. (Where recycled water is used for groundwater recharge, seasonal demands are more constant throughout the year.) Also, since water recycling projects are often planned to supply certain types of customers, the proximity of these customers to each other and to available pipeline distribution systems affects the economic viability of potential recycling projects.

Technology available today allows many municipal wastewater treatment systems to produce water supplies at competitive costs. More stringent treatment requirements for disposal of municipal and industrial wastewater have reduced the incremental cost for higher levels of treatment required for recycled water. The degree of additional treatment depends on the intended use. Recycled water is used for agricultural and landscape irrigation, groundwater recharge, and industrial and environmental uses. Some uses are required to meet more stringent standards for public health protection. An example is the City of San Diego's planned 18 mgd wastewater repurification facility. This project (described in Chapter 5) would produce about 16 taf/yr of repurified water to augment local municipal supplies. If implemented, the project would be California's first indirect potable reuse project that discharges treated water directly into a surface reservoir without percolation or injection into a groundwater basin.

The use of recycled water can lessen the demand for new water supply. However, not all water recycling produces new water supply. Bulletin 160 counts water that would otherwise be lost to the State's hydrologic system (i.e., water discharged directly to the ocean or to another salt sink) as recycled water supply. If water recycling creates a new demand which would not otherwise exist, or if it treats water that would have otherwise been reapplied by downstream entities or recharged to usable groundwater, it is not considered new water supply. Water recycling also provides multiple benefits such as reduced wastewater discharge and improved water quality and may be implemented for these purposes in addition to water supply.

Water Recycling Status

The Department, in coordination with the WateReuse Association of California, conducted a survey of 1995 water recycling to update the association's 1993 survey of local agencies' planned water recycling. The 1993 survey was used in Bulletin 160-93 to estimate recycling potential. Bulletin 160-98 uses 1995 data. The 1993 survey had 111 respondents. The 1995 survey had 230 respondents. Survey data are provided in Appendix 3A.

The survey analyzed three levels of project development—base, planned, and conceptual. Projects in the conceptual stage are not yet defined and are deferred in this Bulletin from further evaluation. Total water recycling in 1995 is estimated to be 485 taf/yr,

Water supplied by the City of San Luis Obispo's water reclamation plant is used to provide instream flows in San Luis Obispo Creek.

with 323 taf/yr being new water supply. (The survey reported 450 taf/yr of base water recycling. While most agencies responded, not all water recycling was reported and data from the survey were augmented by additional data where available.) As shown in Table 3-20, recycling projects do not generate new water supply in the State's interior regions. In these regions, treated water from recycling projects would otherwise be used by downstream entities or would be recharged to usable groundwater.

The 1993 survey respondents reported plans to recycle more than 650 taf/yr of water by 1995. This level of recycling did not materialize. The most obvious reason for the shortfall between 1993 projections for 1995 and the actual 1995 recycling was because the 1993 survey was administered when the memory of the 1987-92 drought was vivid. When asked about factors that influence water recycling decisions, respondents reported that "memory of the last drought" and "concern over long-term supply" were most likely to influence recycling decisions. Financial problems and the recession were identified as least likely to affect recycling decisions in the 1995 survey. Existing use of recycled water is shown by category in Table 3-21.

Water Recycling Potential

By 2020, total water recycling is expected to increase from 485 taf/yr to 577 taf/yr, due to greater production at existing treatment plants and new production at plants currently under construction. This base production is expected to increase new water supplies from 323 taf/yr to 407 taf/yr. All new recycled water is expected to be produced in the San Francisco Bay, Central Coast, and South Coast regions. Table 3-22 shows projections of potential water recycling options and resulting new water supply based on the 1995 survey.

By 2020, water recycling options could bring total water recycling potential to over 1.4 maf/yr and could generate as much as 1.1 maf/yr of new supply, if water agencies implemented all projects identified in the survey. Future water recycling options are discussed in Chapter 6 and in the regional chapters.

Seawater Desalting

Total seawater desalting capacity is currently about 8 taf/yr statewide. Most existing plants are small (less than 1 taf/yr) and have been constructed in coastal communities with limited water supplies. The Santa Barbara desalting plant, with capacity of 7.5 taf/yr, is currently the only large seawater desalting plant. The plant was constructed during the 1987-92 drought and is now on long-term standby. In the 1995-level water budget, 8 taf of seawater desalting is included as a drought year supply. In the 2020-level water budget, 8 taf of seawater desalting is included as average and drought year supplies.

Water Quality

A critical factor in determining the usability and reliability of any particular water source is water quality. Water has many potential uses and the water quality requirements for each use vary. The quality

TABLE 3-20

1995 and 2020 Level Water Recycling by Hydrologic Region (taf)
With Existing Facilities and Programs

	1995		*2020*	
Region	*Total Water Recycling*	*New Water Supply*	*Total Water Recycling*	*New Water Supply*
North Coast	13	13	13	13
San Francisco Bay	40	35	42	37
Central Coast	19	18	36	34
South Coast	263	207	331	273
Sacramento River	12	0	15	0
San Joaquin River	37	0	39	0
Tulare Lake	51	0	51	0
North Lahontan	8	8	8	8
South Lahontan	27	27	27	27
Colorado River	15	15	15	15
Total	**485**	**323**	**577**	**407**

San Francisco's Hetch Hetchy Aqueduct system develops its water supply from the Sierra Nevada at Yosemite National Park. High elevation Sierra sources typically have low levels of mineralization. Hetch Hetchy water may be stored in Crystal Springs Reservoir on the San Francisco Peninsula where public access and land use are managed to protect water quality.

TABLE 3-21

1995 Level Total Water Recycling by Category

Category	*Amount (taf)*	*Percent of Total*
Agricultural Irrigation	155	32
Groundwater Recharge	131	27
Landscape Irrigation	82	17
Industrial Uses	34	7
Environmental Uses	15	3
Seawater Intrusion Barrier	5	1
Other[a]	63	13
Total	**485**	**100**

[a] Includes snow making, dust suppression, fire fighting and recreational ponds.

TABLE 3-22

2020 Level Total Water Recycling and New Water Supply (taf)

Projects	*Total Water Recycling*	*New Water Supply*
Base	577	407
Options	835	655
Total	**1,412**	**1,062**

needed to irrigate landscaping, for example, is lower than that required for human consumption or for making computer chips. Sometimes, different water uses may have conflicting water quality requirements. Water temperatures ideal for crop irrigation may be unsuitable for fish spawning.

Overview of Pollutants and Stressors Causing Water Quality Impairment

Mineralization. When water passes over and through soils, it picks up soluble minerals (salts) that are the result of natural processes such as geologic weathering. As the water passes through a watershed and is used for various purposes, concentrations of dissolved minerals and salts in the water increase, a process called mineralization. For example, Sierra Nevada streams typically pick up 20 to 50 mg/L of dissolved minerals from the valley floors on their way to the Pacific Ocean, which is equivalent to about 50 to 140 pounds of salts per acre-foot. An acre-foot of water with total dissolved solids of 736 mg/L (a concentration typical of water in the lower Colorado River) contains one ton of salt. Increased concentrations of minerals can result from both urban and agricultural water uses.

In the Delta, the export location for much of California's water supply, sea water intrusion is a major source of mineralization. Sea water intrusion in the Delta elevates the salinity (particularly the concentrations of sodium, chloride, and bromide) of fresher river water entering the Delta. Bromides are of particular concern because they contribute to formation of disinfection by-products when the water is treated for drinking. The impact of sea water intrusion is especially significant during periods of low river flows. For example during the 1987-92 drought, the average TDS concentration in the lower Sacramento River was 108 mg/L. In the lower San Joaquin River, the average was 519 mg/L, and at Banks Pumping Plant, the southern Delta export location of the SWP, the average was 310 mg/L. During the wetter years from 1993 to 1995, the average TDS concentration in the lower Sacramento River was 98 mg/L, while the average TDS was 342 mg/L in the lower San Joaquin River and 236 mg/L at Banks Pumping Plant.

Some water agencies south of the Delta blend Delta water supplies with other more saline water. Elevated TDS levels limit agencies' ability to recycle water. Agencies must meet customer objectives for TDS and comply with discharge requirements. Increased TDS levels may limit their ability to do so. Agencies' ability to store water for future use through groundwater recharge or conjunctive use programs depends on the TDS of the source water. RWQCB basin plans generally require that water used for recharge not degrade existing groundwater quality. Increased TDS levels increase salt loadings to groundwater basins and may ultimately limit the use of the existing groundwater.

Eutrophication. Eutrophication results when nutrients such as nitrogen and phosphorus are added to surface waters. In the presence of sunlight, algae and other microscopic organisms use the available nutrients to increase their populations. Slightly or moderately eutrophic water can support a complex web of plant and animal life. However, water containing high concentrations of microorganisms is undesirable for drinking water and other needs. Some microorganisms can produce compounds that, while not directly harmful to human health, may cause taste and odor problems in drinking water.

Eutrophication is of great concern at Lake Tahoe, where stringent regulatory controls have been imposed to maintain the lake's unique clarity or halt its decline. The lake is in the early stages of eutrophication and, if it continues, the lake's clarity will be significantly reduced in 20 to 40 years. Development of the basin's erodible land, as well as construction of highways, streets, and logging roads, mobilizes phosphorous and nitrogen compounds deposited in the lake, spurring algae growth. Algae and suspended sediments cloud the lake and reduce its transparency. The combination of the lake's large volume and the low inflow relative to volume aggravates the impacts of phosphorous and nitrogen loading because there is virtually no flushing action.

Temperature and Turbidity. Temperature is important to aquatic organisms and has been especially of concern for salmonid spawning in rivers such as the Sacramento River. Turbidity also affects aquatic organisms and water treatment plant operations. Significant turbidity increases are observed in rivers and streams during periods of high storm runoff. Phytoplankton abundance is affected by increased turbidity, and increased turbidity requires increased chemical addition or changes in operation of water treatment plants.

Abandoned Mines. Runoff from abandoned mines is a major source of heavy metals such as nickel, silver, chromium, lead, copper, zinc, cadmium, mercury, and arsenic in surface waters. Iron Mountain Mine on Spring Creek above Keswick Reservoir on the Sacramento River and Penn Mine above Camanche Reservoir on the Mokelumne River are examples of abandoned mines that drain into major watersheds. Historically, periodic fish kills occurred at these sites when acidic mine drainage with elevated levels of heavy metals flowed into surface waters. Remedial actions have been in various stages of progress at these sites for many years. Concentration of heavy metals well below levels of concern for humans can be acutely toxic to aquatic species. Much of the heavy metals loading in the Sacramento River is thought to come from abandoned mines in the upper watershed. In the drought years of 1991 and 1992, the CVP contributed 125 taf of water to dilute this metals loading.

Pathogens. *Cryptosporidium parvum* outbreaks have been documented in many places throughout the world. Table 3-23 lists some of the most significant outbreaks documented in recent years. In 1993, approximately 403,000 persons in Milwaukee, Wisconsin, became ill from cryptosporidiosis (the disease caused by *Cryptosporidium*) in their water supply. Approximately 100 deaths resulted from this

TABLE 3-23

Significant *Cryptosporidium* Outbreaks

Year	*Location*	*Reported Cases*	*Reported Deaths*
1984	Braun Station, Texas	2,000	—
1987	Carrollton, Georgia	13,000	—
1989	Thames River area, England	100,000	—
1992	Jackson County, Oregon	15,000	—
1993	Milwaukee, Wisconsin	403,000	100
1994	Las Vegas, Nevada	78	16

outbreak. The suspected sources of *Cryptosporidium* were cattle wastes, slaughterhouse wastes, and sewage carried by rivers tributary to Lake Michigan, the drinking water source. This outbreak was associated with operational deficiencies in the water treatment plant and presents a compelling example of the importance of maintaining the quality of source waters.

More significantly, the 1994 *Cryptosporidium* outbreak in Las Vegas, Nevada was the first documented epidemiologically-confirmed waterborne outbreak from a water system with no associated treatment deficiencies or breakdowns. During this outbreak, 78 immunocompromised persons became ill of cryptosporidiosis, even when no *Cryptosporidium* was detected in the treated drinking water.

State and federal surface water treatment rules require that all surface water supplied for drinking receive filtration, high level disinfection, or both, to inactivate or remove viruses and protozoan cysts such as *Giardia lamblia.* However, if a water supply meets certain source water quality criteria and a watershed management program exists to provide protection against these pathogens, the public water purveyor may receive an exemption from filtration requirements. The City and County of San Francisco is currently the only California water retailer exempted from filtration requirements.

Besides *Giardia* and *Cryptosporidium*, there are many other disease-causing viruses, bacteria, and protozoans. Table 3-24 lists some waterborne diseases of concern in the United States.

Disinfection By-Products. As water passes over and through soils, it also dissolves organic compounds (including humic and fulvic acids) present in the soil as a result of plant decay. High levels of these compounds can be present in drainage from wooded or heavily vegetated areas and from soils high in organic content. Chlorine, when used as a disinfectant in drinking water treatment, reacts with these organic compounds to form DBPs such as trihalomethanes and haloacetic acids. Where present, bromide enters the reaction to produce bromine-containing DBPs. Table 3-25 lists some potential DBPs, or chemical classes of DBPs, which may be produced during disinfection of drinking water. A maximum contaminant level for total THMs for drinking water has been established by EPA and by DHS, in accordance with the federal and State Safe Drinking Water Acts. The current MCL for total THMs in drinking water is 0.10 mg/L; no MCL for haloacetic acids is currently in effect. Under EPA's proposed

TABLE 3-24

Some Waterborne Diseases of Concern in the United States

Disease	*Microbial Agent*
Amebiasis	Protozoan (*Entamoeba histolytica*)
Campylobacteriosis	Bacterium (*Campylobacter jejuni*)
Cholera	Bacterium (*Vibrio cholerae*)
Cryptosporidiosis	Protozoan (*Cryptosporidium parvum*)
Giardiasis	Protozoan (*Giardia lamblia*)
Hepatitis	Virus (*hepatitis A*)
Shigellosis	Bacterium (*Shigella species*)
Typhoid Fever	Bacterium (*Salmonella typhi*)
Viral Gastroenteritis	Viruses (N*orwalk, rotavirus, and other types*)

TABLE 3-25

Disinfectants and Disinfection By-Products

Disinfectant	*Potential DBPs or Classes of DBPs*
Chlorine	Trihalomethanes Halogenated acids Haloacetonitriles Halogenated aldehydes Halogenated ketones Chloropicrin Chlorinated phenols
Chloramine	Trihalomethanes Halogenated acids Haloacetonitriles Halogenated aldehydes Halogenated ketones Chloropicrin Chlorinated phenols Cyanogen chloride
Ozone	Bromate Brominated acids Formaldehyde Acetaldehyde Other aldehydes Carboxylic acids Hydrogen peroxide
Chlorine dioxide	Chlorite

Disinfectant/Disinfection By-Product Rule, the maximum contaminant level for THMs will be lowered from 0.1 to 0.08 mg/L in Stage 1 and to 0.04 mg/L in Stage 2. Stage 1 and Stage 2 of the rule are to be promulgated in November 1998 and May 2002, respectively. Stage 1 of the rule also requires conventional surface water treatment systems to remove a percentage of the DBP precursors in the influent (as measured by TOC). A new MCL of 0.06 mg/L for haloacetic acids is also expected to become effective in late 1998.

Ozone is a powerful oxidant widely used for drinking water disinfection. Its advantages are that it efficiently kills pathogens such as *Giardia* and *Cryptosporidium*, destroys tastes and odors, and minimizes production of THMs and most other unwanted DBPs. However, bromate is formed during ozone disinfection of waters containing bromide. EPA estimates that bromate may be a more potent carcinogen than THMs and haloacetic acids. A new MCL of 0.01 mg/L for bromate is expected to be effective in late 1998.

Agricultural Pollutants. Pollutants from agricultural areas are generally of the nonpoint variety, meaning their sources are usually diffuse and are not readily subject to control. Agricultural runoff may contain chemical residues, trace elements, salts, nutrients, and elevated concentrations of organic compounds which may be converted to DBPs in drinking water. Pathogens from dairies and livestock operations can enter waterways through agricultural runoff. Sediments from land tillage and forestry activities can enter waterways, obstructing water flow and affecting the survival and reproduction of fish and other aquatic organisms.

Drainage from some agricultural lands in the San Joaquin Valley contains high concentrations of salts and sometimes concentrations of pesticides and trace elements. This water quality problem is exacerbated when salts are recirculated as Delta water is delivered to the San Joaquin Valley to irrigate agricultural lands, and then is returned to the Delta through the San Joaquin River.

The TOC level of water is generally a good indication of its propensity to form DBPs during water treatment. Rivers passing through the Delta pick up organic matter, due to the contribution of agricultural drainage from peat soils. As Sacramento River water passes through the Delta, its THM formation potential increases almost threefold by the time it reaches Banks Pumping Plant.

Urban Pollutants. Urban pollutants can come from both point and nonpoint sources. Nonpoint sources of pollution include recreational activities, drainage from industrial sites, runoff from streets and highways, discharges from other land surfaces, and aerial deposition. In California, storm water runoff, a major source of nonpoint source pollution, is regulated by SWRCB on behalf of EPA.

Municipal and industrial wastewater discharges are point sources of urban pollution. Most industries in California discharge to a publicly-owned wastewater treatment plant and only indirectly to the environment. These industries are required to pretreat their industrial waste prior to its discharge to municipal wastewater treatment plants. Like municipal discharges, industrial discharges are subject to regulation through the National Pollutant Discharge Elimination System. Industries discharging directly into the environment are also required to have NPDES permits. California's nine RWQCBs are responsible for enforcing compliance with NPDES, including pretreatment regulations. It is, however, the responsibility of the publicly-owned wastewater treatment plants accepting industrial wastes to ensure that industries are complying with pretreatment requirements. RWQCBs conduct regular inspections on permitted discharges and respond to public complaints on illegal discharges.

Wastewater treatment facilities operated under NPDES have, in general, been successful in maintaining the quality of California's water bodies. However, the discharge permits do not regulate all constituents that may cause adverse impacts. For example, the discharge of organic materials that contribute to the formation of DBPs in drinking water is not regulated. NPDES does not guarantee elimination of pathogens such as *Giardia* and *Cryptosporidium*, which are harder to inactivate (disinfect) than most other waterborne pathogens. In addition, permitted discharges can include nitrogen compounds that can be harmful to aquatic life, cause algae growth in surface water bodies, and force downstream drinking water facilities to increase their use of chlorine or to switch to alternative disinfection processes. Some wastewater treatment plant processes do not completely remove all synthetic chemicals that can be present in the water.

Many municipal wastewater treatment plants discharge to surface waters which are subsequently diverted for urban use. For example, the larger wastewater treatment plants discharging to the Sacramento and San Joaquin river systems above the Delta contribute an average daily discharge volume of almost 250 mgd (280 taf/yr) to the system.

Recently, there has been increasing concern about contamination of drinking water sources by methyl tertiary butyl ether. MTBE is a compound added to gasoline to promote more complete combustion and reduce exhaust emissions. In California, MTBE is used to reduce exhaust emissions and to meet federal Clean Air Act requirements for oxygenated gasoline. MTBE is now being found in wells and reservoirs used for municipal water supply.

In drinking water, MTBE causes taste and odor problems at low concentrations. The EPA drinking water advisory of 20 to 40 *u*g/L or below to protect consumer acceptance of drinking water (taste and odor) would also provide a large margin of protection from MTBE's carcinogenic effects and noncancer toxicity. In California, an action level of 35 *u*g/L in drinking water has been issued.

To evaluate the presence of MTBE in California's drinking water supplies, voluntary testing for MTBE was implemented in 1996 by water suppliers in response to a DHS request. In February 1997, a regulation was adopted requiring public drinking water systems to monitor their drinking water sources for MTBE as an unregulated chemical (a chemical for which there is no established regulatory or enforceable drinking water level or maximum contaminant level). Because MTBE is an unregulated chemical, water suppliers will be monitoring and reporting MTBE in sources of drinking water at least once every three years.

The most extensive MTBE contamination of drinking water sources in California was at two well fields (Charnock and Arcadia) in Santa Monica. This contamination was discovered in February 1996, not long after DHS' request for voluntary testing for MTBE. These well fields supplied 80 percent of Santa Monica's municipal water. MTBE concentrations as high as 610 mg/L were observed in the Charnock well field and seven wells in the field were closed. In the Arcadia well field, two wells were closed due to contamination from an underground storage tank at a nearby gasoline station.

As noted in Chapter 2, legislation enacted in 1997 required DHS to begin adopting primary and secondary drinking water standards for MTBE. The secondary drinking water standard for MTBE was to be established by July 1, 1998, and the primary drinking water standard was to be established by July 1, 1999.

The Office of Environmental Health Hazard Assessment released a draft technical document entitled *Public Health Goal for Methyl Tertiary Butyl Ether (MTBE) in Drinking Water* in April 1998. This draft document provided a review of toxicological studies and other reported data related to the adverse effects of exposures to MTBE. Based on the comprehensive review, OEHHA proposed to adopt a drinking water public health goal of 14 *u*g/L.

PHGs adopted by OEHHA are used by DHS in establishing State MCLs. PHGs are based solely on scientific and public health considerations without regard to economic cost considerations. Drinking water standards adopted by DHS also take into consideration factors related to economic and technical feasibility. PHGs established by OEHHA are not regulatory levels and represent only non-mandatory goals. Federal law requires that MCLs established by DHS must be at least as stringent as the federal MCL (if one exists).

Establishing and Meeting Water Quality Standards

The establishment and enforcement of water quality standards for water bodies in California falls under the authority of SWRCB and the nine RWQCBs. The RWQCBs protect water quality through adoption of region-specific water quality control plans, commonly known as basin plans. In general, water quality control plans designate beneficial uses of water and establish water quality objectives designed to protect them. The designated beneficial uses of water may vary between individual water bodies; some are listed in Table 3-26.

Water quality objectives are the limits or levels of water quality constituents or characteristics which are established to protect beneficial uses. Because a particular water body may have several beneficial uses, the water quality objectives established must be protective of all designated uses. When setting water quality objectives, several sources of existing water quality limits are used (Table 3-27), depending on the uses designated in a water quality control plan. When more than one water quality limit exists for a water quality constituent or characteristic (e.g., human health limit vs. aquatic life limit), the more restrictive limit is used as the water quality objective. Table 3-28 lists some typical water quality constituents or characteristics for which water quality objectives may be established in water quality control plans.

TABLE 3-26

A Partial List of Potential Beneficial Uses of Water

- Municipal and Domestic Supply
- Agricultural Supply
- Industrial Supply
- Groundwater Recharge
- Freshwater Replenishment
- Navigation
- Hydropower Generation
- Recreation
- Commercial and Sport Fishing
- Aquaculture
- Freshwater Habitat
- Estuarine Habitat
- Wildlife Habitat
- Preservation of Biological Habitats of Special Significance
- Preservation of Rare, Threatened, or Endangered Species
- Migration of Aquatic Organisms
- Spawning, Reproduction, and/or Early Development
- Shellfish Harvesting

Drinking Water Standards

Drinking water standards for a total of 81 individual drinking water constituents (Table 3-29) are in place under the mandates of the 1986 SDWA amendments. Using the new SDWA standard setting process established in the 1996 amendments, EPA will select at least five new constituents from the candidate list published in March 1998 and will determine whether to regulate them by August 2001. EPA will publish a contaminant candidate list and select constituents for regulation every five years thereafter. The agency may promulgate an interim national primary drinking water regulation for a contaminant without making the required determination or analysis to address an urgent threat to public health. Selection of the new constituents for regulation must be geared toward contaminants posing the greatest health risks.

Occasionally, drinking water regulatory goals may conflict. For example, concern over pathogens such as *Cryptosporidium* spurred a proposed rule requiring more rigorous disinfection. At the same time, there was considerable regulatory concern over THMs and other DBPs resulting from disinfecting drinking water with chlorine. If disinfection is made more rigorous,

TABLE 3-27

A Partial List of Existing Water Quality Limits

- Drinking Water Maximum Contaminant Levels
- Drinking Water Maximum Contaminant Level Goals
- State Action Levels and Recommended Public Health Levels for Drinking Water
- EPA Health Advisories and Water Quality Advisories
- National Academy of Sciences Suggested No-Adverse-Response Levels
- Proposition 65 Regulatory Levels
- EPA National Ambient Water Quality Criteria

TABLE 3-28

A Partial List of Water Quality Constituents or Characteristics for Which Water Quality Objectives May Be Established

Chemical Constituents	Pesticides
Tastes and Odors	pH
Human Health and Ecological Toxicity	Radioactivity
Bacteria	Salinity
Biostimulatory Substances	Sediment
Color	Settleable Material
Dissolved Oxygen	Suspended Material
Floating Material	Temperature
Oil and Grease	Turbidity

TABLE 3-29

Constituents Regulated Under the Federal Safe Drinking Water Act[a]

1,1-Dichloroethylene	Chromium	Methoxychlor
1,1,1-Trichloroethane	cis-1,2-Dichloroethylene	Nickel
1,1,2-Trichloroethane	Copper	Nitrate
1,2-Dibromo-3-chloropropane (DBCP)	Cyanide	Nitrite
1,2-Dichlorobenzene	Dalapon	Oxamyl
1,2-Dichloroethane	Dichloromethane	Pentachlorophenol
1,2-Dichloropropane	Dinoseb	Phthalates
1,2,4-Trichlorobenzene	Diquat	Picloram
1,4-Dichlorobenzene	Endothall	Polychlorinated biphenyls (PCBs)
2,3,7,8-TCDD (Dioxin)	Endrin	Polynuclear Aromatic Hydrocarbons (PAHs)
2,4-Dichlorophenoxyacetic acid (2,4-D)	Epichlorohydrin	Radium 226
2,4,5-TP (Silvex)	Ethylbenzene	Radium 228
Acrylamide	Ethylene dibromide (EDB)	Selenium
Adipates	Fluoride	Simazine
Alachlor	*Giardia lamblia*	Styrene
Antimony	Glyphosate	Tetrachloroethylene
Arsenic	Gross alpha particle activity	Thallium
Asbestos	Gross beta particle activity	Toluene
Atrazine	Heptachlor	Total coliforms
Barium	Heptachlor epoxide	Total trihalomethane
Benzene	Heterotrophic bacteria	Toxaphene
Beryllium	Hexachlorobenzene	trans-1,2-Dichloroethylene
Cadmium	Hexachlorocyclopentadiene	Trichloroethylene
Carbofuran	Lead	Turbidity
Carbon tetrachloride	*Legionella*	Vinyl chloride
Chlordane	Lindane	Viruses
Chlorobenzene	Mercury	Xylenes (total)

[a] As of February 1997.

DBP formation is increased. Poor quality source waters with elevated concentrations of organic precursors or bromides complicate the problem of reliably meeting standards for disinfection while meeting standards for DBPs. The regulatory community must balance benefits and risks associated with efficient disinfection and against higher DBP levels.

EPA promulgated its Information Collection Rule in 1996 to obtain data on the tradeoff posed by simultaneous control of DBPs and pathogens in drinking water. The ICR requires all large public water systems to collect and report data on the occurrence of DBPs and pathogens (including bacteria, viruses, *Giardia*, and *Cryptosporidium*) in drinking water over an 18-month period. With this information, an assessment of health risks due to the presence of DBPs and pathogens in drinking water can be made. EPA can then determine the need to revise current drinking water filtration and disinfection requirements, and the need for more stringent regulations for disinfectants and DBPs.

Source Water Protection/Watershed Management Activities

The 1996 reauthorization of the federal SDWA requires states to conduct source water assessments and encourages states to establish watershed protection programs. In response to this amendment, DHS, in cooperation with SWRCB, is preparing a drinking water source assessment and protection program. Key elements of this program include delineation of the area surrounding the water source, an inventory of possible contaminating activities, and an analysis of the vulnerability of the drinking water source to contamination. The program draft must be submitted to EPA for approval by February 1999. The assessments must be completed in 2003.

California's DWSAP program will cover both groundwater and surface water sources. Since California has not developed a wellhead protection program as required by the 1986 SDWA amendment, the groundwater portion of the DWSAP will serve as the State's wellhead protection program. DHS is responsible for conducting drinking water source assessments, although any public water agency may perform its own assessment, provided it conforms to DHS procedures. When a public water agency has completed an evaluation through another program, that information may be submitted for the drinking water source assessment. For example, drinking water utilities that utilize surface water sources are required under California law to perform watershed sanitary surveys every 5 years. Many of the watershed sanitary surveys completed prior to the DWSAP program will likely satisfy most requirements of the assessment process. Local agencies that choose to conduct their own assessments and implement source protection may receive financial assistance through the drinking water state revolving fund loan program.

The potential sources and causes of water quality impairment vary from watershed to watershed. Table 3-30 lists potential sources and causes of water quality impairment in a watershed.

A Source Water Protection Example. DHS requested that the Department perform a sanitary survey of the SWP. The Department's 1990 initial survey and 1996 update provide an example of factors considered in source protection studies. Table 3-31 lists some recommendations for action resulting from the sanitary survey.

The 1996 sanitary survey identified the need to address pathogens such as *Giardia* and *Cryptosporidium* in SWP waters. The survey recommended investigating each watershed tributary to the SWP to evaluate the potential sources of pathogens and to develop a coordinated microbiological monitoring and reporting system for municipal SWP contractors and agencies. The Department and MWDSC have implemented a pathogen monitoring program. Under this program, regularly scheduled and storm event sampling for *Giardia*, *Cryptosporidium*, and bacteria which serve as general indicators of microbiological contamination (such as *Clostridium perfringens*, *Escherichia coli*, and total and fecal coliforms) is conducted at sites throughout the SWP.

CALFED Bay-Delta Program Water Quality Planning. CALFED's goal for water quality is to provide good water quality for environmental, agricultural, drinking water, industrial, and recreational beneficial uses. To achieve this goal, CALFED is developing water quality actions to address impairments of beneficial uses in the Bay-Delta, Sacramento River, and San Joaquin River Watersheds, and in streams and rivers within SWP and CVP service areas outside of the Central Valley. Some water quality actions being considered by CALFED include:

- Reducing concentrations of heavy metals from mine drainage entering the Delta and its tributaries.
- Reducing pollutant concentrations entering the Delta from the San Joaquin River.
- Reducing vulnerability of Delta water quality to salinity intrusion by implementing a Delta long-term protection plan.
- Improving water circulation in the Delta by constructing seasonally operated barriers in south Delta channels.
- Promoting and supporting efforts of local watershed programs that improve water quality within the Delta and its tributaries.
- Reducing urban and industrial pollutants entering the Delta and its tributaries by controlling urban and industrial runoff.
- Controlling discharge of domestic wastes from boats within the Delta and its tributaries.
- Identifying and implementing actions to address pollution problems in water and sediment within the Delta and its tributaries.
- Reducing pollutants entering the Delta and its tributaries from agricultural runoff.

CALFED identified water quality parameters of concern to beneficial uses and set numerical or narrative water quality targets for each. These targets represent desirable instream concentrations of parameters of concern and would be used as indicators of success to determine the effectiveness of the water quality actions. However, the degree to which these targets are realized will depend upon overall CALFED solutions. Targets may not be fully realized because of competing CALFED solution requirements or because attainment of a target is technically infeasible.

Colorado River Water Quality. The Colorado River is a major source of water supply to Southern California. The river is subject to various water quality influences because its watershed is so large. Much of the watershed is open space and agricultural lands, and municipal and industrial discharges are not a significant source of water quality degradation.

Perchlorate has been detected in the Colorado River. Concentrations ranging from 5 to 9 *u*g/L have been found in Lake Havasu. The contamination source has been traced to manufacturing facilities in the Las Vegas/Henderson, Nevada, area. Several federal Superfund sites contribute to uranium contamination

TABLE 3-30

Potential Sources and Causes of Water Quality Impairment

Source of Contamination	*Pollutant or Stressor*	*Possible Sources*
General	Dissolved minerals	Mineral deposits, mineralized waters, hot springs, seawater intrusion
	Asbestos	Mine tailings, serpentinite formations
	Hydrogen sulfide	Subsurface organic deposits, such as peat soils in Delta islands
	Metals	Mine tailings
	Microbial agents	Wildlife
	Radon	Geologic formations
	Sediment	Forestry activities, stream banks, construction activities, roads, mining operations, gullies
	Altered flow or habitat modification	Impoundments, storm water runoff, artificial drainage, bank erosion, riparian corridor modification
Commercial Businesses	Gasoline	Service stations' underground storage tanks
	Solvents	Dry cleaners, machine shops
	Metals	Photo processors, laboratories, metal plating works
Municipal	Microbial agents	Sewage discharges, storm water runoff
	Pesticides	Storm water runoff, golf courses
	Nutrients	Storm water runoff
	Miscellaneous liquid wastes	Industrial discharge, household waste, septic tanks
Industrial	SOCs, industrial solvents, metals, acids	Electronics manufacturing, metal fabricating and plating, transformers, storage facilities, hazardous waste disposal
	Pesticides	Chemical formulating plants
	Wood preservatives	Plants that pressure treat power poles, wood pilings, railroad ties
Solid Waste Disposal	Solvents, pesticides, metals, organics, petroleum wastes, microbial agents household waste	Disposal sites receive waste from a variety of industries, municipal solid wastes, petroleum products
Agricultural	Pesticides, fertilizers, concentrated mineral salts, microbial agents, sediment, nutrients	Tailwater runoff, agricultural chemical applications, fertilizer usage, chemical storage at farms and applicators' air strips, packing sheds and processing plants, dairies, feed lots, pastures
Disasters	Solvents, petroleum products, microbial agents, other hazardous materials	Earthquake-caused pipeline and storage tank failures and damage to sewage treatment and containment facilities, major spills of hazardous materials, floodwater contamination of storage reservoirs and groundwater sources

TABLE 3-31
SWP Sanitary Survey Update Recommendations

Water Quality Problem	*Recommendation*
Pathogens	Implement pathogen monitoring program
Disinfection By-Product Precursors (Organic Carbon)	Investigate possible means of reducing organic carbon levels in the Delta and North Bay Aqueduct
Disinfection By-Product Precursors (Bromide)	Investigate possible means of controlling bromide concentrations in SWP waters
Dissolved Solids and Turbidity in the California Aqueduct	Investigate measures to reduce salts and turbidity in the Aqueduct
Hazardous Waste Facilities	Inventory hazardous waste facilities and volume of hazardous materials
Hazardous Materials Releases	Review emergency responses to hazardous materials releases to determine types/amounts of materials released and potential for contamination in watershed
Urban Runoff	Review storm water discharges from cities and urbanized areas
Barker Slough/North Bay Aqueduct	Study watershed to determine sources and extent of contamination
Solid Waste Landfills	Review solid waste landfills in SWP watersheds
Underground Storage Tanks	Evaluate status of leaking underground storage tanks within SWP watersheds
Petroleum Product Pipelines	Review pipeline failures resulting in petroleum releases to determine potential for SWP contamination
Emergency Action Plan	Review SWP emergency action plan to ensure document is up-to-date and functionally adequate

in the Colorado River watershed. Uranium mining occurs in the Colorado River Basin above Lake Mead. As uranium decays, alpha-emitting particles are released. Although gross alpha levels in Colorado River water remain under current federal and State MCLs, a slight upward trend in the levels has been observed.

Salts and turbidity from natural geologic formations and from agricultural operations are the primary forms of water quality degradation in the Colorado River. Unlike Delta soils, Colorado River watershed soils are low in organic content. As a result, water from the Colorado River typically has only about one-half the capacity to produce DBPs during drinking water treatment as does water from the Delta.

Mineral concentrations in the Colorado River are usually much higher than those found in water taken from the Delta. For example, from 1993 to 1995 the average TDS of Colorado River Aqueduct water was 691 mg/L, while the average concentration in the California Aqueduct was 236 mg/L. When possible, MWDSC blends Colorado River water with SWP water or other sources to reduce salt concentrations in the water delivered to customers. MWDSC's interim policy is to blend SWP water with Colorado River water to obtain a target TDS level between 500 and 550 mg/L, during April through September. The agency will adopt a long-term blending policy following completion of a salinity management study in 1998 (see Chapter 7).

The federal Colorado River Basin Salinity Control Act of 1974 authorized and directed the Secretary of the Interior to construct facilities to control Colorado River salinity to meet salinity requirements expressed in Minute 242 of the U.S. - Mexican Treaty. The act also directed the Secretary to expedite investigation, planning, and implementation of a salinity control program in the United States upstream of Imperial Dam. Currently, salinity control activities are removing over

600,000 tons of salt per year from the river system. To maintain the 1975 federally approved salinity standards for the basin it is estimated that by 2010 approximately 1.5 million tons of salt will have to be removed each year.

An example of a salinity control measure in the basin is USBR's Yuma desalting plant, constructed to treat agricultural drainage from Arizona's Wellton-Mohawk Irrigation and Drainage District. The plant, said to be the world's largest reverse osmosis desalter, has a capacity of 73 mgd. Plant construction was completed in 1992, and USBR began operating the plant at one-third capacity. A flood event in the Gila River along with above normal runoff in the Colorado River watershed in years since then has reduced the salinity of Colorado River water, permitting the plant to be taken off-line. Currently, agricultural drainage is bypassed through a concrete-lined canal to the Cienega de Santa Clara in Mexico, as long as Minute 242 water quality requirements are being met. Other salinity control measures implemented in Wyoming, Utah, Colorado, and Nevada have included lining or piping irrigation delivery systems, deep well injection of brines, plugging of flowing brine wells, erosion control on saline lands, and irrigation improvements.

Groundwater Quality

Groundwater pollution presents a serious challenge in California. A variety of contaminants have been found in groundwater; most have been introduced by human activities. Prominent among these are nitrates and chemicals such as pesticides and solvents. Most groundwater contamination sites are small and seldom affect water supplies on a regional basis. These sites may require cessation of pumping from one or two water supply wells, or the installation of wellhead treatment. Of greater water supply concern from a statewide perspective are areas of regional groundwater contamination—such as organics in the San Gabriel Valley or nitrates in parts of the San Joaquin Valley—which require a significant reconfiguration of local agency water supply systems. Another important consideration in evaluating larger-scale groundwater contamination problems is the treatment preference now accorded to groundwater sources under the SDWA. Because the SDWA is imposing more stringent requirements on treatment of drinking water from surface sources, many communities are planning to meet their future municipal needs by turning to groundwater.

In California, nitrates in groundwater are widespread (see Chapter 5). Nitrates may enter the soil as a result of fertilizer application, animal waste, septic tanks, industrial disposal, wastewater treatment plant sludge application, or other sources. Certain organisms have the capacity to take nitrogen from the air and convert it to nitrates. In California, the most significant source of nitrates in soils is from agricultural practices, primarily farming operations and animal husbandry. Nitrates can move through the soil into groundwater and, once there, may seriously degrade its usability. Nitrate removal is expensive; therefore, it is often not cost effective to treat nitrate-contaminated waters.

There has been growing concern over the potential human health threat of pathogens in groundwater used as drinking water. This concern stems from pathogens such as *Giardia*, *Cryptosporidium*, bacteria, and viruses being found in well water. Several waterborne-disease outbreaks associated with groundwater have been reported outside California. Some of these outbreaks are listed in Table 3-32.

Concern about pathogens in groundwater has led

TABLE 3-32

Waterborne-Disease Outbreaks Associated with Groundwater Used as a Drinking Water Source, 1993-94

State	*Date*	*Pathogen*	*Organism Type*	*No. of Cases*
Minnesota	November 1993	*Campylobacter jejuni*	Bacterium	32
Missouri	November 1993	*Salmonella serotype Typhimurium*	Bacterium	625
New York	June 1993	*Campylobacter jejuni*	Bacterium	172
Pennsylvania	January 1993	*Giardia lamblia*	Protozoan	20
South Dakota	September 1993	*Giardia lamblia*	Protozoan	7
Washington	April 1993	*Cryptosporidium parvum*	Protozoan	7
Idaho	June 1994	*Shigella flexneri*	Bacterium	33
Minnesota	June 1994	*Campylobacter jejuni*	Bacterium	19
New York	June 1994	*Shigella sonnei*	Bacterium	230
Washington	August 1994	*Cryptosporidium parvum*	Protozoan	134

to regulatory discussions on disinfection requirements for groundwater. EPA is currently developing a Groundwater Disinfection Rule proposal for release in March 1999, with a final rule by November 2000. Data obtained through the ICR will provide information to assess the extent and severity of risk.

The SDWA requires states to implement wellhead protection programs designed to prevent the contamination of groundwater supplying public drinking water wells. Wellhead protection programs rely heavily on local efforts to be effective, because communities have primary access to information on potential contamination sources and can adopt locally-based measures to manage these potential contamination sources. EPA has recommended five steps that communities can take to implement wellhead protection:

- Form a community planning organization.
- Define the land area around the well to be protected.
- Identify potential sources of contamination within the area.
- Develop and implement a management plan to protect the area.
- Plan for emergencies and future water supply needs.

Water Supply Summary by Hydrologic Region

This chapter described how the State's water supplies are affected by climate and hydrology, how water supplies are calculated, and how water supplies are reallocated through storage and conveyance facilities and through water transfers. Also, this chapter discussed water quality considerations that affect beneficial uses of California's water supplies.

Table 3-33 summarizes average year water supplies by hydrologic region assuming 1995 and 2020 levels of development and existing facilities and programs. Similarly, Table 3-34 summarizes drought year water supplies by hydrologic region for existing and future levels of development. Regional water supplies, along with water demands presented in the following chapter, provide the basis for the statewide water budget developed in Chapter 6 and regional water budgets developed in Chapters 7-9.

TABLE 3-33

California Average Year Water Supplies by Hydrologic Region (with existing facilities and programs, in taf)

Region	1995 Surface	1995 Groundwater[a]	1995 Recycled & Desalted	1995 Total (rounded)	2020 Surface	2020 Groundwater[a]	2020 Recycled & Desalted	2020 Total (rounded)
North Coast	20,331	263	13	20,610	20,371	288	13	20,670
San Francisco Bay	7,011	68	35	7,110	7,067	72	37	7,180
Central Coast	318	1,045	18	1,380	368	1,041	42	1,450
South Coast	3,839	1,177	207	5,220	3,625	1,243	273	5,140
Sacramento River	11,881	2,672	0	14,550	12,196	2,636	0	14,830
San Joaquin River	8,562	2,195	0	10,760	8,458	2,295	0	10,750
Tulare Lake	7,888	4,340	0	12,230	7,791	4,386	0	12,180
North Lahontan	777	157	8	940	759	183	8	950
South Lahontan	322	239	27	590	437	248	27	710
Colorado River	4,154	337	15	4,510	3,920	285	15	4,220
Total (rounded)	**65,090**	**12,490**	**320**	**77,900**	**64,990**	**12,680**	**410**	**78,080**

[a] Excludes groundwater overdraft.

TABLE 3-34

California Drought Year Water Supplies by Hydrologic Region (with existing facilities and programs, in taf)

Region	1995 Surface	1995 Groundwater[a]	1995 Recycled & Desalted	1995 Total (rounded)	2020 Surface	2020 Groundwater[a]	2020 Recycled & Desalted	2020 Total (rounded)
North Coast	10,183	294	14	10,490	10,212	321	14	10,550
San Francisco Bay	5,285	92	35	5,410	5,417	89	37	5,540
Central Coast	160	1,142	26	1,330	180	1,159	42	1,380
South Coast	3,196	1,371	207	4,780	3,130	1,462	273	4,870
Sacramento River	10,022	3,218	0	13,240	10,012	3,281	0	13,290
San Joaquin River	6,043	2,900	0	8,940	5,986	2,912	0	8,900
Tulare Lake	3,693	5,970	0	9,660	3,593	5,999	0	9,590
North Lahontan	557	187	8	750	557	208	8	770
South Lahontan	259	273	27	560	326	296	27	650
Colorado River	4,128	337	15	4,480	3,909	284	15	4,210
Total (rounded)	**43,530**	**15,780**	**330**	**59,640**	**43,320**	**16,010**	**420**	**59,750**

[a] Excludes groundwater overdraft.

3A

Survey of Planned Water Recycling

The Department, in coordination with the WateReuse Association of California, conducted a 1995 survey to update the Association's 1993 survey of local agencies' planned water recycling. The following tables show survey results for each of the State's ten hydrologic regions.

Data presented in the tables represent survey respondents' maximum estimates of potential recycling. Often, agencies reported multiple projects that may be alternatives to one another. Some reported projects have multiple local agency sponsors. Their supplies are shown as reported by each sponsor.

TABLE 3A-1

Planned Water Recycling for North Coast Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Lourenco Dairy Irrigation	McKinleyville Community Services District	Planned	400	0	Agriculture	Preliminary Design
Santa Rosa Long-Term Wastewater Project	Santa Rosa, City of	Planned	15,000	0	Agriculture	Preliminary Design
Total			**15,400**	**0**		
Weaverville Water Reclamation Plant	Weaverville Community Services District	Conceptual	90	0	Industrial	
	Weaverville Community Services District	Conceptual	250	0	Landscape	
Total			**340**	**0**		

TABLE 3A-2

Planned Water Recycling for San Francisco Bay Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Phase 1 Water Reclamation Program	Alameda County Water District	Planned	1,628	1,628	Landscape	Feasibility Study
Phase 2 Water Reclamation Program	Alameda County Water District	Planned	1,045	1,045	Landscape	Feasibility Study
Industrial Use	Central Contra Costa Sanitary District	Planned	20,000	20,000	Industrial	Feasibility Study
Lamorinda	Central Contra Costa Sanitary District	Planned	1,300	1,300	Landscape	Preliminary Design
Zone 1	Central Contra Costa Sanitary District	Planned	1,200	1,200	Landscape	Final Design
San Ramon Valley Recycled Water Program	DSRSD/EBMUD Recycled Water Authority	Planned	6,870	6,870	Landscape	Feasibility Study
Hercules/Franklin Canyon WRP-Phase 2	East Bay Municipal Utilities District	Planned	1,300	1,300	Industrial	Feasibility Study
Hercules/Franklin Canyon WRP-Phase 2	East Bay Municipal Utilities District	Planned	950	950	Landscape	Feasibility Study
Lamorinda Water Recycling Project	East Bay Municipal Utilities District	Planned	1,200	0	Landscape	Feasibility Study
San Ramon Valley Water Recycling Project	East Bay Municipal Utilities District	Planned	3,100	3,100	Landscape	Feasibility Study
Central Fairfield-Phase 1	Fairfield-Suisun Sewer District	Planned	342	0	Industrial	Preliminary Design
Central Fairfield-Phase 1	Fairfield-Suisun Sewer District	Planned	281	0	Landscape	Preliminary Design
Central Fairfield-Phase 2	Fairfield-Suisun Sewer District	Planned	599	0	Landscape	Feasibility Study
Lower Suisun Valley Project	Fairfield-Suisun Sewer District	Planned	630	0	Landscape	Feasibility Study
Suisun City/Tolenas	Fairfield-Suisun Sewer District	Planned	22	0	Industrial	Feasibility Study
Suisun City/Tolenas	Fairfield-Suisun Sewer District	Planned	1,066	0	Landscape	Feasibility Study
Central Marin Water Recycling Project	Marin Municipal Water District	Planned	55	55	Industrial	Feasibility Study
Central Marin Water Recycling Project	Marin Municipal Water District	Planned	800	800	Landscape	Feasibility Study
Bel Marin Keys Golf Course	North Marin Water District	Planned	382	382	Landscape	Feasibility Study
Black Point Golf Links	North Marin Water District	Planned	382	382	Landscape	Feasibility Study
Golf Course Irrigation, City Park Irrigation	North San Mateo County San. District	Planned	1,120	1,120	Industrial	Preliminary Design
Golf Course Irrigation, City Park Irrigation	North San Mateo County San. District	Planned	3,300	3,300	Landscape	Preliminary Design
Water Reclamation	Petaluma, City of	Planned	5,750	0	Agriculture	Feasibility Study
Water Reclamation	Petaluma, City of	Planned	500	0	Landscape	Feasibility Study
S.F. Water Recycling Master Plan	San Francisco Department of Public Works	Planned	920	920	Industrial	Preliminary Design
S.F. Water Recycling Master Plan	San Francisco Department of Public Works	Planned	8,280	8,280	Landscape	Preliminary Design
S.F. Water Recycling Master Plan	San Francisco Department of Public Works	Planned	2,300	2,300	Other	Preliminary Design
South Bay Water Recycling Project	Santa Clara, City of	Planned	840	840	Landscape	Final Design
South Bay Water Recycling Project	South Bay Water Recycling-San Jose	Planned	1,000	1,000	Agriculture	Feasibility Study

TABLE 3A-2

Planned Water Recycling for San Francisco Bay Region (continued)

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
South Bay Water Recycling Project	South Bay Water Recycling-San Jose	Planned	10,000	10,000	Environmental	Feasibility Study
South Bay Water Recycling Project	South Bay Water Recycling-San Jose	Planned	10,000	10,000	Industrial	Feasibility Study
South Bay Water Recycling Project	South Bay Water Recycling-San Jose	Planned	10,000	10,000	Landscape	Feasibility Study
Nonpotable Wastewater Reuse Master Plan	Union Sanitation District	Planned	4,031	4,031	Landscape	Feasibility Study
Total			**101,193**	**90,803**		
Exxon Refinery	Benicia, City of	Conceptual	2,800	2,800	Industrial	
Future Irrigation	Central Contra Costa Sanitary District	Conceptual	2,000	2,000	Landscape	
Delta Diablo Primary Treatment Plant Phase 1	Delta Diablo Sanitation District	Conceptual	1,120	1,120	Landscape	
Oakland/Berkeley/I-80 Water Reclamation Project	East Bay Municipal Utilities District	Conceptual	100	100	Industrial	
Oakland/Berkeley/I-80 Water Reclamation Project	East Bay Municipal Utilities District	Conceptual	1,250	1,250	Landscape	
San Leandro Reclamation Facility-Phase 2	East Bay Municipal Utilities District	Conceptual	900	900	Landscape	
Carneros	Napa Sanitation District	Conceptual	1,000	0	Agriculture	
Kennedy Golf Course	Napa Sanitation District	Conceptual	460	0	Landscape	
Imola Recycled Water Pipeline Installation	Napa, City of	Conceptual	400	0	Landscape	
South County Water Reclamation	Santa Clara Valley Water District	Conceptual	200	0	Agriculture	
South County Water Reclamation	Santa Clara Valley Water District	Conceptual	4,300	0	Landscape	
South County Water Reclamation	Santa Clara Valley Water District	Conceptual	1,350	0	Other	
Total			**15,880**	**8,170**		

TABLE 3A-3

Planned Water Recycling for Central Coast Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
SSLOCSD Reclamation Project	Arroyo Grande, City of	Planned	200	200	Agriculture	Preliminary Design
SSLOCSD Reclamation Project	Arroyo Grande, City of	Planned	700	700	Groundwater Recharge	Preliminary Design
SSLOCSD Reclamation Project	Arroyo Grande, City of	Planned	600	600	Landscape	Preliminary Design
Aquifer Storage/Recovery	Monterey County Regional Water Agency	Planned	10,000	10,000		
Castroville Seawater Intrusion Project	Monterey County Water Resources Agency	Planned	3,700	3,700	Agriculture	Construction
Urban Reuse Project	Monterey Regional Water Pollution Control Agency	Planned	3,000	3,000	Landscape	Feasibility Study
Santa Cruz Water Reuse Project	Pajaro Valley Water Management Agency	Planned	6,000	6,000		
Watsonville Water Reuse Project	Pajaro Valley Water Management Agency	Planned	12,000	12,000		
Water Reuse Project	San Luis Obispo, City of	Planned	300	0	Agriculture	Feasibility Study
Water Reuse Project	San Luis Obispo, City of	Planned	1,200	0	Environmental	Feasibility Study
Water Reuse Project	San Luis Obispo, City of	Planned	900	0	Landscape	Feasibility Study
SVWD Recycled Water Plant	Scotts Valley Water District	Planned	450	450	Landscape	Preliminary Design
Total			**39,050**	**36,650**		
City of Buellton	Buellton, City of	Conceptual	375	0	Groundwater Recharge	
City of Morro Bay WWTP	Morro Bay, City of	Conceptual	625	0	Agriculture	
Envest Water Initiative/Landfill Groundwater Recharge	Vandenberg Air Force Base	Conceptual	20	0	Agriculture	
Total			**1,020**	**0**		

TABLE 3A-4

Planned Water Recycling for South Coast Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Reclaimed Water Wholesale Transmission System	Calleguas Municipal Water District	Planned	617	0	Other	Preliminary Design
Non-domestic Irrigation System	Capistrano Valley Water District	Planned	200	200	Agriculture	Feasibility Study
Non-domestic Irrigation System	Capistrano Valley Water District	Planned	3,100	3,100	Landscape	Feasibility Study
Carlsbad Water Reclamation Plan-Encina Basin-P2	Carlsbad Municipal Water District	Planned	500	500	Agriculture	Preliminary Design
Carlsbad Water Reclamation Plan-Encina Basin-P2	Carlsbad Municipal Water District	Planned	11,000	11,000	Landscape	Preliminary Design
Reclaimed Water System	Castaic Lake Water Agency	Planned	1,300	0	Industrial	Preliminary Design
Reclaimed Water System	Castaic Lake Water Agency	Planned	8,000	0	Landscape	Preliminary Design
Esteban Torres Water Recycling Project	Central Basin Municipal Water District	Planned	4,400	4,400	Industrial	Preliminary Design
Esteban Torres Water Recycling Project	Central Basin Municipal Water District	Planned	4,600	4,600	Landscape	Preliminary Design
Carbon Canyon Reclamation Project-Phase 1	Chino Basin Municipal Water District	Planned	800	0	Industrial	Final Design
Carbon Canyon Reclamation Project-Phase 1	Chino Basin Municipal Water District	Planned	1,090	0	Landscape	Final Design
Carbon Canyon Reclamation Project-Phase 1	Chino Basin Municipal Water District	Planned	10,000	0	Other	Final Design
Expanded Carbon Canyon Reclamation Project	Chino Basin Municipal Water District	Planned	6,000	0	Agriculture	Feasibility Study
Expanded Carbon Canyon Reclamation Project	Chino Basin Municipal Water District	Planned	1,620	0	Industrial	Feasibility Study
Expanded Carbon Canyon Reclamation Project	Chino Basin Municipal Water District	Planned	7,598	0	Landscape	Feasibility Study
Expanded Carbon Canyon Reclamation Project	Chino Basin Municipal Water District	Planned	10,000	0	Other	Feasibility Study
Regional Plant No. 4 Outfall Project	Chino Basin Municipal Water District	Planned	4,670	0	Industrial	Final Design
Regional Plant No. 4 Outfall Project	Chino Basin Municipal Water District	Planned	4,090	0	Landscape	Final Design
Carbon Canyon Water Reclamation Facility	Chino, City of	Planned	90	0	Industrial	Construction
Carbon Canyon Water Reclamation Facility	Chino, City of	Planned	80	0	Landscape	Construction
Reclamation Project 1	Corona, City of	Planned	2,200	0	Landscape	Feasibility Study
T-Plant Filter Washwater Recycling Project	Covina Irrigating Company	Planned	500	0	Other	Preliminary Design
E. Thornton Ibbetson Century Recycled Water Project	Downey, City of	Planned	1,180	1,180	Landscape	Feasibility Study
El Toro Water District Reclamation	El Toro Water District	Planned	432	432	Landscape	Feasibility Study
City of Escondido Regional Water Recycling Program	Escondido, City of	Planned	8,000	8,000	Groundwater Recharge	Final Design

TABLE 3A-4

Planned Water Recycling for South Coast Region (continued)

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
City of Escondido Regional Water Recycling Program	Escondido, City of	Planned	600	600	Industrial	Final Design
City of Escondido Regional Water Recycling Program	Escondido, City of	Planned	3,000	3,000	Landscape	Final Design
Verdugo-Schol-Brand Project	Glendale, City of	Planned	418	418	Landscape	Construction
Irvine Ranch Water District	Irvine Ranch Water District	Planned	75	75	Agriculture	Feasibility Study
Irvine Ranch Water District	Irvine Ranch Water District	Planned	825	825	Industrial	Feasibility Study
Irvine Ranch Water District	Irvine Ranch Water District	Planned	26,500	26,500	Landscape	Feasibility Study
North San Diego County Reclamation Project Phase 2	Leucadia County Water District	Planned	8,000	8,000	Landscape	Feasibility Study
Alamitos Barrier	Los Angeles County Sanitation Districts	Planned	10,000	10,000	Seawater Intrusion Barrier	Preliminary Design
Castaic Lake Water Agency Reclaimed Water Master Plan	Los Angeles County Sanitation Districts	Planned	10,360	10,360	Landscape	Preliminary Design
City of West Covina	Los Angeles County Sanitation Districts	Planned	2,800	2,800	Landscape	Final Design
Northlake	Los Angeles County Sanitation Districts	Planned	2,800	0	Groundwater Recharge	Preliminary Design
Northlake	Los Angeles County Sanitation Districts	Planned	1,680	0	Landscape	Preliminary Design
Puente Hills/Rose Hills Reclaimed Water District System	Los Angeles County Sanitation Districts	Planned	1,500	1,500	Landscape	Construction
San Gabriel Valley Groundwater Recharge Demonstration	Los Angeles County Sanitation Districts	Planned	25,000	25,000	Groundwater Recharge	Preliminary Design
Whittier Narrows Recreation Area	Los Angeles County Sanitation Districts	Planned	4,000	4,000	Landscape	Preliminary Design
Central City/Elysian Park Water Recycling Project	Los Angeles, City of (DWP)	Planned	2,000	2,000	Industrial	Feasibility Study
Central City/Elysian Park Water Recycling Project	Los Angeles, City of (DWP)	Planned	2,000	2,000	Landscape	Feasibility Study
East Valley Water Recycling Project	Los Angeles, City of (DWP)	Planned	22,000	22,000	Groundwater Recharge	Construction
East Valley Water Recycling Project	Los Angeles, City of (DWP)	Planned	6,500	6,500	Landscape	Construction
Headworks Water Recycling Project	Los Angeles, City of (DWP)	Planned	10,000	10,000	Groundwater Recharge	Feasibility Study

TABLE 3A-4

Planned Water Recycling for South Coast Region (continued)

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Los Angeles Harbor Water Recycling Project	Los Angeles, City of (DWP)	Planned	9,000	9,000	Industrial	Preliminary Design
Los Angeles Harbor Water Recycling Project	Los Angeles, City of (DWP)	Planned	3,000	3,000	Landscape	Preliminary Design
Los Angeles Harbor Water Recycling Project	Los Angeles, City of (DWP)	Planned	5,000	5,000	Seawater Intrusion Barrier	Preliminary Design
Sepulveda Basin Water Recycling Project	Los Angeles, City of (DWP)	Planned	3,000	3,000	Landscape	Preliminary Design
Westside Water Recycling Project	Los Angeles, City of (DWP)	Planned	900	900	Industrial	Construction
Westside Water Recycling Project	Los Angeles, City of (DWP)	Planned	250	250	Landscape	Construction
Olivenhain/Kelwood Reclamation Project	Olivenhain Municipal Water District	Planned	100	0	Agriculture	Feasibility Study
Olivenhain/Kelwood Reclamation Project	Olivenhain Municipal Water District	Planned	1,800	0	Landscape	Feasibility Study
OCR Project-CSDOC	Orange County Sanitation Districts	Planned	100,000	100,000	Groundwater Recharge	Feasibility Study
Green Acres-Phase 2	Orange County Water District	Planned	1,900	1,900	Landscape	Final Design
Orange County Reclamation Project	Orange County Water District	Planned	75,000	75,000	Groundwater Recharge	Feasibility Study
Upgrade-Padre Dam W.R. Facilities	Padre Dam Municipal Water District	Planned	200	0	Industrial	Construction
Upgrade-Padre Dam W.R. Facilities	Padre Dam Municipal Water District	Planned	1,000	0	Landscape	Construction
Upgrade-Padre Dam W.R. Facilities	Padre Dam Municipal Water District	Planned	10,000	0	Other	Construction
City of Poway-Escondido	Poway, City of	Planned	500	500	Agriculture	Construction
City of Poway-Escondido	Poway, City of	Planned	1,500	1,500	Landscape	Construction
City of Poway-S.D.	Poway, City of	Planned	500	500	Agriculture	Construction
City of Poway-S.D.	Poway, City of	Planned	500	500	Agriculture	Construction
City of Poway-S.D.	Poway, City of	Planned	1,500	1,500	Landscape	Construction
North City Reclamation Plant-Poway Resources	Poway, City of	Planned	1,000	1,000	Landscape	Construction
Bonsall Basin Desalter	Rainbow Municipal Water Disrict	Planned	3,000	0	Agriculture	Feasibility Study
Santa Margarita Live Stream Discharge	Rancho California Water District	Planned	15,000	0	Groundwater Recharge	Feasibility Study
Irrigation & Industrial Projects	Riverside , City of	Planned	606	0	Industrial	Final Design
Irrigation & Industrial Projects	Riverside , City of	Planned	3,322	0	Landscape	Final Design
San Pasqual Groundwater Management Program	San Diego, City of	Planned	8,000	8,000	Groundwater Recharge	Feasibility Study

TABLE 3A-4

Planned Water Recycling for South Coast Region (continued)

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
South Bay Water Reclamation Project	San Diego, City of	Planned	2,500	2,500	Agriculture	Final Design
South Bay Water Reclamation Project	San Diego, City of	Planned	5,500	5,500	Landscape	Final Design
Water Repurification Project	San Diego, City of	Planned	13,000	13,000	Other	Feasibility Study
San Elijo Joint Powers Authority WRF	San Elijo Joint Powers Authority	Planned	580	580	Agriculture	Final Design
San Elijo Joint Powers Authority WRF	San Elijo Joint Powers Authority	Planned	2,200	2,200	Landscape	Final Design
San Elijo Joint Powers Authority	Santa Fe Irrigation District	Planned	100	100	Agriculture	Final Design
San Elijo Joint Powers Authority	Santa Fe Irrigation District	Planned	700	700	Landscape	Final Design
Lower Sweetwater River Demineralization Project	Sweetwater Authority	Planned	4,000	0	Seawater Intrusion Barrier	Final Design
Dove Canyon Weather Recovery System	Trabuco Canyon Water District	Planned	100	0	Landscape	Feasibility Study
Central Valley Water Reclamation Facility	Valley Center Municipal Water District	Planned	700	0	Agriculture	Final Design
Central Valley Water Reclamation Facility	Valley Center Municipal Water District	Planned	250	0	Landscape	Final Design
Lower Moosa Canyon W.R.F.-Expansion	Valley Center Municipal Water District	Planned	820	0	Groundwater Recharge	Construction
Reclamation Distribution System	Ventura County Waterworks District #1	Planned	2,234	0	Agriculture	Preliminary Design
Reclamation Distribution System	Ventura County Waterworks District #1	Planned	3,351	0	Landscape	Preliminary Design
Alamitos Barrier Recycled Water Project	Water Replenishment District	Planned	6,000	6,000	Seawater Intrusion Barrier	Preliminary Design
Dominguez Gap Barrier Recycled Water Project	Water Replenishment District	Planned	2,600	2,600	Industrial	Preliminary Design
Dominguez Gap Barrier Recycled Water Project	Water Replenishment District	Planned	6,000	6,000	Seawater Intrusion Barrier	Preliminary Design
Montebello Forebay Advanced Treatment Plant	Water Replenishment District	Planned	10,000	10,000	Groundwater Recharge	Feasibility Study
West Basin Recycling Project-Phase 2	West Basin Municipal Water District	Planned	48,000	48,000	Industrial	Final Design
West Basin Recycling Project-Phase 2	West Basin Municipal Water District	Planned	27,000	27,000	Landscape	Final Design
West Basin Recycling Project-Phase 2	West Basin Municipal Water District	Planned	20,000	20,000	Seawater Intrusion Barrier	Final Design
West Los Angeles Extension	West Basin Municipal Water District	Planned	1,240	1,240	Industrial	Construction
West Los Angeles Extension	West Basin Municipal Water District	Planned	1,400	1,400	Landscape	Construction
March Air Force Base	Western Municipal Water District	Planned	200	0	Landscape	Construction

TABLE 3A-4

Planned Water Recycling for South Coast Region (continued)

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Vogel Property	Yucaipa Valley Water District	Planned	500	0	Agriculture	Feasibility Study
Vogel Property	Yucaipa Valley Water District	Planned	1,700	0	Landscape	Feasibility Study
Total			**639,378**	**527,360**		
Regional Groundwater Recharge Project	Chino Basin Municipal Water District	Conceptual	1,000	0	Groundwater Recharge	
Reclaimed Water Distribution System-Phase 2	Lakewood, City of	Conceptual	107	0	Landscape	
City of Escondido	Rincon del Diablo Municipal Water District	Conceptual	450	0	Landscape	
West Basin Municipal Water Recycling Plant	Torrance, City of Municipal Water District	Conceptual	10,000	0	Industrial	
West Basin Municipal Water Recycling Plant	Torrance, City of Municipal Water District	Conceptual	1,500	0	Landscape	
Walnut Valley WD R.W. Expansion Project	Walnut Valley Water District	Conceptual	800	0	Industrial	
Walnut Valley WD R.W. Expansion Project	Walnut Valley Water District	Conceptual	2,500	0	Landscape	
Shadow Ridge Reclamation-Phase 2	Buena Sanitation District	Conceptual	600	600	Landscape	
Los Alisos Water District Tertiary Upgrade Plant	Los Alisos Water District	Conceptual	3,000	3,000	Landscape	
Eastside Greenbelt	Los Angeles, City of (DWP)	Conceptual	1,500	1,500	Industrial	
West Valley Water Recycling Project	Los Angeles, City of (DWP)	Conceptual	2,400	2,400	Landscape	
SCRWTP-5MGD	Oceanside, City of	Conceptual	5,603	5,603	Landscape	
Water Reclamation Project-Phase 2	Otay Water District	Conceptual	4,550	4,550	Landscape	
Santa Monica Dry-Weather Runoff Reclamation Project	Santa Monica, City of	Conceptual	450	450	Landscape	
Connejo Creek Diversion Project	Thousand Oaks, City of	Conceptual	5,000	5,000	Seawater Intrusion Barrier	
Total			**39,460**	**23,103**		

TABLE 3A-5

Planned Water Recycling for Sacramento River Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Land Based Discharge	Beale Air Force Base	Planned	400	0	Other	Feasibility Study
Plumas Lake Wastewater Treatment & Reclamation	Olivehurst Public Utilities District	Planned	300	0	Environmental	Final Design
Plumas Lake Wastewater Treatment & Reclamation	Olivehurst Public Utilities District	Planned	300	0	Landscape	Final Design
Water Reclamation Plant-Phase 1	Sacramento Regional County Sanitation District	Planned	3,500	0	Landscape	Final Design
Water Reclamation Plant-Phase 1	Sacramento Regional County Sanitation District	Planned	1,500	0	Other	Final Design
Total			**6,000**	**0**		
BEAY-94-1002 Golf Course Expansion	Beale Air Force Base	Conceptual	150	0	Landscape	
Laundry Dept. Water Reuse	California State Prison-Solano	Conceptual	19	0	Industrial	
City of Lakeport Municipal Sewer District	Lakeport, City of	Conceptual	1,500	0	Agriculture	
City of Live Oak	Live Oak, City of	Conceptual	1	0	Landscape	
Total			**1,670**	**0**		

TABLE 3A-6

Planned Water Recycling for San Joaquin River Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Forest Meadows	Calaveras County Water District	Planned	170	0	Landscape	Preliminary Design
City of Ceres WWRF Expansion Project	Ceres, City of	Planned	4,480	0	Agriculture	Preliminary Design
Turlock Irrigation District Almond Power Plant	Ceres, City of	Planned	448	0	Other	Construction
Wastewater Reclamation Project	Groveland Community Services District	Planned	425	0	Agriculture	Preliminary Design
California Youth Soccer Association	Lodi, City of	Planned	1,100	0	Landscape	Preliminary Design
Effluent Pipeline	Sierra Conservation Center	Planned	170	0	Agriculture	Preliminary Design
Effluent Pipeline	Sierra Conservation Center	Planned	100	0	Landscape	Preliminary Design
Total			**6,893**	**0**		
Title 22 Plant	Angels Camp, City of	Conceptual	50	0	Agriculture	
Title 22 Plant	Angels Camp, City of	Conceptual	150	0	Environmental	
Title 22 Plant	Angels Camp, City of	Conceptual	400	0	Landscape	
Copper Cove	Calaveras County Water District	Conceptual	300	0	Landscape	
City of Galt WWTP	Galt, City of	Conceptual	340	0	Agriculture	
Modesto Reclamation Project	Modesto, City of	Conceptual	5	0	Landscape	
Modesto Reclamation Project	Modesto, City of	Conceptual	15	0	Other	
Uncertain	Stockton, City of	Conceptual	60,000	0	Groundwater Recharge	
Ag Reuse	Turlock, City of	Conceptual	5,000	0	Agriculture	
Total			**66,260**	**0**		

TABLE 3A-7

Planned Water Recycling for Tulare Lake Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Wastewater Reclamation Phase 1	Dinuba, City of	Planned	11,202	0	Groundwater Recharge	Preliminary Design
Filtration/Disinfection Conjuctive Use Project	Malaga Community Water District	Planned	392	0	Other	Preliminary Design
Airport Golf Course/Open Areas Rec.	Porterville, City of	Planned	6,017	0	Agriculture	Preliminary Design
Airport Golf Course/Open Areas Rec.	Porterville, City of	Planned	2,580	0	Groundwater Recharge	Preliminary Design
Airport Golf Course/Open Areas Rec.	Porterville, City of	Planned	365	0	Landscape	Preliminary Design
Reclaimed Waste Water	U.S. Navy	Planned	4,000	0	Agriculture	Final Design
Total			**24,556**	**0**		

TABLE 3A-8

Planned Water Recycling for North Lahontan Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
No projects reported.	-	-	-	-	-	-

TABLE 3A-9

Planned Water Recycling for South Lahontan Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
MCWD Recycled Water District	Mammoth Comm. Water District	Planned	1,000	0	Environmental	Preliminary Design
MCWD Recycled Water District	Mammoth Comm. Water District	Planned	500	0	Groundwater Recharge	Preliminary Design
MCWD Recycled Water District	Mammoth Comm. Water District	Planned	100	0	Industrial	Preliminary Design
MCWD Recycled Water District	Mammoth Comm. Water District	Planned	600	0	Landscape	Preliminary Design
MCWD Recycled Water District	Mammoth Comm. Water District	Planned	300	0	Other	Preliminary Design
Effluent Re-use	Running Springs Water District	Planned	250	0	Other	Preliminary Design
Total			**2,750**	**0**		
Golf Course	Barstow, City of	Conceptual	5,289	0	Landscape	
Total			**5,289**	**0**		

TABLE 3A-10

Planned Water Recycling for Colorado River Region

Project Name	*Agency Name*	*Type*	*Total Supply (af)*	*New Supply (af)*	*Category of Use*	*Comments*
Hi-Desert W.D. W.W. Collection & Treatment Plant	Hi-Desert Water District	Conceptual	975	0	Groundwater Recharge	
Hi-Desert W.D. W.W. Collection & Treatment Plant	Hi-Desert Water District	Conceptual	350	0	Landscape	
Total			**1,325**	**0**		

4

Urban, Agricultural, and Environmental Water Use

This chapter describes present and forecasted urban, agricultural, and environmental water use. The chapter is organized into three major sections, one for each category of water use.

Water use information is presented at the hydrologic region level of detail under normalized hydrologic conditions. Forecasted 2020-level urban and agricultural water use have not changed greatly since publication of Bulletin 160-93. Forecasted urban water use depends heavily on population forecasts. Although the DOF has updated its California population projections since the last Bulletin, U.S. census data are an important foundation for the projections, and a new census will not be performed until 2000. The Department's forecasts of agricultural water use change relatively slowly in the short-term because the corresponding changes in forecasted agricultural acreage are a small percentage of the State's total irrigated acreage. Changes in base year and forecasted environmental water use from the last Bulletin reflect implementation of SWRCB's Order WR 95-6 for the Bay-Delta.

Nursery products are California's third largest farm product in gross value. The nursery industry is affected by the availability of both agricultural and urban water supplies.

Summary of Key Statistics

Shown below for quick reference are some key statistics presented in this chapter. Water use information values shown are for applied water use in average water year conditions. The details behind the statistics are discussed later.

	1995	*2020*	*Change*
Population (million)	32.1	47.5	+15.4
Irrigated crops (million acres)	9.5	9.2	-0.3
Urban water use (maf)	8.8	12.0	+3.2
Agricultural water use (maf)	33.8	31.5	-2.3
Environmental water use (maf)	36.9	37.0	+0.1
Percent of total			
Urban water use (%)	11	15	+4
Agricultural water use (%)	43	39	-4
Environmental water use (%)	46	46	0

Water Use Calculation

The urban, agricultural, and environmental water uses calculated in this chapter are combined with water supply information (Chapter 3) to form statewide balances (Chapter 6) and regional balances (Chapters 7-9). As noted in the Chapter 3 discussion of water supplies, Bulletin 160-98 water balances are computed with applied water data, instead of the net water data used in previous editions of the Bulletin.

Figure 4-1 shows statewide water use in terms of applied water and depletions. The two methods provide similar results at a statewide level. (The large depletion associated with environmental water use reflects the magnitude of wild and scenic river outflow to the Pacific Ocean, as discussed later in the chapter.)

For purposes of presentation in the Bulletin, urban, agricultural, and environmental water uses are treated separately. In reality, these uses are usually linked by California's hydrologic system. As discussed in Chapter 3, the return flow from one water user often becomes the supply for a downstream user. The applied water budgets used in Bulletin 160-98 reflect the multiple uses of water in a river basin. Water supplies in a river basin may count toward meeting wild and scenic river use in the Sierra Nevada foothills, count toward urban and/or agricultural uses on the Central Valley floor, and count toward meeting Bay-Delta outflow farther downstream.

Another change from Bulletin 160-93 was eliminating the "other" water use category to simplify information presentation. This category included major canal conveyance losses, recreation use, cooling water use, energy recovery use, and use by high water using industries. Water uses previously categorized as "other" are now included in urban, agricultural, or environmental water use, according to their intended purpose. At a statewide level, the magnitude of these other uses is small in comparison to that of the major categories.

Land Use Considerations

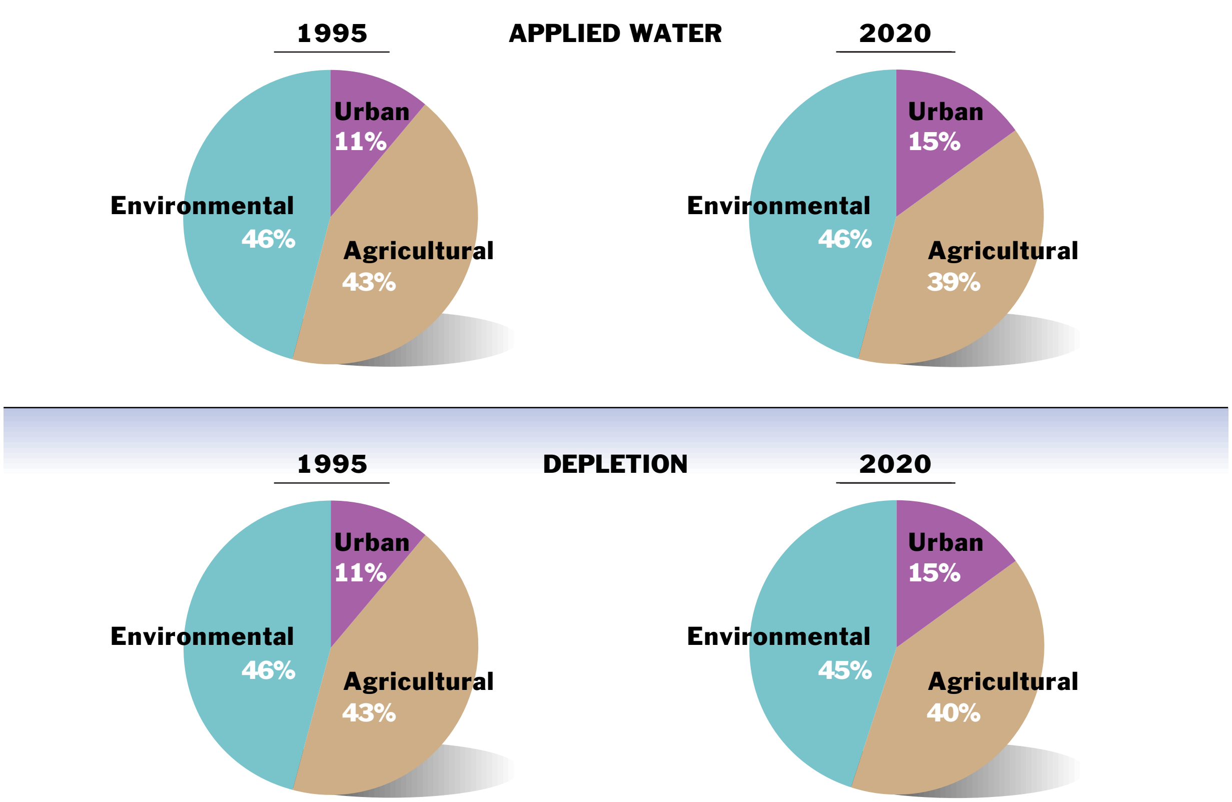
It is important to understand how urban, agricultural, and environmental water use are shaped by land use patterns and land use planning. Patterns of future development and water use trends are dictated by city and county land use planning decisions. Urbanization of agricultural lands, open space preservation, habitat creation, and wetlands preservation policies are examples of land use-related decisions that have water use implications.

DOF forecasts that California's population will increase by more than 15 million people by 2020. Where these additional people live affects statewide urban water use. For example, in terms of percent population increase, DOF forecasts that the City and County of San Francisco will have one of the slowest growth rates statewide. Adjoining Bay Area counties are also forecasted to grow slowly, reflecting the region's intensive urbanization and relatively small amounts of remaining undeveloped land. Areas expected to experience high growth rates include some San Joaquin Valley counties and the Inland Empire region in South-

Future land use patterns are important in forecasting future water use. How and where presently undeveloped lands are developed—or are preserved from development—affects water use calculations.

FIGURE 4-1

California Applied Water Use and Depletion



ern California. This population shift to warmer, drier inland areas where urban outdoor water use is higher affects future statewide water demands.

The location of urban development also affects agricultural water use. For example, subdivisions constructed on non-irrigated grazing lands do not directly displace agricultural use (although they may compete with existing agricultural water users for a supply). Subdivisions constructed on irrigated farmland result in direct conversion of water use from agricultural to urban. Bulletin 160-98 forecasts a statewide decline in irrigated acreage by 2020. Most of that decline is the result of expected urbanization of irrigated agricultural lands, especially in the San Joaquin Valley and South Coast areas. (To some extent, urbanization may shift agricultural development to presently undeveloped lands, but such lands are usually of lower quality and can economically support only limited crop types.) Local open space preservation goals can affect the extent of land use conversion. Williamson Act contracts are a commonly used means of encouraging preservation of agricultural land use, especially for agricultural lands near urban areas. Not all open space preservation goals affect water use. For example, some land use planning agencies in urban areas have set aside ridgetop areas as lands to be managed for recreation or open space to preserve viewsheds. If the areas set aside are non-irrigated grazing lands, water use impacts are minimal.

Policies to preserve and enhance wetlands can entail creating new wetlands or providing increased water supplies to existing wetlands, thus increasing environmental water use, often by conversion of agricultural water supplies. Programs creating new wildlife habitat areas would entail conversion of agricultural lands and water supplies to environmental uses.

Urban Water Use

Forecasts of urban water use for the Bulletin are based on population information and per capita water use estimates, as described later in this section. Factors influencing per capita water use include expected demand reduction due to implementation of water conservation programs. The Department has modeled effects of conservation measures and socioeconomic changes on per capita use in 20 major water service areas to estimate future changes in per capita use by hydrologic region.

The Department's Bulletin 160 series makes per capita water use estimates at a statewide level of detail. An urban water agency making estimates for its own service area would be able to incorporate more complexity in its forecasting because the scope of its effort is narrow. For this reason, and because DOF population projections seldom exactly match population projections prepared by cities and counties, the Bulletin's water use forecasts are expected to be representative of, rather than identical to, those of local water agencies.

Population Growth

Data about California's population—its geographic distribution and projections of future population and their distribution—come from several sources. The Department works with base year and projected year population information developed by DOF for each county in the State. The decadal census is a major benchmark for population projections. DOF works from census data to calculate the State's population in noncensus years, and to project future populations. Figure 4-2 shows DOF's projected growth rates by county for year 2020. (State policy requires that all State agencies use DOF population projections for planning, funding, and policy making activities.)

DOF uses as its starting population the 1990 census, modified by the Bureau of the Census for known misreporting. (These counts represent a modification to the age distribution of the census count and not an adjustment for undercount to the total.) Between 1950 and 1980 the birthrate in California mirrored the nation's. A sharp divergence began during the 1980s; the nation's birthrate was flat while the birthrate in California rose sharply.

California's annual growth rate was 2 to 3 percent throughout the 1980s. After 1990, the rate slowed to 1.3 percent and the State's population grew by only 2 million, for a 1995 population of 32.1 million. California's growth since 1992 has also been affected by lower than projected natural increase (births minus deaths) and net migration. Domestic migration patterns tend to parallel the unemployment differential rate between California and other states. Between 1990 and 1994, California lost more than 700,000 jobs due to the economic recession. This job loss resulted in a new demographic phenomenon for California—a net migration of California residents to other states. By 1996, California had replaced the jobs lost during the recession.

Migration is the most volatile component of

FIGURE 4-2

Projected Growth Rates by County, 1995-2020

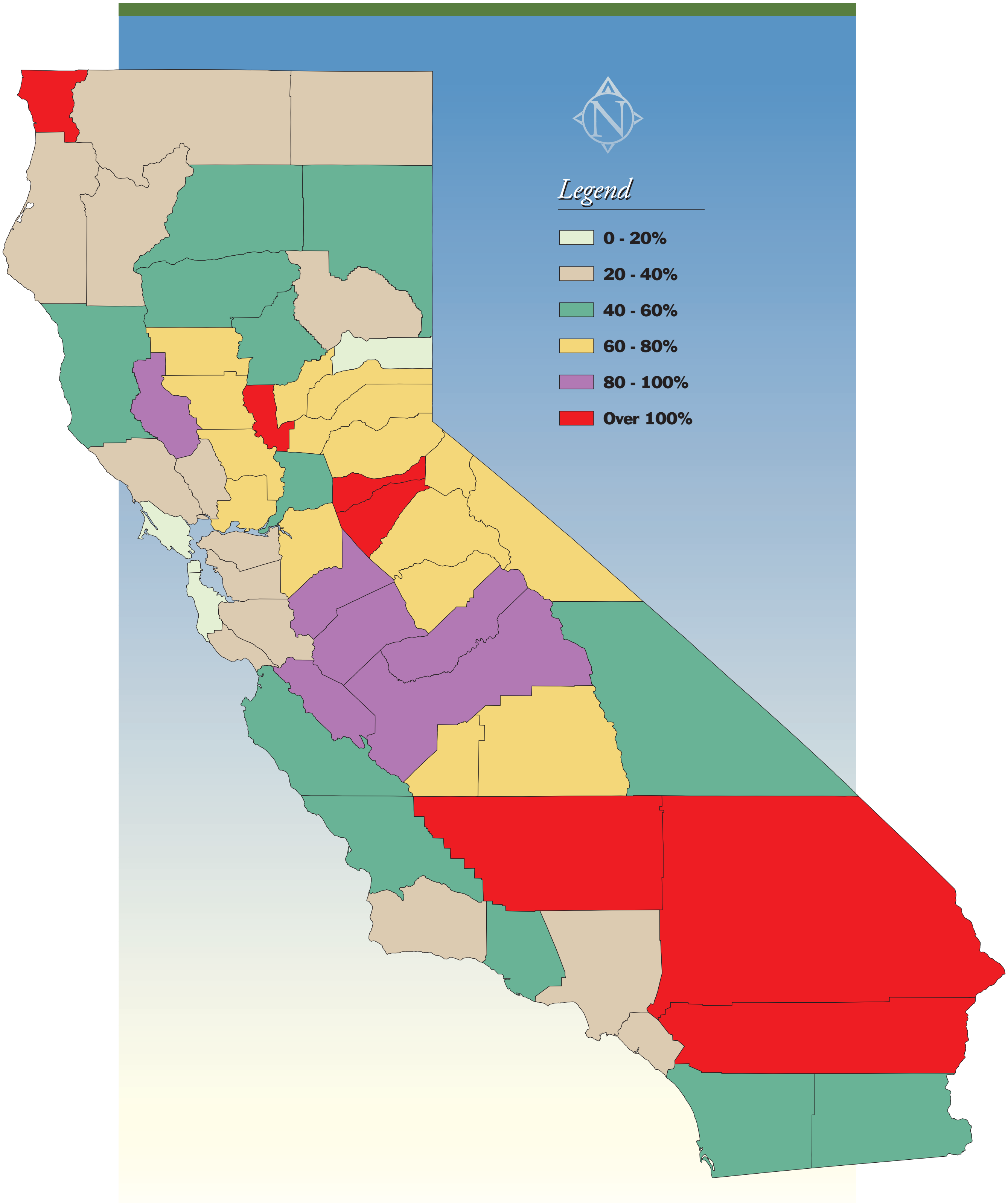
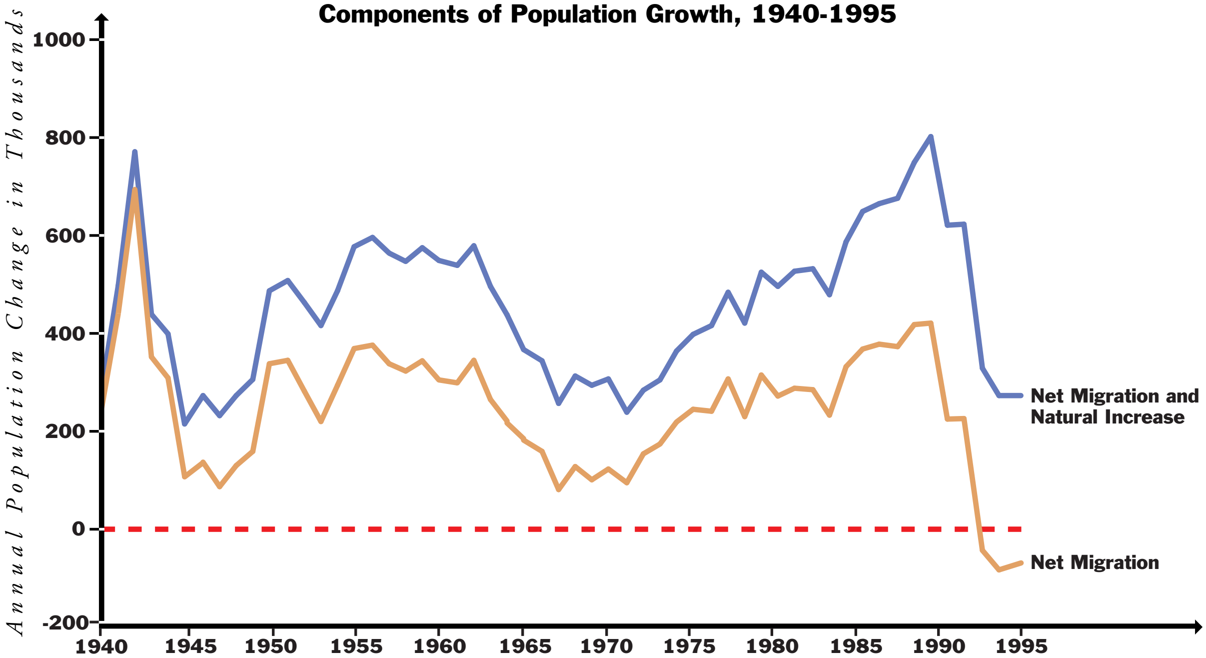


FIGURE 4-3

Components of Population Growth, 1940-1995



Urban water demand forecasts are driven by the expected increase in California's population—more than 15 million new residents by 2020. Multipurpose reservoirs help meet needs for water-based recreational opportunities, especially in arid Southern California.

population change. Migrants are separated into two categories: domestic (from other states) or foreign (from other countries). Since 1980, approximately 30 percent of net migration has been domestic and 70 percent foreign. DOF attributes fluctuations in migration primarily to domestic migration, since undocumented migration has been fairly constant and legal foreign migration has slowly increased. Figure 4-3 shows natural increase and net migration for the years 1940-95.

DOF uses a baseline cohort-component method to project population by gender, race/ethnicity, and age. A baseline projection assumes people have the right to migrate where they choose and no major natural catastrophes or wars will occur. A cohort-component method traces people born in a given year throughout their lives. As each year passes, cohorts change due to mortality and migration assumptions. New cohorts are formed by applying birthrate assumptions to women of childbearing age. Special populations display different demographic behavior and other characteristics and must be projected separately. The primary sources of special populations are prisons, colleges, and military installations.

Population projections used in Bulletin 160-98 are based on DOF's *Interim County Population Projections (April 1997).* Table 4-1 shows the 1995 through 2020 population figures for Bulletin 160-98 by hydrologic

TABLE 4-1

California Population by Hydrologic Region (in thousands)

Region	*1995*	*2020*
North Coast	606	835
San Francisco Bay	5,780	7,025
Central Coast	1,347	1,946
South Coast	17,299	24,327
Sacramento River	2,372	3,813
San Joaquin River	1,592	3,025
Tulare Lake	1,738	3,296
North Lahontan	84	125
South Lahontan	713	2,019
Colorado River	533	1,096
Total (rounded)	**32,060**	**47,510**

region. DOF periodically updates its population forecasts to respond to changing conditions. Its 2020 population forecast used for Bulletin 160-93 was 1.4 million higher than the 2020 forecast used in Bulletin 160-98. The latter forecast incorporated the effects of the recession of the early 1990s. Small fluctuations in the forecast do not obscure the overall trend—an increase in population on the order of 50 percent.

The Department apportioned county population data to Bulletin 160 study areas based on watershed or water district boundaries. Factors considered in distributing the data to Bulletin 160 study areas included population projections prepared by cities, counties, and local councils of governments, which typically incorporate expected future development from city and county general plans. The local agency projections indicate which areas within a county are expected to experience growth and provide guidance in allocating DOF's projection for an entire county into smaller Bulletin 160 study areas. Table 4-2 compares DOF interim projections with councils of governments projections.

Factors Affecting Urban Per Capita Water Use

Urban per capita water use includes residential, commercial, industrial, and institutional uses of water. Each of these categories can be examined at a greater level of detail. Residential water use, for example, includes interior and exterior (e.g., landscaping) water use. Forecasts of urban water use for an individual community may be separated into components and forecasted individually. It is not possible to use this level of detail for each community in the State in Bulletin 160-98. Bulletin 160-98 modeled components of urban use for representative urban water agencies in each of the State's ten hydrologic regions and extrapolated those results to the remainder of each hydrologic region, as described later in the chapter.

Demand reduction achieved by implementing water conservation measures is important in forecasting per capita water use. Bulletin 160-98 incorporates demand reductions from implementation of urban best management practices contained in the 1991 *Memorandum of Understanding Regarding Urban Water Conservation in California.* Bulletin 160-98 assumes implementation of the urban MOU's BMPs by 2020, resulting in a demand reduction of about 1.5 maf over the year 2020 demand forecast without BMP implementation. The following subsections detail existing urban water conservation programs and estimated demand reductions. For simplicity of presentation, conservation plans required of USBR water contractors are described in the agricultural water conservation section, since agricultural water supply comprises the majority of CVP water contracts. USBR's urban water contractors are also required to comply with these requirements.

The relationship of water pricing to water consumption, and the role of pricing in achieving water conservation, has been a subject of discussion in recent years. Elected board members of public water

TABLE 4-2

Comparison Between Department of Finance and Councils of Governments Population Projections (in thousands)

	1990 Census	*2010 Projections*[a]	
		DOF	*COG*
Southern California Counties	17,139	23,352	24,038
Bay Area Counties	6,020	7,489	7,540
Central Coast Counties	1,172	1,508	1,518
Greater Sacramento Counties	1,684	2,542	2,586
San Joaquin Valley Counties	2,742	4,608	4,641

[a] COG data were only available for 2010, thus 2010 COG forecasts are compared with DOF 2010 forecasts.

Landscape Water Use

The Model Water Efficient Landscape Ordinance was added to Title 23 of the California Code of Regulations in response to requirements of the 1990 Water Conservation in Landscaping Act. Local agencies that did not adopt their own ordinances by January 1993 were required to begin enforcement of the model ordinance as of that date.

The model ordinance applies to all new and rehabilitated landscaping (more than 2,500 square feet in size) for public agency projects and private development projects that require a local agency permit, and to developer-installed landscaping for single-family and multifamily residential projects. The purpose of the ordinance was to promote water efficient landscape design, installation, and maintenance. The general approach of the ordinance was to use 0.8 ET_0 as a water use goal for new and renovated landscapes. (ET_0 is a reference evapotranspiration, established according to specific criteria.) Tools to help meet that goal include proper landscape and irrigation system design.

To date, there has been no statewide-level review of how cities and counties are implementing this requirement; thus, its water savings potential remains to be quantified.

agencies ultimately have the responsibility for balancing desires to achieve demand reduction through water pricing with desires to provide affordable water rates to consumers. Urban water rates in California vary widely and are affected by factors such as geographic location, source of supply, and type of water treatment provided. Water rates are set by local agencies to recover costs of providing water service and are highly site-specific. Appendix 4A provides background information on urban water pricing. As described in the appendix's summary of price elasticity studies for urban water use, residential water demand is inelastic in most cases—water users were relatively insensitive to changes in price, for the price ranges evaluated. Water price plays a small role in relation to other factors affecting water use, such as public education and plumbing retrofit programs.

Urban Water Conservation Actions. State and federal legislation imposed standards to improve the water use efficiency of plumbing fixtures, requiring that fixtures manufactured, sold, or installed after specified dates meet the targets shown in Table 4-3. These requirements apply to new construction or to retrofitting existing plumbing fixtures, but do not require removal and replacement of existing fixtures. One water conservation action being taken by urban water agencies is to sponsor programs for voluntary retrofitting of fixtures, to accelerate demand reductions. (This action is one of the BMPs included in the urban MOU.) Some water purveyors, such as the City and County of San Francisco, have regulations requiring retrofit when homes are sold.

More than 200 urban water suppliers have signed the urban MOU and are now members of the California Urban Water Conservation Council. Some key points from the MOU are highlighted in the sidebar. Water suppliers signing the urban MOU committed to implement BMPs unless a cost-benefit analysis conducted according to CUWCC guidelines showed individual BMPs not to be cost-effective, or unless there was a legal barrier to implementation. The MOU also committed CUWCC to study measures that could be added as new BMPs, such as establishing efficiency standards for water-using appliances.

The urban use forecasts in Bulletin 160-98 assume that water users statewide will implement BMPs by 2020, as set forth in Exhibit 1 of the MOU, whether or not the BMPs are cost-effective from a water supply standpoint. In making this assumption, the Bulletin recognizes that water conservation measures have potential benefits in addition to water supply, such as reduced water and wastewater treatment costs, other water quality improvements, reduced entrainment of fish at urban points of diversion, and greater control of temperature and timing of wastewater discharges. The Department believes this assumption is reasonable, given that funding sources for non-water supply benefits could help support BMP implementation, and that the planning horizon over which the Bulletin assumes that BMPs would be implemented (from 1995 to 2020) provides more time for implementation than does the MOU. The widespread acceptance that the existing BMPs have achieved, as evidenced by the number of MOU signatories, indicates that the BMPs are generally considered to be technologically feasible, so technology should not be a limiting factor in implementation.

Quantifying demand reduction from implementation of some BMPs is difficult (for example, public information programs and water education in schools). These actions contribute to implementation of other BMPs, such as demand reduction from installing water meters, but do not by themselves save quantifiable amounts of water. CUWCC reviewed implementation

TABLE 4-3

Summary of California and Federal Plumbing Fixture Requirements

Plumbing Device	*California (covers sale and installation)*	*Effective Date*	*Energy Policy Act of 1992 (covers only manufacture)*
Showerheads	2.5 gpm	CA 3/20/92 US 1/1/94	 2.5 gpm
Lavatory Faucets[a]	2.75 gpm 2.2 gpm	CA 12/22/78 CA 3/20/92 US 1/1/94	 2.5 gpm
Sink Faucets[a]	2.2 gpm	CA 3/20/92 US 1/1/94	 2.5 gpm
Metering (self-closing) Faucets[b] (public restrooms)	hot water maximum flow rates range from 0.25 to 0.75 gallons/ cycle and/or from 0.5 gpm to 2.5 gpm, depending on controls and hot water system	CA 7/1/92 US 1/1/94	 0.25 gallons/cycle (maximum water delivery per cycle)
Tub Spout Diverter[a]	0.1 (new), to 0.3 gpm (after 15,000 cycles of diverting)	CA 3/20/92	(does not appear to be included in EPA)
Toilets (residential)	1.6 gpf	CA 1/1/92 (new construction) CA 1/1/94 (all toilets for sale or installation) US 1/1/94 (non-commercial)	 1.6 gpf
Flushometer valves[a]	1.6 gpf	CA 1/1/92 (new construction) CA 1/1/94 (all toilets) US 1/1/94 (commercial) US 1/1/97 (commercial)	 3.5 gpf 1.6 gpf
Toilets (Commercial)[a]	1.6 gpf	CA 1/1/94 (all toilets for sale or installation) US 1/1/97	 1.6 gpf
Urinals	1.0 gpf	CA 1/1/92 (new) CA 1/1/94 (all) US 1/1/94	 1.0 gpf

[a] California requirements are preexisting and more stringent than federal law; therefore California requirements prevail in California.

[b] Federal law is more stringent than California requirements.

Local agencies were required by the 1990 Water Conservation in Landscaping Act to enforce ordinances intended to promote water-efficient designs. The act's requirements apply to landscapes greater than 2,500 sq. ft. in size.

and quantification of the initial BMPs, and developed a strategic plan in 1996 that included evaluating the BMPs and revising them to make them easier to quantify. The revised BMPs (see sidebar) were adopted by CUWCC in September 1997. The revisions included restructuring the original 16 BMPs to 14 BMPs (new BMPs were also added—rebate programs for high efficiency washing machines and wholesale water agency assistance to retail water agencies), revising implementation schedules and coverage requirements, and adding new evaluation criteria. Implementation of some BMPs was extended beyond the original 10-year term of the existing MOU. Appendix 4B presents a synopsis of the revisions.

Urban Best Management Practices (1997 Revision)

BMP 1	Water Audit Programs for Single-Family Residential and Multifamily Residential Customers
BMP 2	Residential Plumbing Retrofit
BMP 3	System Water Audits, Leak Detection and Repair
BMP 4	Metering With Commodity Rates for All New Connections and Retrofit of Existing Connections
BMP 5	Large Landscape Conservation Programs and Incentives
BMP 6	High-Efficiency Washing Machine Rebate Programs (New)
BMP 7	Public Information Programs
BMP 8	School Education Programs
BMP 9	Conservation Programs for Commercial, Industrial, and Institutional Accounts
BMP 10	Wholesale Agency Assistance Programs (New)
BMP 11	Conservation Pricing
BMP 12	Conservation Coordinator (Formerly BMP 14)
BMP 13	Water Waste Prohibition
BMP 14	Residential ULFT Replacement Programs (Formerly BMP 16)

Highlights of the Urban MOU

Shown below are several excerpts from the urban MOU that are relevant to the water conservation measures discussed in Chapters 4 and 6.

Recital F *It is the intent of this MOU that individual signatory water suppliers (1) develop comprehensive conservation BMP programs using sound economic criteria and (2) consider water conservation on an equal basis with other water management options.*

Recital G *It is recognized that present urban water use throughout the State varies according to many factors including, but not limited to, climate, types of housing and landscaping, amounts and kinds of commercial, industrial and recreational development, and the extent to which conservation measures have already been implemented. It is further recognized that many of the BMPs identified in Exhibit 1 to this MOU have already been implemented in some areas and that even with broader employment of BMPs, future urban water use will continue to vary from area to area. Therefore, this MOU is not intended to establish uniform per capita water use allotments throughout the urban areas of the State. This MOU is also not intended to limit the amount or types of conservation a water supplier can pursue or to limit a water supplier's more rapid implementation of BMPs.*

Section 4.1 (c) *Assumptions for use in developing estimates of reliable savings from the implementation of BMPs. Estimates of reliable savings are the water conservation savings which can be achieved with a high degree of confidence in a given service area. The estimate of reliable savings for each BMP depends upon the nature of the BMP and upon the amount of data available to evaluate potential savings. For some BMPs (e.g., public information) estimates of reliable savings may never be generated. For others, additional data may lead to significant changes in the estimate of reliable savings. It is probable that average savings achieved by water suppliers will exceed the estimates of reliable savings.*

Section 4.5 *Exemptions. A signatory water supplier will be exempt from the implementation of specific BMPs for as long as the supplier substantiates each reporting period that, based upon then prevailing local conditions, one or more of the following findings applies: (a) A full cost-benefit analysis, performed in accordance with the principles set forth in Exhibit 3, demonstrates that either the program (i) would not be cost-effective overall when total program benefits and costs are considered; OR (ii) would not be cost-effective to the individual water supplier even after the water supplier has made a good faith effort to share costs with other program beneficiaries.*

(b) Adequate funds are not and cannot reasonably be made available from sources accessible to the water supplier including funds from other entities. However, this exemption cannot be used if a new, less cost-effective water management option would be implemented instead of the BMP for which the water supplier is seeking this exemption.

(c) Implementation of the BMP is (i) not within the legal authority of the water supplier; and (ii) the water supplier has made a good faith effort to work with other entities that have the legal authority to carry out the BMP; and (iii) the water supplier has made a good faith effort to work with other relevant entities to encourage the removal of institutional barriers to the implementation of BMPs within its service area.

Bulletin 160-98 estimates water savings due to BMP implementation based on the assumptions set forth in Exhibit 1 of the urban MOU, and assumes that California will achieve a level of water conservation equivalent to that expected from full BMP implementation by 2020. The MOU specifies implementation schedules, water use reduction factors, and installation and/or compliance rates that allow quantification of water savings for 7 of the 14 BMPs. The MOU identifies the remaining BMPs as not having quantifiable water savings. The Bulletin's estimated water savings (Appendix 4B) are based on evaluation of the following BMPs in accordance with the Exhibit 1 provisions: residential water use surveys, residential plumbing retrofits, distribution system water audits/leak detection/repairs, metering with commodity rates, programs for commercial/industrial/institutional accounts, and residential ultra-low flush toilet replacement. Water savings for the BMP on large landscape water conservation (3 acres or greater) could not be evaluated due to lack of data on existing irrigated landscape acreage.

BMP implementation is estimated to result in a statewide 2020 demand reduction of 1.5 maf statewide. As discussed in Chapter 6, this demand reduction is not the same as creating new water supply. Only conservation actions that reduce irrecoverable losses or reduce depletions actually create new water supply from a statewide perspective. Table 4-4 shows applied water and depletion reductions due to BMP implementation by hydrologic region.

As more water conservation measures are implemented, especially structural changes such as plumbing retrofits, it will become increasingly difficult for urban water agencies and their customers to achieve drought year demand reductions. Demand hardening is discussed in more detail in Chapter 6. The urban MOU acknowledges that demand hardening will be a

TABLE 4-4

Annual Reductions in Applied Water and Depletions Due to BMP Implementation by 2020 (taf)

Region	*Applied Water*	*Depletion*
North Coast	20	11
San Francisco Bay	176	172
Central Coast	48	30
South Coast	768	500
Sacramento River	91	0
San Joaquin River	111	30
Tulare Lake	125	50
North Lahontan	5	2
South Lahontan	59	21
Colorado River	111	52
Total	**1,514**	**868**

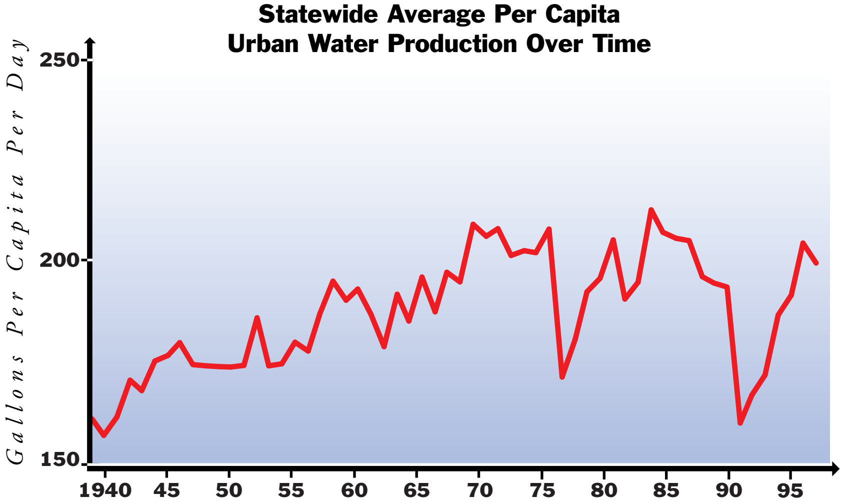
consequence of BMP implementation.

Although there are other urban water conservation programs besides those associated with the urban MOU, only the MOU presently addresses quantification of water savings. EPA has started developing water conservation guidelines pursuant to Section 1455 of the 1996 SDWA. USBR has developed guidelines for Reclamation Reform Act water conservation plans and for the more detailed conservation plans required by CVPIA. The USBR conservation plans apply to both urban and agricultural contractors, and are described in more detail in a later section on agricultural water conservation.

Effects of Droughts on Urban Water Production. To illustrate the effects of droughts, Figure 4-4 shows statewide per capita urban water production over time. (Per capita production is the water provided by urban suppliers, divided by population. Urban water production is not the same as total urban water use; total use includes self-produced supplies, water for recreation and energy production uses, and losses from major conveyance facilities.) After the severe, but brief, 1976-77 drought, statewide urban per capita water production rates returned to pre-drought levels within 3 to 4 years. During the longer 1987-92 drought, urban per capita water production rates declined by about 19 percent on the average statewide. (Most requirements for water-conserving plumbing fixtures did not take effect until after the 1987-92 drought.) The Department's data show increases in per capita water production following the drought, due to removal of mandatory water rationing and other short-term restrictions. When viewed at a statewide level, the data show a strong response to hydrologic conditions.

FIGURE 4-4

Statewide Average Per Capita Urban Water Production Over Time



Urban Water Use Planning Activities

The Department has surveyed retail water agencies and analyzed their water production data for more than 35 years, publishing the data in the Bulletin 166 series, *Urban Water Use in California.* Bulletin 166-4, published in 1994, summarized monthly urban water production data from 1980-90 for nearly 300 retail water purveyors throughout the State. This water use information, updated in the Department's annual surveys, is a primary data source for water use estimates made for Bulletin 160. The Department also conducted a statewide survey of industrial water use by water-using sector in 1994. Industrial water use information is periodically published in the Department's Bulletin 124 series, *Industrial Water Use in California.*

The Urban Water Management Planning Act requires that urban water suppliers with 3,000 or more connections, or that deliver over 3 taf of water per year, prepare urban water management plans and submit them to the Department. The initial set of plans was due in 1985; plans are to be updated every five years. Table 4-5 shows the number of agencies affected by the law and those submitting their 1995 plans as of March 1997. The 1995 plans received were from agencies representing almost 90 percent of all urban water deliveries. These plans have multiple purposes, including demonstrating how local agencies

TABLE 4-5

1995 Urban Water Management Plans by Hydrologic Region

Region	*Expected*	*Filed*
North Coast	13	10
San Francisco Bay	60	46
Central Coast	28	17
South Coast	187	152
Sacramento River	35	33
San Joaquin River	29	12
Tulare Lake	22	13
North Lahontan	5	2
South Lahontan	12	11
Colorado River	13	6
Total	**404**	**302**

propose to implement water conservation measures and how the agencies plan to meet drought year water supply reliability goals.

The CALFED Bay-Delta program includes water use efficiency—urban, agricultural, and environmental—as one of the common elements required for all proposed Delta alternatives. As described in the water use efficiency technical appendix for the March 1998 draft programmatic EIR/EIS, potential elements of an urban water use efficiency program include:

- Requirements that urban water management plans be implemented more vigorously and that the Department review and certify those plans.
- Revisions to the BMPs to make them more quantifiable.
- Requirements that CUWCC certify BMP implementation.
- Provision of financial and technical assistance to water agencies to encourage program implementation.

CALFED is also examining ways to require that the urban water use efficiency program be implemented vigorously. For example, urban water agencies that choose not to implement the program could be excluded from participation in water transfers requiring approval by a CALFED agency, from use of facilities operated by a CALFED agency, from new supplies made available by a CALFED actions, or from participating in certain loan and grant programs. In addition, CALFED has suggested that SWRCB could be asked to pursue its obligations to investigate waste and unreasonable use more vigorously. Methods to achieve assurances remain under discussion. Depending on the methods chosen, amendments to existing statutes or execution of new agreements would be needed. Quantification of CALFED's future water use efficiency program is discussed in Chapter 6.

Urban Water Use Forecasting

Urban water use forecasting relates future use to changes in factors influencing water use. Early forecasting methods were relatively simple and relied only on service area population to explain water use, assuming a direct relationship between population growth and applied water demand. These methods can provide acceptable results over the short term, especially during periods of abundant water supply and steady economic growth. However, mid- to long-term forecast accuracy may decrease sharply due to changes in other variables influencing water use. Among these factors are changes in the ratio of single to multifamily dwellings, commercial and industrial growth, income, future water conservation actions, and water pricing. The price of water currently plays a small role in water use; it could become more important if water prices increased substantially. The water price elasticity section in Appendix 4A provides more detail on this subject. New urban water supplies will be relatively expensive, so understanding interactions between price and water use is important for forecasting urban use. As described in the appendix, the Department's forecast used single family residential price elasticities of -0.1 for winter months and -0.2 for summer months.

The Department forecasted change in per capita water use in each hydrologic region to estimate 2020 urban applied water by hydrologic region. Variables included population, income, economic activity, water price, and conservation measures (implementation of urban BMPs and changes to State and federal plumbing fixture standards). The general forecasting procedure was to determine 1995 base per capita water use, estimate the effects of conservation measures and socioeconomic change on future use for 20 major representative water service areas in California, and calculate 2020 base per capita water use by hydrologic region from the results of service area forecasts.

1995 Base Per Capita Water Use. The 1995 base per capita water use includes water supplied by public water systems for municipal and industrial purposes and self-produced (not delivered by a water purveyor) surface water and groundwater. Per capita water use is not the same as the applied water use shown in Bulletin 160 water budgets. Per capita use does not include recreation water use, energy production water use, and losses from major conveyance facilities (the urban share of the "other" water demand category used in Bulletin 160-93). In most hydrologic regions, 1995 base per capita water use was calculated for each of the Department's DAUs. In the South Lahontan and Colorado River regions, analyses were done at the PSA level due to the relatively sparse populations in those regions.

The 1995 base per capita water use was computed from normalized water use data to account for variation in annual weather patterns, water supply, and residual effects of the 1987-92 drought. Appendix 4C discusses the relationship between normalized data and actual urban water production data. Actual urban water use during 1995 was less than the Bulletin 160-98 base level in many areas, largely due to wet hydrologic conditions that decreased landscape irrigation requirements. (Likewise, urban water use during a dry year would likely exceed base year use due to higher landscape irrigation water use, assuming no constraints on water supplies). Base per capita 1995 water use was developed from historical water use during recent years with normal water supply and water use patterns. Data for years during and immediately following the drought were removed from consideration due to the effects of water shortages of unprecedented severity and duration, mandatory and voluntary rationing programs, and a multi-year post-drought rebound in per capita water use on water use patterns. The 1995 base was computed from the 1990 per capita use in Bulletin 160-93, adjusted to account for permanent effects of urban BMPs and post-1990 changes to federal and State plumbing fixture standards. The most significant post-1990 change to the plumbing fixture standards was that all toilets for sale or installation in California must use no more than 1.6 gallons per flush, compared to 3.5 gallons or more per flush for older toilets. Plumbing code effects were quantified based on the proportion of total housing stock subject to the new code. ULFT retrofit water savings were estimated based on information on toilet retrofit programs from local water agencies. The final 1995 base value for each DAU was weighted by population to yield 1995 base per capita water use by hydrologic region.

2020 Per Capita Water Use Forecast. Forecasts for the urban water use study were based on three types of input data: actual values of base year water and socioeconomic variables, forecasted values of socioeconomic variables for the year 2020, and savings assumptions for BMPs. Table 4-6 lists the input variables specified for each water service area. Table 4-7 shows data sources for the study.

TABLE 4-6

Urban Water Use Study Input Variables

Water Use
Water use by sector, base year
Single family
Multifamily
Commercial
Industrial
Landscape
Seasonal water use, base year
Socioeconomic
Population, base year, and forecast year
Total population
Population by dwelling type
Persons per household by dwelling type
Group quarters population
Housing, base year, and forecast year
Number of housing units by dwelling type
Growth rate of housing stock by dwelling type
Employment, base year, and forecast year
Commercial
Industrial
Income, base year, and forecast year
Water price, base year, and forecast year

The urban water use study estimated future change in per capita water use in 20 representative water service areas. (The results in Tables 4-8 and 4-9 display changes from 1990, rather than from the Bulletin's 1995 base year, to illustrate all effects of water conservation implementation, including the changes in plumbing fixture standards that began in 1992.) The results of the 20 individual model runs were extrapolated to forecast 2020 level per capita water use by hydrologic region (Tables 4-9 and 4-10). The difference between the 1995 and 2020 base levels reflects the influence of water conservation measures, socioeconomic change, and differential population growth on per capita water use in each region.

The forecast results for the representative water service areas were expressed as a percent change in per capita use by 2020, and were averaged (weighted by service area population) to arrive at the percent change in per capita use by hydrologic region. For each region, the 2020 change was applied to the 1995 level per capita water use in each DAU to obtain 2020 per capita water use. The 2020 per capita water use then

TABLE 4-7

Urban Water Use Study Data Sources

Water Use
Survey of Public Water System Statistics, DWR
Urban water management plans
Regional and local water agency reports on water use and conservation
Socioeconomic
Census of Population and Housing, U.S. Department of Commerce
Survey of Current Business, USDC
Statistical Abstract of the United States, USDC
California Statistical Abstract, DOF
California Population Characteristics, Center for Continuing Study of the California Economy
Population Projections by Race and Ethnicity for California and its Counties 1990-2040, DOF
Regional and local planning agencies

TABLE 4-8

Model Study Results—Per Capita Water Use With Economic Growth and Conservation Measures

Region	*Representative Water Service Area*	*1990 (gpcd)*	*2020 (gpcd)*	*Percent Change from 1990*	
				Economic Effects	*Conservation Effects*
North Coast	City of Santa Rosa	156	136	-14	2
San Francisco Bay	EBMUD	196	171	-16	3
	Marin Municipal WD	153	136	-16	5
	City and County of San Francisco	132	115	-16	3
Central Coast	California Water Service Company, Salinas	153	132	-14	0
	City of Santa Barbara	177	156	-15	4
South Coast	City of Los Angeles	180	158	-16	4
	City of San Bernardino	269	243	-11	1
	San Diego County WA	196	176	-14	4
Sacramento River	California Water Service Company, Chico	296	272	-10	2
	City of Sacramento	290	263	-13	3
San Joaquin River	California Water Service Company, Stockton	187	162	-12	-1
	City of Merced	336	299	-10	0
Tulare Lake	California Water Service Company, Visalia	273	235	-11	-3
	City of Fresno	285	262	-10	2
North Lahontan	South Lake Tahoe PUD	179	147	-15	-2
South Lahontan	Indian Wells Valley WD	247	230	-10	3
	Victor Valley County WD	340	322	-8	3
Colorado River	City of Blythe	349	326	-11	4
	City of El Centro	221	197	-13	2

TABLE 4-9

2020 Change in Per Capita Use by Hydrologic Region—Application of Model Results[a]

Region	*Economic Effects % Change from 1990*	*Conservation Effects % Change from 1990*
North Coast	2	-14
San Francisco Bay	3	-16
Central Coast	2	-15
South Coast	4	-14
Sacramento River	3	-12
San Joaquin River	-1	-12
Tulare Lake	1	-10
North Lahontan	-2	-15
South Lahontan	3	-9
Colorado River	3	-12
Statewide	**3**	**-15**

[a] Model results applied to per capita use in each DAU.

TABLE 4-10

Effects of Conservation on Per Capita Water Use[a] by Hydrologic Region (gallons per capita per day)

Region	*1995*	*2020*	
		without conservation	*with conservation*
North Coast	249	236	215
San Francisco Bay	192	188	166
Central Coast	179	188	166
South Coast	208	219	191
Sacramento River	286	286	264
San Joaquin River	310	307	274
Tulare Lake	298	302	268
North Lahontan	411	390	356
South Lahontan	282	294	268
Colorado River	564	626	535
Statewide	**229**	**243**	**215**

[a] Includes residential, commercial, industrial, and landscape use supplied by public water systems and self-produced surface and groundwater. Does not include recreational use, energy production use, and losses from major conveyance facilities. These are normalized data.

was multiplied by the population forecast to compute 2020 urban applied water use for each DAU. The DAU-level results were aggregated and combined with minor components of urban use (conveyance losses, recreation water use, and energy production water use) to obtain total applied urban water demands.

This method of computing future water use captures localized effects of differential population growth. The most significant example of variation in growth patterns is the relatively high growth rate in warmer, drier inland areas of California where increased landscape irrigation requirements are reflected in higher per capita use values. Growth in inland areas tends to partially offset reductions in per capita use due to water conservation.

Summary of Urban Water Use

Table 4-11 summarizes Bulletin 160-98 urban applied water use by hydrologic region. Statewide urban use at the 1995 base level is 8.8 maf in average water years and 9.0 maf in drought years. (Drought year demands are slightly higher because less precipitation is available to meet exterior urban water uses, such as landscape watering.) Forecasted 2020 use increases to 12.0 maf in average years and 12.4 maf in drought years. Full implementation of urban BMPs is estimated to result in demand reduction of 1.5 maf in average year water use by 2020. Without implementation of urban BMPs, average year use would have increased to 13.5 maf.

TABLE 4-11

Applied Urban Water Use by Hydrologic Region (taf)

	1995		*2020*	
Region	*Average*	*Drought*	*Average*	*Drought*
North Coast	169	177	201	212
San Francisco Bay	1,255	1,358	1,317	1,428
Central Coast	286	294	379	391
South Coast	4,340	4,382	5,519	5,612
Sacramento River	766	830	1,139	1,236
San Joaquin River	574	583	954	970
Tulare Lake	690	690	1,099	1,099
North Lahontan	39	40	50	51
South Lahontan	238	238	619	619
Colorado River	418	418	740	740
Total (rounded)	**8,770**	**9,010**	**12,020**	**12,360**

As indicated in the Table 4-11, the South Coast and San Francisco Bay Hydrologic Regions together amount to over half of the State's total urban water use. The table also illustrates that precipitation plays a small role in meeting urban outdoor water needs (landscape water needs) in arid regions such as the Tulare Lake, South Lahontan, and Colorado River regions.

All of the acreage amounts discussed in this chapter are irrigated acres, because estimates of irrigated acreage are needed to calculate agricultural water use. Crop production also occurs (to a much lesser extent) on non-irrigated lands. Dry-farmed grains are an example of crop production on non-irrigated lands.

Agricultural Water Use

The Department's estimates of agricultural water use are derived by multiplying water use requirements for different crop types by their corresponding irrigated acreage, and summing the results to obtain a total for irrigated crops in the State. This section begins by covering crop water use requirements, including demand reduction from water conservation programs. Irrigation efficiency and distribution uniformity are discussed in detail. A description of the process for forecasting irrigated acreage and factors affecting acreage forecasts follows. Forecasted 2020 agricultural water demands are summarized at the end of the section.

Crop Water Use

The water requirement of a crop is directly related to the water lost through evapotranspiration. The amount of water that can be consumed through ET depends in the short term on local weather and in the long term on climatic conditions. Energy from solar radiation is the primary factor that determines the rate of crop ET. Also important are humidity, temperature, wind, stage of crop growth, and the size and aerodynamic roughness of the crop canopy. Irrigation frequency affects ET after planting and during early growth because evaporation increases when the soil

There is a perception that only drip irrigation is an efficient agricultural water use technology. As described in Chapter 5, high efficiencies are possible with a variety of irrigation techniques. Considerations such as soil type, field configuration, and crop type influence the choice of irrigation technique.

surface is wet and is exposed to sunlight. Growing season ET varies significantly among crop types, depending primarily on how long the crop actively grows.

Direct measurement of crop ET requires costly investments in time and sophisticated equipment. There are more than 9 million acres of irrigated crop land in California, encompassing a wide range of climate, soils, and crops. Even where annual ET for two areas is similar, monthly totals may differ. For example, average annual ET for Central Coast interior valleys is similar to that in the Central Valley. Central Valley ET is lower than that in coastal valleys during the winter fog season and higher during the hot summers. Obtaining actual measurements for every combination of environmental variables would be prohibitively difficult and expensive. A more practical approach is to estimate ET using methods based on correlation of measured ET with observed evaporation, temperature, and other climatologic conditions. Such methods can be used to transfer the results of measured ET to other areas with similar climates.

The Department uses the ET/evaporation correlation method to estimate growing season ET. Concurrent with field measurement of ET rates, the Department developed a network of agroclimate stations to determine the relationship between measured ET rates and pan evaporation. Data from agroclimatic studies show that water evaporation from a standard water surface (the Department uses the U.S. Weather Bureau Class A evaporation pan) closely correlates to crop ET. The ET/evaporation method estimates crop water use to within ± 10 percent of measured seasonal ET.

Crop coefficients are applied to pan evaporation data to estimate evapotranspiration rates for specific crops. (Crop coefficients vary by crop, stage of crop growth, planting and harvest dates, and growing season duration.) The resulting data, combined with information on effective rainfall and water use efficiency, form the basis for calculating ETAW and applied water use. Crop applied water use includes the irrigation water required to meet crop ETAW and cultural water requirements.

The amount of water applied to a given field for crop production is influenced by considerations such as crop water requirements, soil characteristics, the ability of an irrigation system to distribute water uniformly on a given field, and irrigation management practices. In addition to ET, other crop water requirements can include water needed to leach soluble salts below the crop root zone, water that must be applied for frost protection or cooling, and water for seed germination. The amount required for these uses depends upon the crop, irrigation water quality, and weather conditions.

Part of a crop's water requirements can be met by rainfall. The amount of rainfall beneficially used for crop production is called effective rainfall. Effective rainfall is stored in the soil and is available to satisfy crop ET or to offset water needed for special cultural practices such as leaching of salts. Irrigation provides the remainder of the crop water requirement. Irrigation efficiency influences the amount of applied water needed, since a portion of each irrigation goes to system leaks and deep percolation of irrigation water below the crop root zone.

The Bulletin's 1995 base applied agricultural water use values were computed from normalized data to account for variation in annual weather patterns and water supply. Normalizing entails applying crop coefficients to long-term average evaporative demand data. Actual applied crop water use during 1995 was less than the Bulletin 160-98 base in many areas due to wet hydrologic conditions that increased effective rainfall, thus decreasing crop ETAW. Likewise, applied water use during a dry year (assuming no constraints on water supplies) would likely exceed the base due to less than average effective rainfall with an attendant increase in crop ETAW. For most hydrologic regions, 1995 base applied water use was computed for the major crop types found in each of the Department's DAUs. Analyses were done at the planning subarea level in the South Lahontan and Colorado River Regions.

Figure 4-5 shows ranges of 1995 base applied water and ETAW for some common California crops or crop types. ETAW represents a major depletion of water supply, and therefore is an important component of statewide and local water supply planning, groundwater modeling, and water transfer feasibility studies. Except in areas adjacent to the ocean, or areas where the groundwater or surface water is unacceptable for reapplication, irrigation water applied in excess of ET and cultural requirements (e.g., frost protection) is available to downstream users or to users pumping from groundwater.

The purpose of the data presented in Figure 4-5 is to illustrate how great the range of applied water and ETAW can be for a single crop or crop type in California. Climate and soil types are major factors that affect crop water use. Other factors include farming practices, irrigation systems, and water availability. Crop water use is extremely site-specific, and no one value of crop water use can be expected to represent a statewide condition.

Factors Influencing Agricultural Water Use

Irrigation Water Use Efficiency. Distribution uniformity is an important element in on-farm irrigation water use efficiencies. DU measures the variation in the amount of water applied to the soil throughout the irrigated area. Since no irrigation system is capable of applying and distributing water uniformly to all parts of a field, growers often apply enough water to meet crop water requirements of the driest part of the field to achieve optimum crop yields. Achieving a high DU requires excellent system design, maintenance, and management. Irrigation experts maintain that current hardware design and manufacturing technology limit the DU of most systems to 80 percent. As design and manufacturing technology advance and more refined manufacturing processes and hardware are developed, it may be possible to achieve DUs up to 90 percent. Chapter 5 describes the relationship of DU to irrigation efficiencies in more detail.

Seasonal application efficiency is the sum of ETAW and cultural water requirements (such as for leaching salts below the root zone) divided by applied water.

SAE is an appropriate index of water use efficiency for planning purposes, because it is based on the amount of water required to fully satisfy crop water needs while maintaining the favorable salt balance in the root zone required for long-term sustainability of agriculture. It differs from values of irrigation efficiency calculated by growers to compare the amount of water beneficially used to the amount applied, because the amount beneficially used may be less than that needed to fully satisfy crop and cultural water requirements. Efficiency measures used by growers, such as DU and IE, are typically based on the average amount of water infiltrating the quarter of the field receiving the least water. These methods presume that one-half of the low quarter, or 12.5 percent of the field, is under-irrigated to some degree. The result is inadequate leaching and a reduction in crop yield in that part of the field.

Values of SAE cannot be directly compared to IE values commonly cited in literature because they are based on different levels of irrigation effectiveness. Optimal SAE occurs when the driest part of the field receives an amount of water equal to ETAW plus leaching water requirements, resulting in a 100 percent effective irrigation. On the other hand, optimal IE occurs when the amount infiltrated in the low quarter equals ETAW plus leaching requirements, resulting in an 87.5 percent effective irrigation. (Since DU is also calculated based on the low-quarter method, optimal IE is equivalent to DU.) SAE is related to DU and to optimal IE by a linear function so that, for example, a DU of 75 percent implies an optimal SAE of 67 percent. The relationship among DU and optimal values of IE and SAE is illustrated in Table 4-12. The maximum efficiency values achieved on-farm are generally less than shown due to conveyance losses, evaporation, and uncollected surface runoff.

TABLE 4-12

Relationship Among Agricultural Water Use Efficiency Measures

Distribution Uniformity	*Irrigation Efficiency*[a]	*Seasonal Application Efficiency*[a]
90	90	87
85	85	80
80	80	73
75	75	67
70	70	60

[a] Optimal values

Relationships between on-farm and regional efficiencies are complex. Often a portion of irrigation water applied to a field runs off the field or percolates into groundwater. Runoff and/or deep percolation from a given field may be considered a water loss to that particular field; nevertheless, this water is not lost to the system unless it goes directly to a nonreusable water source such as saline groundwater or to the ocean. If water quality is good, that water may be reapplied on a field or on other fields several times. Irrigation efficiency formulas developed for on-farm irrigation management cannot necessarily be applied to larger areas or regions. Numerical values of on-farm and regional efficiencies almost always differ. On-farm

Efficient Water Management Practices for Agricultural Water Suppliers in California

List A—Generally Applicable EWMPs

- Prepare and adopt a water management plan
- Designate a water conservation coordinator
- Support the availability of water management services to water users
- Improve communication and cooperation among water suppliers, water users, and other agencies
- Evaluate the need, if any, for changes in institutional policies to which the water supplier is subject
- Evaluate and improve efficiencies of the water supplier's pumps

List B—Conditionally Applicable EWMPs

- Facilitate alternative land use
- Facilitate using available recycled water that otherwise would not be used beneficially, meets all health and safety criteria, and does not cause harm to crops or soil
- Facilitate financing capital improvements for on-farm irrigation systems
- Facilitate voluntary water transfers that do not unreasonably affect the water user, water supplier, the environment, or third parties
- Line or pipe ditches and canals
- Increase flexibility in water ordering by, and delivery to, water users within operational limits
- Construct and operate water supplier spill and tailwater recovery systems
- Optimize conjunctive use of surface and groundwater
- Automate canal structures

List C—Other EWMPs

- Water measurement and water use reporting
- Pricing or other incentives

efficiencies are usually lower than regional efficiencies due to reapplication of water in a region. A region can reach very high efficiencies as a result of a few reapplications, even if on-farm efficiencies are fairly low. Practices that encourage reapplication, such as tailwater return and spill recovery systems, provide an opportunity to increase regional efficiency. Water reapplication can be the fastest and most economical way to boost regional efficiencies.

Agricultural Water Conservation Programs. The amount of applied water saved depends on the actions of both water suppliers and irrigation water users. Achieving high on-farm water use efficiency is accomplished by optimizing many factors including management (such as irrigation scheduling), irrigation method, crop selection, and supply reliability. On-farm evaluations conducted by the Department and others show that irrigation management is more important than irrigation method in improving water use efficiency. (Chapter 5 describes common irrigation methods.)

Bulletin 160-98 quantifies agricultural water conservation based on assumed statewide implementation of the 1996 agricultural MOU described in Chapter 2. The agricultural MOU provides a mechanism for planning and implementing EWMPs (see sidebar) that benefit water suppliers. The primary objective of EWMPs is for suppliers to better serve farmers in order to facilitate improvements in on-farm practices. As of May 1998, 31 agricultural water agencies serving about 3 million acres of land had signed the MOU. Signatories to the MOU have committed to implement specified EWMPs, based on their evaluation of the benefits of each practice.

EWMPs can lessen runoff and deep percolation of irrigation water, reducing the amount of water farmers must order from an irrigation district or pump from their wells. Because the MOU is orientated to water suppliers, it does not specify water use reduction factors and installation and/or compliance rates for farm irrigation system improvements. Therefore, the Department estimated water savings due to EWMPs based on their potential to remove impediments to optimal on-farm efficiency, expressed as increased SAE. SAE resolves the interrelated effects of EWMPs and improved on-farm management into one variable that quantifies the net result of water conservation efforts by water suppliers and irrigation water users. It is expected that increasing use of EWMPs will yield more information on their water savings potential.

Water savings due to agricultural water conservation were quantified for each DAU on the basis of expected improvements in SAE. It is assumed that by 2020 SAE will reach 73 percent in all regions of California, averaged across crop types, farmland characteristics, and management practices. The DU of irrigation methods limits SAE. The average DU of irrigation systems in California is currently in the 70 to 75 percent range, based on irrigation system evaluations conducted by the Department, resource conservation districts, water districts, and others. By 2020, the average DU is expected to be about 80 percent. An irrigation method with a DU of 80 percent can achieve a maximum SAE of about 73 percent, assuming that irrigation events are properly timed, the soil is well drained, and none of the field is under-irrigated.

The Bulletin 160-98 forecast of conservation savings was calculated by comparing two scenarios of 2020 crop applied water demand under differing levels of SAE. First, crop applied water demand was computed based on the 2020 forecast of irrigated acreage and crop mix, but at existing (1995 base) levels of SAE for each major crop category. Then SAE for each crop category was set to the 2020 forecast value and applied water demand was recomputed. Applied water savings due to conservation were taken as the difference in applied water demand under the two scenarios.

Table 4-13 shows that agricultural water conservation would reduce applied water demands by about 800 taf annually by 2020. Such reductions of applied water generally do not create new water supply; in most areas of California, excess irrigation water becomes available to other users. Even so, a reduction in ap-

TABLE 4-13

2020 Agricultural Water Use Reductions Due to Conservation (taf)

Region	*Applied Water*	*Depletion*
North Coast	1	0
San Francisco Bay	1	0
Central Coast	82	0
South Coast	31	10
Sacramento River	203	0
San Joaquin River	148	2
Tulare Lake	45	1
North Lahontan	17	0
South Lahontan	20	10
Colorado River	249	210
Total	**797**	**233**

plied water can serve other beneficial purposes such as reducing leaching of plant nutrients, reducing degradation of groundwater quality, and reducing agricultural drainage.

Only practices that lessen evaporation from water surfaces, reduce evapotranspiration, or diminish irrecoverable losses actually reduce depletions. Efficient water management practices have relatively little effect on evaporation and ET. It is the location of water use, rather than the conservation measure employed, that is key to determining whether a reduction in irrigation water application translates into a depletion reduction. Agricultural lands adjacent to the ocean, or where the groundwater or surface water is unacceptable for reapplication, have the greatest potential for reducing depletions through efficient water management practices. In California, such agricultural lands are found in the South Coast Region, the west side of the San Joaquin Valley, and the Colorado River Region.

Other water conservation planning requirements exist in addition to those in the agricultural MOU, most notably those applying to water agencies contracting with USBR. (CALFED's proposed future water use efficiency program is discussed in Chapter 6.) The Reclamation Reform Act of 1982 directed DOI to establish a water conservation planning program. In 1992, CVPIA established additional water conservation requirements for federal contractors receiving CVP supplies. USBR published criteria for CVPIA conservation plans and is reviewing the plans which contractors are required to submit. As of March 1998, more than 70 federal water contractors had submitted plans pursuant to CVPIA criteria. Discussions are underway with the agricultural council established by the 1996 MOU regarding developing a way for CVPIA plans to be accepted as plans complying with the agricultural MOU. CVPIA further requires that new, renewed, or amended CVP water service or repayment contracts mandate that surface water delivery systems have water measurement devices or comparable methods of measuring water use.

Agricultural Water Pricing. The relationship of agricultural water pricing to water use and the role of pricing in achieving water conservation have been subjects of discussion in recent years. For water supplied by public agencies, the elected board members of those agencies ultimately have the responsibility for balancing desires to achieve demand reduction through water pricing with desires to provide affordable water rates to growers. For self-supplied agricultural water users, good business practices dictate maximizing water use efficiency, in terms of crop yield per unit of water applied. Agricultural water prices in California vary widely and are affected by factors such as geographic location and source of water supply. Appendix 4A provides background information on agricultural water pricing. As described in the price elasticity information in the appendix, demand for irrigation water is generally price inelastic over the price ranges evaluated. There is no other commodity that can be substituted for the water required to grow crops. Water costs are typically a relatively small percentage of the total cost of producing most crops.

Crop markets, not water prices, generally dominate the economics of crop production. Bulletin 160-98 considers markets and other economic effects in the modeling performed to forecast future irrigated acreage, as described later in this chapter. When fully implemented, CVPIA tiered pricing requirements may provide new data on water price/water use relationships for CVP contractors, as described in the appendix.

Agricultural Acreage Forecasting

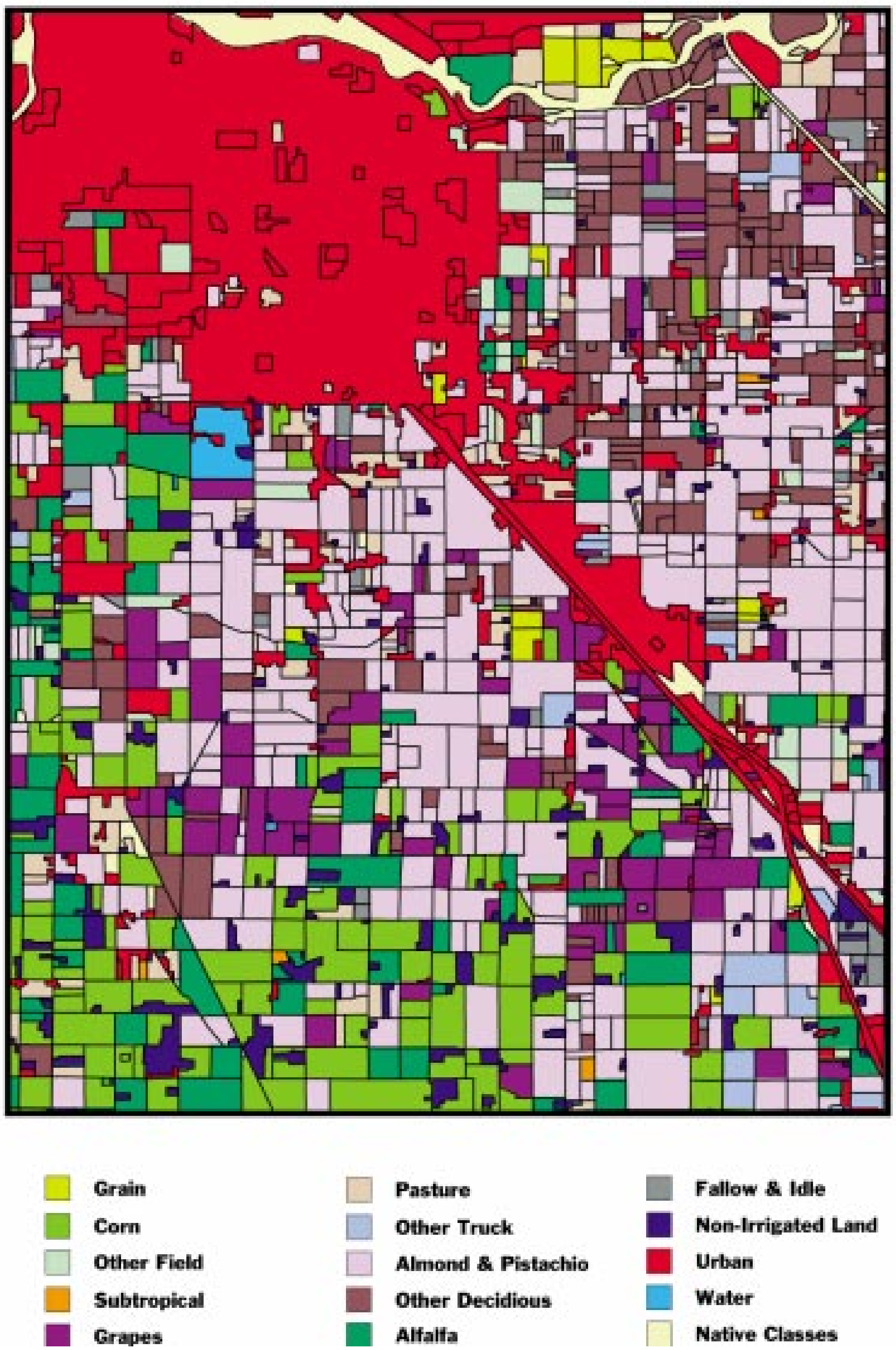
This section describes how 1995 base year irrigated acreage is established, and how that information is used to forecast 2020 irrigated acreage.

Quantifying Present Irrigated Acreage. Forecasts of future agricultural acreage start with land use data that characterize existing crop acreage. The Department has performed land use surveys since the 1950s to quantify acreage of irrigated land and corresponding crop types, and currently maps irrigated acreage in six to seven counties per year. The base data for land use surveys is obtained from aerial photography or satellite imagery, which is superimposed on a cartographic base. Site visits are used to identify or verify crop types growing in the fields. From this information, maps showing locations and acreage of crop types are developed. Figure 4-6 is an example of a typical land use survey map, showing crop types in the Ceres 7.5 minute USGS quadrangle from the Department's 1996 Stanislaus County survey.

The Department's land use surveys focus on quantifying irrigated agricultural acreage. Although fields of dry-farmed crops are mapped in the land use surveys, their acreage is not tabulated for calculating water use. In certain areas of the State, climate and market conditions are favorable for producing multiple crops per year on the same field (for example, winter veg-

FIGURE 4-6

Typical Land Use Survey Map



California's Nursery Industry

When people think of irrigated agriculture, crops that often come to mind are commodities such as hay, grains, rice, row crops, and cotton. However, nursery products (flowers, plants, turf-grass) rank as the State's fourth largest farm product in gross value, behind milk/cream, grapes, and cattle, and ahead of cotton, almonds, and hay, according to 1996 California Department of Food and Agriculture statistics. The prominence of the nursery industry reflects the extent of urbanization in California, as well as favorable climatic conditions.

California nursery products had a $1.6 billion farmgate value (wholesale value at the farm) in 1996. San Diego is the leading California county in nursery product valuation, followed by Santa Barbara, San Mateo, and Los Angeles Counties. California wholesale production represents about 26 percent of national nursery product sales.

An important difference between the nursery industry and other agricultural sectors is the extent to which the industry's revenues are tied to urban, as well as to agricultural, water supplies. Bulletin 160 treats nursery water use as an agricultural use. Many of the industry's products, however, are destined for urban and commercial locations where urban water supply availability influences landscaping choices and the market for nursery products.

About 25,000 acres are devoted to nursery products in California. Much of the acreage is in proximity to urbanized, coastal regions of the State near markets and major transportation routes.

etables followed by a summer cotton crop). In these cases, annual irrigated acreage is counted as the sum of the acreage of the individual crop types. In the years between county land use surveys, the Department estimates crop types and acreage using data collected from county agricultural commissioners, local water agencies, University of California Cooperative Extension Programs, and the California Department of Food and Agriculture.

The starting point for determining Bulletin 160-98 1995 base acreage was normalized 1990 irrigated acreage from Bulletin 160-93. Changes in crop acreage between 1990 and 1995 were evaluated to determine if they were due to short-term causes (e.g., drought or abnormal spring rainfall), or if there was an actual change in cropping patterns. Base year acreage was normalized to represent the acreage that would most likely be expected in the absence of weather and market related abnormalities. (More detail on the concept of normalizing base year data is presented in Chapter 3.) Figure 4-7 illustrates some general trends in California cropping patterns over time.

The Central Valley produces most of California's tomato crop. Much of the crop is used for processed tomato products, such as canned tomatoes and tomato sauces. Acreage devoted to truck crops like tomatoes is expected to increase in the future.

Crop acreage by region for the normalized 1995 base is presented in Table 4-14. The 1995 base irrigated land acreage is about 9.1 million acres, which, when multiple cropped areas are tabulated, becomes a base irrigated cropped acreage of about 9.5 million acres.

Forecasting Future Irrigated Acreage. The

FIGURE 4-7

General Trends in Cropping Patterns Over Time

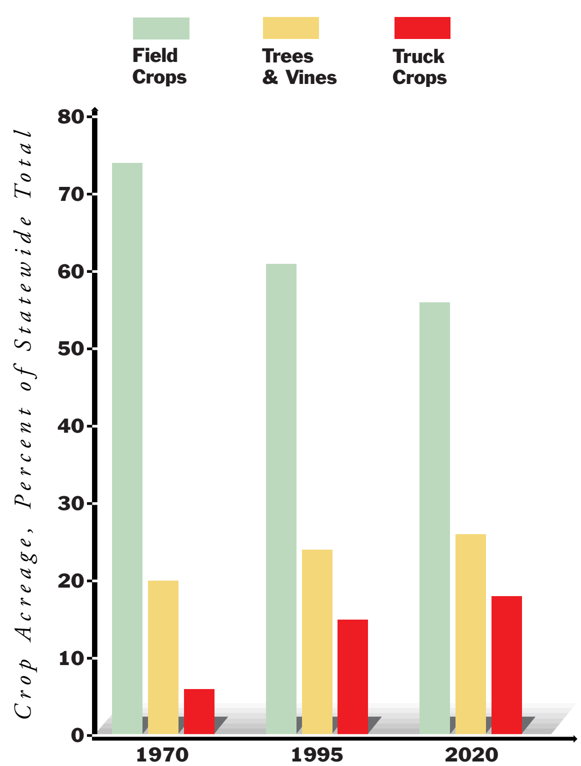


TABLE 4-14

California Crop and Irrigated Acreage by Hydrologic Region, 1995 level (thousands of acres)

Irrigated Crop	*NC*	*SF*	*CC*	*SC*	*SR*	*SJ*	*TL*	*NL*	*SL*	*CR*	*Total*
Grain	72	2	26	11	270	180	260	7	2	70	900
Rice	0	0	0	0	494	22	0	1	0	0	517
Cotton	0	0	0	0	9	185	1,026	0	0	24	1,244
Sugar beets	6	0	3	0	54	47	30	0	0	38	178
Corn	1	1	3	4	92	212	116	0	0	9	438
Other field	3	1	16	4	155	120	97	0	1	70	467
Alfalfa	53	0	21	10	149	231	296	44	34	256	1,094
Pasture	122	5	18	20	352	199	49	107	18	43	933
Tomatoes	0	0	10	7	138	82	111	0	0	9	357
Other truck	23	11	382	87	56	130	194	2	3	172	1,060
Almond/pistachios	0	0	0	0	106	251	177	0	0	0	534
Other deciduous	7	6	18	3	219	154	191	0	3	1	602
Subtropical	0	0	19	161	28	8	202	0	0	37	455
Grapes	36	39	56	6	17	184	378	0	0	20	736
Total Crop Area	**323**	**65**	**572**	**313**	**2,139**	**2,005**	**3,127**	**161**	**61**	**749**	**9,515**
Multiple Crop	0	0	142	30	52	56	63	0	0	104	447
Irrigated Land Area	323	65	430	283	2,087	1,949	3,064	161	61	645	9,068

Water Use Impacts from Urbanization of Agricultural Lands—A San Joaquin Valley Example

The Department projects a decline in California's irrigated acreage by 2020, due in part to urbanization of agricultural lands. Much of this urbanization will occur in the South Coast Region and in the San Joaquin Valley. Potential changes in water use resulting from land use conversion are often of concern to local agencies responsible for land use planning or for providing water supplies. Changes in water use must be evaluated on a site-specific basis, as the following example for the San Joaquin Valley illustrates.

Changes in water use depend on the kinds of crops grown and the density and type of urban development in an area. In the case of single-family dwellings, applied water use varies with housing density. Numerous studies have shown that dwellings on larger lots use more water per dwelling unit due to the larger landscaped areas. However, higher density developments have the greater applied water use per acre of land. A recent Department study of the Fresno area showed that applied water use of single-family dwellings and agricultural crops were similar at low housing densities (four or five units per acre). However, higher density single-family dwellings (six units or more per acre) that have become common in today's new home construction market tended to have greater applied water requirements than some crops.

Growth in the Fresno area has caused expansion of urban development onto adjoining agricultural lands. Figure 4-8 is a plot of Department land use data illustrating the long-term expansion of urban development onto agricultural lands in the area. Department data show that average urban applied water use in the Fresno area (urban water use includes residential, commercial, and industrial purposes) is equivalent to about 3.2 af/acre. Typical agricultural applied water use for crops grown in the area is shown below. Actual agricultural applied water use for an individual crop will vary with field-specific conditions such as soil type and irrigation method.

Type of Use	*Applied Water Use (af/acre)*
Urban	3.2
Agricultural	
Barley	1.3
Grapes	2.9
Cotton	3.2
Deciduous orchard	3.5
Pasture (improved)	4.5
Alfalfa	4.7

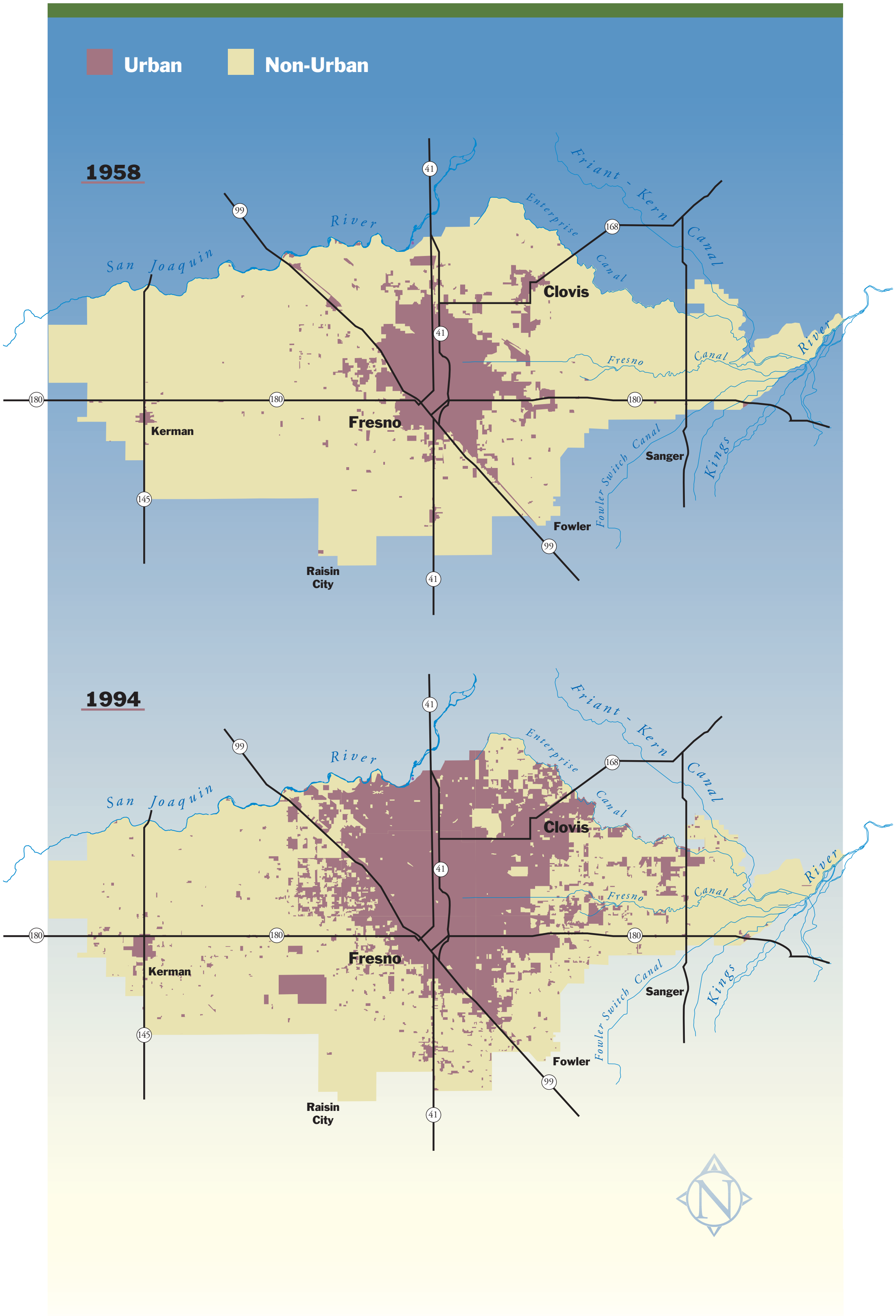
Department's 2020 irrigated acreage forecast was derived from staff research, a crop market outlook study, and results from the Central Valley Production Model. As with any forecast of future conditions, there are uncertainties associated with each of these approaches. The Department's integration of the results from three independent approaches is intended to represent a best estimate of future acreage, absent major changes from present conditions. It is important to emphasize that many factors affecting future cropped acreage are based on national (federal Farm Bill programs) or international (world export markets) circumstances. California agricultural products compete with products from other regions in the global economy and are affected by trade policies and market conditions that reach far beyond the State's boundaries.

The Federal Agriculture Improvement and Reform Act of 1996, for example, affects agricultural markets nationwide, by changing federal price supports for specified agricultural commodities. Under the terms of that act, federal payments to growers will be reduced by 2002, and prior farm bill provisions that required growers to reduce planted acreages of regulated commodities are no longer in force. (Commodities with significant federal price support include wheat, feed grains, rice, cotton, dairy products, sugar, and peanuts.) The overall impact of the act to California may be less than its impact to states whose agriculture is less diversified and who are less active in export markets. In 1994, for example, federal farm bill production payments to California growers represented about 1 percent of California's agricultural revenue. The potential impacts of FAIRA to California's agricultural market are considered in Bulletin 160-98 by the crop market outlook study.

Intrastate factors considered in making acreage forecasts included urban encroachment onto agricultural land and land retirement due to drainage problems (discussed in more detail in the following section). Urbanization on lands presently used for irrigated agriculture is a significant consideration in the South Coast Region and in the San Joaquin Valley, based on projected patterns of population growth. (See sidebar on water use impacts of land conversion.) DOF 2020 population forecasts, along with information gathered from local agency land use plans, were used

FIGURE 4-8

Changes in Land Use Over Time, DAU 233



to identify irrigated lands most likely to be affected by urbanization. Local water agencies and county farm advisors were interviewed to assess their perspective on land use changes affecting agricultural acreage. For example, urbanization may eliminate irrigated acreage in one area, but shift agricultural development onto lands presently used as non-irrigated pasture. Soil types and landforms are important constraints in agricultural land development. If urbanization occurs on prime Central Valley farmland, some agricultural production may be able to shift to poorer quality soils on hilly lands adjoining the valley floor. A consequent shift in crop types and irrigation practices would likely result—for example, from furrow-irrigated row crops to vineyards on drip irrigation.

The Department's crop market outlook, a form of Delphi analysis, was developed using information and expert opinions gathered from interviews with more than 130 University of California farm advisors, agricultural bankers, commodity marketing specialists, managers of cooperatives, and others. Three basic factors guided the CMO: current and future demand for food and fiber by the world's consumers; the share California could produce to meet this worldwide demand; and technical factors, such as crop yields, pasture carrying capacities, and livestock feed conversion ratios that affect demand for agricultural products. (Milk and dairy products are California's largest agricultural product, in terms of gross value. The demand for these products is reflected in the markets for alfalfa, grains, and other fodder used by dairies.) The CMO forecasts a statewide crop mix and estimates corresponding irrigated acreage. The major findings of the CMO for year 2020 were that grain and field crop acreage would decrease, while acreage of truck crops and permanent crops would increase.

The Central Valley Production Model is a mathematical programming model that simulates farming decisions by growers. Inputs include detailed information about production practices and costs as well as water availability and cost by source. The model also uses information on the relationship between production levels of individual crops and crop market prices. The model's geographic coverage is limited to the Central Valley, which represents about 80 percent of the State's irrigated agricultural acreage. The CVPM results also indicated future crop shifting, from grains and field crops to vegetables, trees, and vines. The CVPM forecast showed a small reduction in crop acreage from 1995 to 2020.

Other Factors Affecting Forecasted Irrigated Acreage. The process of estimating future irrigated acreage considered statewide factors such as crop markets and urban expansion onto agricultural lands. The Department considered an additional region-specific factor, the long-standing agricultural drainage management issues on the west side of the San Joaquin Valley. Drainage management issues in this area have a dual focus—salt management to permit continued agricultural production on lands requiring drainage systems, and trace minerals management (principally selenium) to limit adverse water quality and environmental impacts.

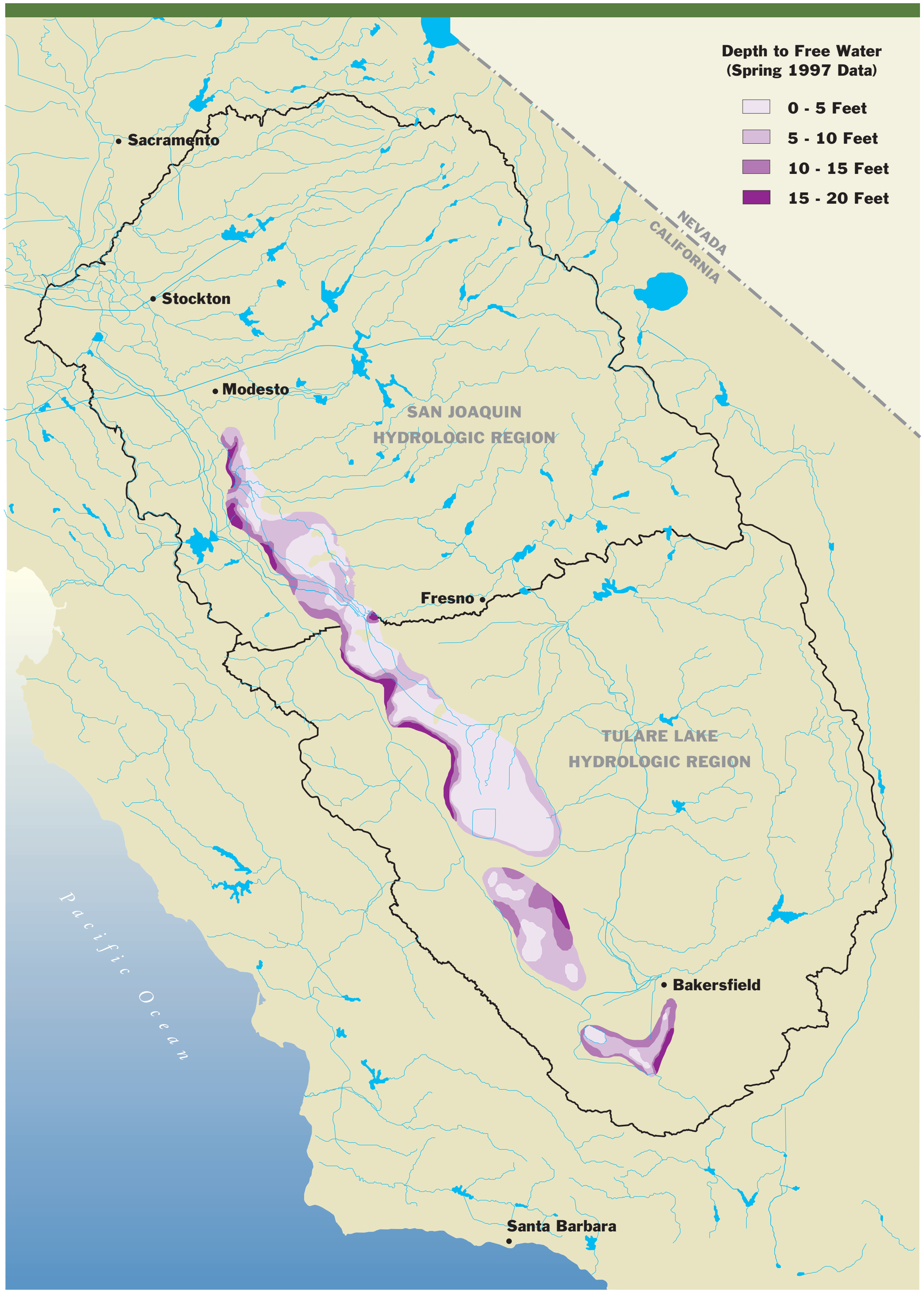
The need for drainage systems to permit farming in some westside areas was recognized concurrently with the development of irrigated agriculture in the region. USBR's San Luis Drain, for example, was originally planned to convey drainage water out of the valley to the Delta. The drain was instead terminated at Kesterson Reservoir, where waterfowl mortalities led to discovery of elevated selenium levels in the early 1980s. The drain was subsequently closed. (A discussion of trial reopening of part of the drain for the Grasslands Bypass Channel Project is provided in Chapter 8.) Post-Kesterson studies of valley drainage problems have sought to quantify factors such as extent of areas with shallow depths to groundwater, tributary areas in Coast Range sediments from which trace minerals are derived, and water quality characteristics of drain water and shallow groundwater.

The 1990 report of the interagency San Joaquin Valley Drainage Program projected that as much as 460,000 acres of irrigated land would be taken out of production by the year 2020 if the report's recommendations were not implemented. The report recommended retirement of 75,000 acres of land having the worst drainage problems by 2040. The Bulletin 160-98 year 2020 acreage forecast follows the same procedure used in Bulletin 160-93 and assumes that the 75,000 acres would be retired at an average rate of 1,500 acres per year. Thus, 45,000 acres of land would be retired between 1990 and 2020. USBR's 1997 request for proposals for the CVPIA land retirement program (described in Chapter 6) elicited offers to sell 31,000 acres of drainage-impaired lands, suggesting that the assumed 45,000 acres of land retirement could occur by 2020.

Data from the Department's monitoring program for groundwater levels in the San Joaquin Valley are shown in Figure 4-9. Agricultural acreage with a water

FIGURE 4-9

Areas of Shallow Groundwater in the San Joaquin Valley



Agroforestry Research

Agroforestry is being tested for managing drainage impaired lands. Agroforestry systems integrate trees and shrubs into cropping activities to produce marketable products and/or provide resource conservation. Agroforestry principles could be applied to on-farm water management, where increasingly saline water would be applied to successively more salt-tolerant plants to reduce drainage volumes. For example, drainage water from salt-sensitive crops could be used to irrigate a salt-tolerant crop like cotton. Drainage water from the cotton would then be used to irrigate salt-tolerant trees, such as eucalyptus. Drainage water from the trees would be reused again to irrigate highly salt-tolerant plants such as saltgrass. Finally, the drainage water would be discharged into a solar evaporator. This is an experimental program. To be commercially successful, markets would need to be found for the eucalyptus trees and other biomass produced. In 1985 a cooperative effort among several growers and agencies began at a 27-acre site near Mendota. A second research project of 622 acres was established at Red Rock Ranch in Fresno County in 1993, and a third research project was started by Tulare Lake Basin Drainage District.

table within 10 feet of the surface increased from 1,061,000 acres in 1991 to 1,262,000 acres in 1997. Agricultural lands with a water table within 5 feet of the surface increased from 311,000 acres in 1991 to 743,000 acres in 1997. Increases in the extent of shallow groundwater coincide with the end of drought conditions and above-average rainfall. (The Department's monitoring program is limited to measurement of groundwater levels. There has been no region-wide monitoring of selenium and other constituents in shallow groundwater since the 1987 work performed for the 1990 report.)

To implement recommendations of the 1990 report, four State agencies (DWR, SWRCB, DFG, and DFA) and four federal agencies (USBR, USFWS, USGS, and Natural Resource Conservation Service) signed a 1991 MOU to participate in a cooperative interagency program. The program was to address the management plan's eight major recommendations: source control, drainage reuse, evaporation ponds, land retirement, groundwater management, limiting discharge to the San Joaquin River, and institutional change. (The plan's recommendations did not address disposal of drain water outside of the Central Valley.) Significant progress has been made on some recommendations. Some examples of drainage management activities are described in Chapters 7-9.

In 1997, the interagency drainage program drafted

Factors that influence the conversion of irrigated lands to urban use include the lands' proximity to existing urban areas and transportation corridors, and local agency land use planning and zoning policies.

an activity plan to update the report's recommendations with new information. The activity plan is scheduled for completion in 1999. Source control objectives of the 1990 report have been achieved or exceeded over large areas. In the first year of Grasslands Bypass Channel Project implementation (described in Chapter 8), irrigation and drainage modifications by Grasslands area farmers reduced selenium discharges to the San Joaquin River. Tiered water pricing has been implemented in the drainage problem area of the Grasslands subarea. Three agroforestry drainage reuse research projects have been implemented (see sidebar).

One factor not included in Bulletin 160-98 irrigated acreage forecasts is the potential large-scale conversion of agricultural land to wildlife habitat for reasons other than the westside drainage problems described above. The CALFED program represents the largest pending example of potential conversion of irrigated agricultural lands to habitat, as described in CALFED's March 1998 draft programmatic EIR/EIS and supporting documents. CALFED's potential land conversion amounts have not been included in the Bulletin 160-98 irrigated acreage forecast because they are preliminary at this time (a site-specific environmental document with an implementation schedule for land conversion has not yet been prepared), and because CALFED's preliminary numbers are so large relative to the Bulletin's market-based forecast of irrigated acreage that they would negate the results of the forecast. Overall, CALFED program activities as presently planned could convert up to 290,000 irrigated acres to habitat and other uses, an amount almost as great as the 325,000 acre reduction in irrigated acreage forecast in the Bulletin. Water use implications of large-scale land conversions are not included in the Bulletin 160-98 forecast. Impacts of such land conversions are expected to be addressed in the next water plan update, when CALFED's program may be better defined.

The difficulty in estimating impacts from large-scale land conversion programs stems from the domino effect that changes in acreage in one location have on acreage and crop types in other areas, and how crop markets determine which crop shifts are feasible. For example, CALFED's preliminary reports suggest that up to 190,000 irrigated acres in the Delta could be converted to other land uses. This amount represents about 40 percent of Delta irrigated acreage, where principal crops are corn, alfalfa, tomatoes, grain, orchard

Alfalfa and Market Conditions

The market for California alfalfa is closely tied to the State's dairy industry. California is the nation's leading dairy state. According to DFA's 1996 statistics, milk/cream production amounted to $3.7 billion, making it the State's top-valued agricultural commodity. California, with about 1.3 million dairy cows and over 2,300 dairy farms, accounted for almost 17 percent of the nation's dairy production in 1996. Leading dairy counties are Tulare, San Bernardino, Merced, Stanislaus, and Riverside.

Alfalfa supports the dairy and livestock industries (including the recreational horse industry) and also provides about one-third of the nation's honey production. In-state alfalfa production does not meet all of the demand within California. Alfalfa is trucked from the intermountain states to Central California dairies. Although some alfalfa is exported from California (mostly to Japan), imports into California have exceeded exports by 1 to 8 percent over the past several years.

California milk/cream production has increased more than 50 percent in the past 12 years. About half of this increase is due to increases in milk yield per cow and the remainder is due to increased numbers of cows. This has created a continuing demand for alfalfa. Most dairy rations in California contain some component of alfalfa.

Relatively little raw milk flows into or out of the State. California's dairy industry is based on in-state production and processing capacity. The demand for milk products is greatest in the State's major population centers — the San Francisco Bay Area and urbanized Southern California. Dairy production has been concentrated in the San Joaquin Valley and in the Inland Empire region of Southern California, within convenient distances of major markets. Increasing urbanization of formerly agricultural lands in Southern California is shifting more dairy production to the southern San Joaquin Valley. To supply feed to these dairies, the San Joaquin Valley has become the largest production area for alfalfa in the State, producing nearly half of California's alfalfa.

According to DFA, California's Grade A milk production can be broken down into the following categories:

Cheese	36%
Butter & nonfat dry milk	29%
Fluid milk products	24%
Frozen dairy products	6%
Soft products	5%

TABLE 4-15

California Crop and Irrigated Acreage by Hydrologic Region, 2020 Level
(thousands of acres)

Irrigated Crop	*NC*	*SF*	*CC*	*SC*	*SR*	*SJ*	*TL*	*NL*	*SL*	*CR*	*Total*
Grain	66	1	21	5	249	152	201	8	0	97	800
Rice	0	0	0	0	484	15	0	1	0	0	500
Cotton	0	0	0	0	15	171	888	0	0	46	1,120
Sugar beets	6	0	2	0	52	18	13	0	0	29	120
Corn	2	0	3	2	90	188	101	1	0	3	390
Other field	3	1	14	1	154	139	110	0	0	33	455
Alfalfa	62	0	20	6	147	181	238	50	24	217	945
Pasture	123	5	16	6	316	165	26	103	18	32	810
Tomatoes	0	0	8	4	141	93	130	0	0	14	390
Other truck	28	11	373	43	79	197	300	2	1	231	1,265
Almond/pistachios	0	0	0	0	127	270	198	0	0	0	595
Other Deciduous	7	6	20	3	234	153	199	0	2	1	625
Subtropical	0	0	18	117	33	10	215	0	0	32	425
Grapes	38	41	75	3	29	183	366	0	0	15	750
Total Crop Area	**335**	**65**	**570**	**190**	**2,150**	**1,935**	**2,985**	**165**	**45**	**750**	**9,190**
Multiple Crop	0	0	150	10	70	80	100	0	0	145	555
Irrigated Land Area	335	65	420	180	2,080	1,855	2,885	165	45	605	8,635

The proximity of California agriculture to densely populated urban markets encourages the production of specialty crops. Pumpkin patches and Christmas tree lots are examples of specialized urban niche markets.

crops, and truck crops (e.g., asparagus). Some land conversion in the Delta might result in production on new agricultural lands—most likely, rolling hills on the edge of the valley floor which are suitable for only limited crop types (orchards and vineyards). Some of the land conversion might result in increased demand in other areas for the affected crops, such as increased demand for asparagus from the Imperial and Salinas Valleys.

Results of 2020 Acreage Forecast. Table 4-15 shows the 2020 irrigated acreage forecast. The total irrigated crop acreage is forecasted to decline by 325,000 acres from 1995 to 2020, primarily in the San Joaquin Valley and South Coast areas. Reductions in crop acreage are due to urban encroachment, drainage problems in the westside San Joaquin Valley, and a more competitive economic market for California agricultural products. Pasture and field crops are forecasted to decline by about 631,000 acres. Truck crops and permanent crops are forecasted to increase by about 238,000 and 68,000 acres, respectively. Acreage with multiple cropping is forecasted to increase by 108,000 acres, reflecting the expected increased production of truck crops. These statewide findings are used in developing the forecasted agricultural water demands.

Summary of Agricultural Water Use

Crop water use information and irrigated acreage data are combined to generate the 2020 agricultural water use by hydrologic region shown in Table 4-16. As previously noted, the 2020 forecasted values take into account EWMP implementation, which results in a 2020 applied water reduction of about 800 taf.

TABLE 4-16

Applied Agricultural Water Use by Hydrologic Region (taf)

	1995		*2020*	
Region	*Average*	*Drought*	*Average*	*Drought*
North Coast	894	973	927	1,011
San Francisco Bay	98	108	98	108
Central Coast	1,192	1,279	1,127	1,223
South Coast	784	820	462	484
Sacramento River	8,065	9,054	7,939	8,822
San Joaquin River	7,027	7,244	6,450	6,719
Tulare Lake	10,736	10,026	10,123	9,532
North Lahontan	530	584	536	594
South Lahontan	332	332	257	257
Colorado River	4,118	4,118	3,583	3,583
Total (rounded)	**33,780**	**34,540**	**31,500**	**32,330**

Environmental Water Use

Bulletin 160-98 defines environmental water as the sum of:

- Dedicated flows in State and federal wild and scenic rivers
- Instream flow requirements established by water right permits, DFG agreements, court actions, or other administrative documents
- Bay-Delta outflows required by SWRCB
- Applied water demands of managed freshwater wildlife areas

This definition recognizes that certain quantities of water have been set aside or otherwise managed for environmental purposes, and that these quantities cannot be put to use for other purposes in the locations where the water has been reserved or otherwise managed. This definition also recognizes that these uses of environmental water can be quantified. Unlike urban and agricultural water use, much of this environmental water use is brought about by legislative or regulatory processes. Certainly the environment uses more water than is encompassed in this definition—the rainfall that sustains the forests of the Sierra Nevada and the North Coast, the winter runoff that supports flora and fauna in numerous small streams, the shallow groundwater that supports riparian vegetation in some ephemeral streams—but the Bulletin's definition captures uses of water that are managed (in one fashion or another) and quantifiable. As described earlier, average annual statewide precipitation over California's land surface amounts to about 200 maf. About 65 percent of this precipitation is consumed through evaporation and transpiration by the State's forests, grasslands, and other vegetation. The remaining 35 percent comprises the State's average annual runoff of about 71 maf. The environmental water demands discussed in this section are demands that would be met through a designated portion of that average annual runoff.

The following discussion covers factors affecting the four categories of environmental water use. As with urban and agricultural water use, options for meeting future environmental water needs—such as federal acquisition and transfer of water to meet CVPIA AFRP goals—are covered in Chapter 6 and in the regional water management chapters. The environmental water use categories below are discussed in order of size—from greatest (wild and scenic rivers) to smallest (wildlife refuges). Environmental water use is shown on an applied water basis.

Flows in Wild and Scenic Rivers

Flows in wild and scenic rivers constitute the largest environmental water use in the State. Figure 4-10 is a map of California's State and federal wild and scenic rivers.

The 1968 National Wild and Scenic Rivers Act, codified to preserve the free-flowing characteristics of rivers having outstanding natural resources values, prohibited federal agencies from constructing, authorizing, or funding the construction of water resources projects having a direct or adverse effect on the values for which the river was designated. (This restriction also applies to rivers designated for potential addition to the national wild and scenic rivers system.) There are two methods for having a river segment added to the federal system—congressional legislation, or a state's petition to the Secretary of the Interior for federal designation of a river already protected under state statutes. No new federal designations have been made since publication of Bulletin 160-93.

A number of river systems within lands managed by federal agencies are being studied as candidates. For example, U.S. Forest Service draft environmental documentation in 1994 and 1996 recommended designation of 5 streams (129 river miles) in Tahoe National Forest and 160 river miles in Stanislaus National Forest. These waterways drain to the Central Valley where their flows are used for other purposes, and wild and scenic designation would not affect the existing downstream uses.

The California Wild and Scenic Rivers Act of 1972 prohibited construction of any dam, reservoir, diversion, or other water impoundment on a designated river. As shown on Figure 4-10, some rivers are included in both federal and State systems. No new State designations have been made since Bulletin 160-93, although the Mill and Deer Creeks Protection Act of 1995 (Section 5093.70 of the Public Resources Code) gave portions of these streams special status similar to wild and scenic designation, by restricting construction of dams, reservoirs, diversions or other water impoundments.

Tables 4-17 and 4-18 show the wild and scenic river flows used in Bulletin 160-98 water budgets by waterway and by hydrologic region. The flows shown are based on the rivers' unimpaired flow. (The unimpaired flow in a river is the flow measured or calculated at some specific location that would be unaffected by stream diversions, storage, imports or exports, and return flows.) For the average year condition, the

FIGURE 4-10

California Wild and Scenic Rivers

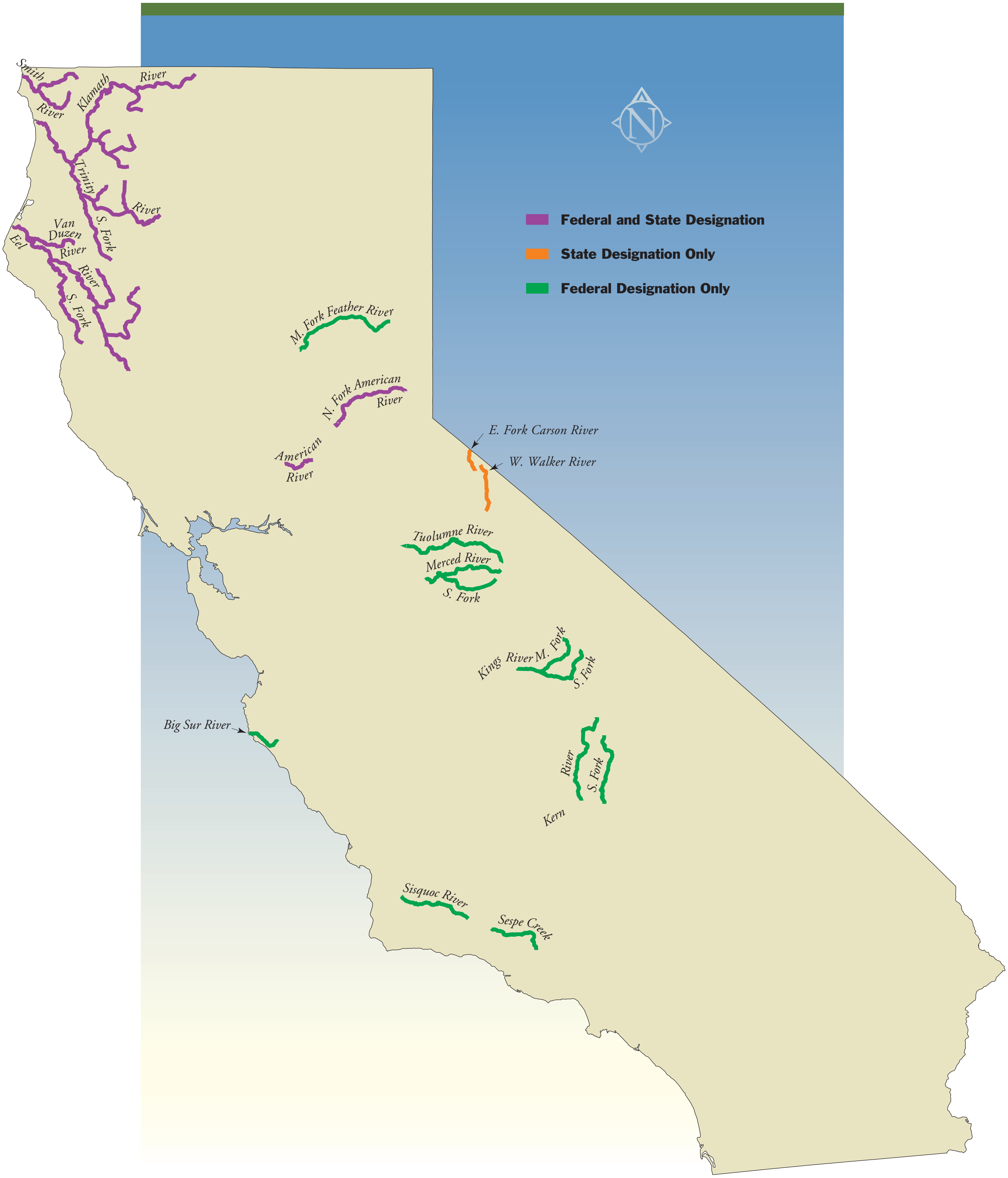


TABLE 4-17

Wild and Scenic River Flows by Waterway (taf)

Waterway	*1995* Average	*1995* Drought	*2020* Average	*2020* Drought
Klamath	9,070	3,980	9,070	3,980
Smith	2,920	1,720	2,920	1,720
Eel	5,810	2,200	5,810	2,200
Big Sur	83	22	83	22
Sisquoc	15	6	15	6
Sespe Creek	69	51	69	51
Middle Fork Feather	1,129	497	1,129	497
North Fork American	584	239	584	239
Lower American	20	0	20	0
Tuolumne	1,192	572	1,192	572
Merced	782	367	782	367
Kings	896	448	896	448
North Fork Kern	628	275	628	275
South Fork Kern	90	28	90	28
East Fork Carson	71	34	71	34
West Walker	200	120	200	120
Total (rounded)	**23,560**	**10,560**	**23,560**	**10,560**

TABLE 4-18

Wild and Scenic River Flows by Hydrologic Region (taf)

Region	*1995* Average	*1995* Drought	*2020* Average	*2020* Drought
North Coast	17,800	7,900	17,800	7,900
San Francisco Bay	0	0	0	0
Central Coast	98	28	98	28
South Coast	69	51	69	51
Sacramento River	1,733	736	1,733	736
San Joaquin River	1,974	939	1,974	939
Tulare Lake	1,614	751	1,614	751
North Lahontan	271	154	271	154
South Lahontan	0	0	0	0
Colorado River	0	0	0	0
Total (rounded)	**23,560**	**10,560**	**23,560**	**10,560**

long-term unimpaired flow from the Department's Bulletin 1 was used. The estimated average unimpaired flow for the 1990-91 water years was used for the drought condition.

Instream Flows

Instream flow is the water maintained in a stream or river for instream beneficial uses such as fisheries, wildlife, aesthetics, recreation, and navigation. Instream flow is a major factor influencing the productivity and diversity of California's rivers and streams.

Instream flows may be established in a variety of ways—by agreements executed between DFG and a water agency, by terms and conditions in a water right permit from SWRCB, by terms and conditions in a FERC hydropower license, by a court order, or by an agreement among interested parties. Required flows on most rivers vary by month and year type, with wet year requirements generally being higher than dry year requirements. Converting from net water use budgets used in prior editions of Bulletin 160 to the applied water budgets used in Bulletin 160-98 created a challenge in properly accounting for multiple instream flows within a river basin. Bulletin 160-98 used a simplified approach in which only the largest downstream flow requirement was included in the water budgets.

Part of Sespe Creek is included in the wild and scenic river system. The creek, located in Ventura County, is tributary to the Santa Clara River.

This simplified approach undercounts applied instream flow requirements on streams having multiple requirements. The Department is developing a new modeling approach for the next water plan update that will more accurately quantify applied instream flows.

Since the determination of 1990-level instream flow values used as base conditions in Bulletin 160-93, subsequent agreements or decisions have increased or added instream flow requirements for the Trinity River, Mokelumne River, Stanislaus River, Tuolumne River, Owens River, Putah Creek, and Mono Lake tributaries. In addition, ten new waterways have been added to the Bulletin 160-98 instream flow water budgets—the Mad River, Eel River, Russian River, Truckee River, East Walker River, Nacimiento River, San Joaquin River (at Vernalis), Walker Creek, Lagunitas Creek, and Piru Creek. The sidebar on American River environmental water use illustrates how environmental water demands are treated in Bulletin 160 water budgets.

Factors Affecting Future Instream Flows. It is difficult to forecast future regulatory actions or agreements that could change existing instream flow requirements. Bulletin 160-98 thus does not attempt to quantify the outcome of future regulatory or administrative actions. Factors likely to affect future flow requirements include listings or potential listings of new fish species, habitat restoration programs, and programs to acquire water for environmental purposes.

Recent decisions on federal listing of coho salmon and steelhead trout (see Chapter 2) are likely to influence water management decisions affecting these species, but the specific actions will ultimately depend on the outcome of consultations, biological assessments, biological opinions, and habitat conservation plans. In 1997, the Governor's Executive Order W-159-97 created the Watershed Protection and Restoration Council. The council oversees State watershed protection and enhancement activities, including restoration of anadromous fish. One goal of this effort is to provide sufficient protection to coho, steelhead, and other anadromous salmonids to satisfy ESA requirements. Successful implementation of this program could lessen water supply impacts of salmonid listings.

Coho salmon are found in coastal streams and in large river systems such as the Klamath River and its tributaries. Some of the greatest potential for new water supply impacts could be on the Klamath River system (including its Trinity River tributary), where USFWS is finalizing instream flow studies for several salmonids. Steelhead populations are distributed throughout coastal streams and rivers, and are also found in the Sacramento Valley. (Wild stocks of steelhead in the Sacramento River system are mostly confined to upper watershed tributaries such as Antelope, Deer, and Mill Creeks, and the Yuba River. The San Joaquin River system no longer supports a significant natural steelhead population—most steelhead found in the system are hatchery fish.) Data from the SWP and CVP pumping plants in the southern Delta indicate that most juvenile steelhead move through the Delta during the winter and early spring, when Bay-Delta Accord restrictions are already in place. Water supply impacts on coastal rivers and streams must be evaluated from a basin-specific standpoint.

The spring-run chinook salmon traditionally spawned in upper reaches of Central Valley rivers and their tributaries. Today, Deer, Mill, and Butte Creeks are considered crucial Sacramento River tributaries for spring-run spawning. Sustaining populations of spring-run are also found in Battle Creek, and the Feather and Yuba Rivers, although there are questions about the genetic integrity of these populations because of interbreeding between fall-run and spring-run salmon. Portions of Deer and Mill Creeks have been given special status by State legislation to help protect the fishery.

As described in Chapters 5 and 6, many habitat restoration programs are underway and substantial funding is available for restoration actions. Improvements such as facilitating fish passage, replenishing spawning gravel, and restoring shaded riverine habitat will help in efficient management of water used for environmental purposes. Specific benefits of habitat restoration will have to be evaluated on a watershed-by-watershed basis—it is not possible to quantify potential water supply implications of present and future habitat restoration actions at a statewide level. Examples of programs or projects now underway are described in later chapters.

The 1997 draft programmatic EIS for CVPIA implementation describes federal water acquisition alternatives for the AFRP. Table 4-19 shows the amounts proposed in alternative 4 of the draft PEIS. These flows represent the high end of potential federal water acquisition actions. Under USBR's assumptions for alternative 4, the instream flows are not allowed to be exported at the Delta. Quantification of alternative 4 flows was provided by PROSIM operations studies. The federal agencies' ability to acquire the water would be subject to their finding willing sellers.

In addition to water acquisition on major rivers

Environmental Water Use—An American River Example

As discussed in Chapter 3, the return flow from one water use can become the supply for the next downstream use. The applied water budgets in Bulletin 160-98 reflect the multiple uses which supplies in a river basin may have. Reapplication of flows in the American River for environmental purposes provides an illustration of how the Bulletin accounts for multiple uses in its water budgets.

The American River originates in the Sierra Nevada, flowing generally from east to west down through the foothills into the Sacramento Valley, ultimately reaching the Sacramento River and the Delta. The upper watershed of the American River consists of the north, middle and south forks. The mainstem, or Lower American River, begins near Folsom at the confluence of the north and south forks. Environmental water supplies are reapplied at several locations between the upper watershed and the Delta.

Wild and scenic environmental water demands exist on the American River's north fork (584 taf) and mainstem (20 taf). In Bulletin 160-98 water budgets, American River wild and scenic flows are classified as environmental water use on the demand side of the budget and as required environmental instream flow on the supply side of the budget. These environmental demands are not consumptive; hence, the surface supplies are available for downstream use.

The American River has several instream flow requirements on its three forks as well as on its mainstem. For example, a 54 taf (75 cfs) requirement exists below Ralston Afterbay Dam on the middle fork and a 72 taf (100 cfs) requirement exists below Chili Bar Dam on the south fork. The river's largest instream flow requirement is on the mainstem below Nimbus Dam. This 234 taf requirement is the only American River instream flow requirement accounted for in the water budgets. As with wild and scenic demands, the American River instream flow requirement is shown as environmental water use on the demand side of the budget and as required environmental instream flow on the supply side of the budget. This environmental demand is not consumptive; therefore, the surface supply is available for downstream use.

Required instream flow in the American River is reapplied downstream to meet Delta outflow requirements. The Bulletin 160-98 water budgets classify this flow as reapplied surface water supply. About 70 percent of the Delta's 5.6 maf environmental demand (4.0 maf) is satisfied through reapplication of water released to meet environmental instream requirements in rivers tributary to the Delta.

TABLE 4-19

Proposed Instream Flows, CVPIA PEIS Alternative 4 (taf)

Location	*Region*	*Target*	*Average*
Merced River	San Joaquin River	200	194
Tuolumne River	San Joaquin River	200	197
Stanislaus River	San Joaquin River	200	194
Calaveras River	San Joaquin River	30	27
Mokelumne River	San Joaquin River	70	62
Yuba River	Sacramento River	100	87
Total		**800**	**761**

for the Alternative 4 instream flows shown in the table, the draft PEIS also proposes water acquisition on smaller Sacramento River tributaries such as Deer, Mill, and Battle Creeks. The draft PEIS does not quantify target flows and acquisitions for these smaller tributaries.

The public comment period on the draft CVPIA PEIS closed in April 1998 and USBR and USFWS expect to release a final PEIS in 1999, after the publication date of this Bulletin.

CVPIA authorizes DOI to acquire supplemental water from willing sellers. At this time, no long-term sources (e.g., long-term contracts for water transfers) have been established—water acquired has been purchased on a year-to-year basis. It is not possible to identify specifically how and where the supplemental water would be obtained in the future, or what other water demands might be reduced as a result of CVPIA water transfers. Chapter 6 provides more detail on how water marketing arrangements are treated in Bulletin 160 water budgets.

As discussed in Chapter 2, CVPIA also affects Trinity River instream flows, by requiring that Trinity River flows be maintained at not less than 340 taf/yr while USFWS conducts an instream flow study that was to be completed by 1996. USFWS's preliminary results suggest that instream flows of 592 taf/yr (weighted average of five water year types) may be proposed. USBR, USFWS, Trinity County, and the Hoopa Valley Tribe are preparing an EIR/EIS to evaluate impacts of the proposed flows. A draft EIR/EIS has not yet been released. Bulletin 160-98 uses the existing instream flow requirement of 340 taf/yr since a formal proposal for new Trinity River instream flows has not yet been released.

Instream Flow Summary. Tables 4-20 and 4-21 show instream flows used in Bulletin 160-98 water budgets by waterway and by hydrologic region. The drought year scenario shown in the tables represents the minimum annual required flow volume. For average water years, the annual required flow volume is computed by combining the expected number of years in each year type (wet, above normal, normal, below normal, and/or dry, as specified in the existing agreement or order).

In water budget computations, the Department counts instream flows as depleted if the flows go directly to a salt sink, such as the ocean. In the Central Valley where some instream flows may reach the ocean, any depletions are counted toward required Delta outflow (see following section). This approach avoids counting depletions twice—once as instream flow and once as Delta outflow.

Bay-Delta Outflow

Environmental water use for Bay-Delta outflow is computed by using operations studies to quantify SWRCB Order WR 95-6 requirements. This section briefly describes the Delta's setting and some of its environmental resource issues. Readers interested in detailed descriptions of Delta hydrodynamics, facilities, and environmental resources may wish to review the extensive materials prepared by the Interagency Ecological Program, San Francisco Estuary Program, or CALFED program.

Setting. The Bay-Delta has two high tides and two low tides every day. An enormous volume of water (an average of about one-fourth of the estuary's total volume), moves in and out of the estuary with each tidal cycle. Tidal action and Delta outflow are two important physical processes which establish salinity gradients and carry sediments through the system. Tidal action and Delta outflow cause seaward-flowing fresh water from the rivers to mix with denser landward-flowing salt water from the ocean. The average tidal flow rate in the Delta is about 170,000 cfs, much greater than the average seaward flow of fresh water from rivers and streams.

CVPIA Anadromous Fish Restoration Program

One provision of CVPIA directed DOI to develop (by October 1995) and to implement a program "which makes all reasonable efforts to ensure that, by the year 2002, natural production of anadromous fish in Central Valley rivers and streams will be sustainable, on a long-term basis, at levels not less than twice the average levels attained during the period of 1967-1991". (The San Joaquin River between Friant Dam and Mendota Pool is not covered by this goal.) In response to this provision, USFWS prepared a 1995 working paper listing many potential restoration actions (some involving instream flows, and some not) without regard to their reasonableness. Elements of that working paper were subsequently incorporated into a revised draft restoration plan prepared in May 1997. One function of the draft plan was to evaluate (at a programmatic level) the reasonableness of implementing potential restoration actions, given the authority and funding provided DOI by CVPIA. (For example, a potential restoration action that would involve modifying the diversion works of a local water agency would only be reasonable if the local agency wished to participate with USBR or USFWS in the action.) The revised draft plan is scheduled to be followed by an implementation plan that would review priority actions to be taken in the next three to five years.

The CVPIA tools available to USFWS and USBR to carry out the AFRP include the 800 taf of project water dedicated for environmental purposes, the authority to acquire supplemental water to achieve AFRP goals, and the many physical habitat restoration measures required in the act (e.g., restoring spawning gravel, screening diversions, improving fish passage at Red Bluff Diversion Dam). The CVP dedicated water is only available to USFWS and USBR on CVP-controlled rivers below the major project dams. For other Central Valley waterways, the agencies are proposing to carry out a water acquisition program to buy water to meet AFRP needs. The quantity of water to be acquired is subject to available federal funding and the availability of water on the market. USBR's 1997 draft CVPIA PEIS illustrates costs and impacts associated with different levels of supplemental water acquisition.

Fish species covered by the CVPIA's doubling goal are salmon, steelhead, striped bass, sturgeon, and American shad. This sturgeon was photographed at the Steinhart Aquarium.

TABLE 4-20

Instream Flow Requirements by Waterway (taf)[a]

River or Creek	*1995*		*2020*	
	Average	*Drought*	*Average*	*Drought*
Klamath	833	833	833	833
Trinity	341	341	341	341
Mad	46	46	46	46
Eel	49	15	49	15
Russian	142	51	142	51
Lagunitas Creek	10	9	10	9
Walker Creek	6	0	6	0
Carmel	4	2	4	2
Nacimiento	16	7	16	7
Piru Creek	4	4	4	4
Clear Creek	25	25	25	25
Cache Creek	7	7	7	7
Putah Creek	22	22	22	22
Sacramento	1,945	1,702	1,945	1,702
Feather	880	588	880	588
Yuba	274	196	274	196
Bear	10	10	10	10
American	234	234	234	234
Mokelumne	158	84	158	84
Stanislaus	187	158	187	158
Tuolumne	214	94	214	94
Merced	79	67	79	67
San Joaquin	532	309	532	309
Truckee	70	70	70	70
East Walker	15	15	15	15
Mono tributaries	82	56	82	56
Owens	25	25	25	25
Total (rounded)	**6,210**	**4,970**	**6,210**	**4,970**

[a] On streams with multiple instream requirements, only the largest downstream requirement is included in Bulletin 160-98 water budgets.

TABLE 4-21

Instream Flow Requirements by Hydrologic Region (taf)

Region	*1995*		*2020*	
	Average	*Drought*	*Average*	*Drought*
North Coast	1,410	1,285	1,410	1,285
San Francisco Bay	17	9	17	9
Central Coast	20	9	20	9
South Coast	4	4	4	4
Sacramento River	3,397	2,784	3,397	2,784
San Joaquin River	1,169	712	1,169	712
Tulare Lake	0	0	0	0
North Lahontan	85	84	85	84
South Lahontan	107	81	107	81
Colorado River	0	0	0	0
Total (rounded)	**6,210**	**4,970**	**6,210**	**4,970**

Recovery Efforts for Winter-Run Chinook Salmon

As indicated by the plot of winter-run salmon escapement, there has been a long-term decline in the species' population. The ultimate goal for recovery of winter-run salmon would be restoration of a self-sustaining, naturally spawning population. Two efforts being conducted to help achieve this goal are a captive broodstock program and an artificial propagation program. The purpose of the broodstock program is to maintain the genetic composition of the existing population, and that of the artificial propagation program is to stabilize and increase the naturally spawning population.

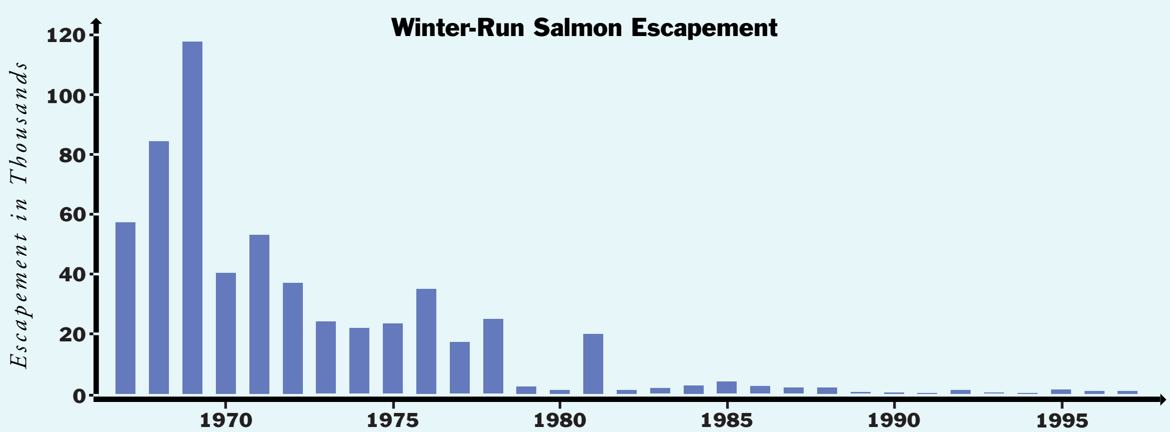
Discussions among State and federal agencies and stakeholder groups in 1991 and 1992 led to creation of a program to evaluate the feasibility of rearing Sacramento River winter-run fry in captivity, so that a broodstock would be available if wild winter-run fish were to disappear. (The population's small size makes it vulnerable to catastrophic loss of a year class, such as a loss that could be caused by a chemical spill in the vicinity of winter-run spawning areas. The captive broodstock would provide an alternative source of genetic material as insurance against such a loss.) Agencies participating in funding the program include USBR, USFWS, NOAA, the Department, and DFG. Rearing facilities were established at the University of California's Bodega Marine Laboratory and the California Academy of Sciences' Steinhart Aquarium. Juvenile fish, beginning with the 1991 year class, were delivered to the facilities in 1992. The parent broodstock were wild winter-run captured in the Sacramento River. Presently, fish from four year classes are being held at the facilities.

The artificial propagation program entails trapping known wild adult winter-run fish, spawning them in a controlled environment, and rearing the offspring for release back to the river system. As adults, the artificially propagated fish would return to winter-run spawning areas and commingle with wild winter-run. Artificial propagation activities were originally begun at USFWS's Coleman National Fish Hatchery on Battle Creek, but fish reared at Coleman imprinted on Battle Creek water and returned there to spawn, rather than going to the upper Sacramento River as desired. (There were also difficulties associated with distinguishing between winter-run and spring-run chinook, in selecting the fish to be propagated. Better genetic identification techniques have been developed to address this problem.)

CVPIA directed USFWS to rehabilitate and expand Coleman National Fish Hatchery. The hatchery was constructed in 1942 to mitigate loss of Sacramento River salmon spawning areas due to construction of Shasta and Keswick Dams.

The most recent development in the artificial propagation program was construction of an interim rearing facility, the Livingston Stone National Fish Hatchery, on the mainstem Sacramento River immediately downstream from Shasta Dam. This facility will allow the artificially spawned winter-run salmon to imprint on mainstem Sacramento River water, so that they will return to natural spawning grounds on the mainstem as adults. Water supply for the hatchery is provided via piping from the dam's penstocks. The hatchery is beginning operations in 1998.

Additional efforts to help recover winter-run chinook salmon, such as screening diversions and habitat improvement projects, are described in Chapter 8.



Three major components of Delta inflow include precipitation, inflow from the Sacramento and San Joaquin Rivers, and inflow from east side streams (including the Calaveras, Mokelumne and Cosumnes Rivers). Figure 4-11 shows annual inflow and outflow values for 1980-96. For this period, the average annual inflow to the Delta was 25.7 maf, more than 75 percent of which was contributed by the Sacramento and San Joaquin Rivers.

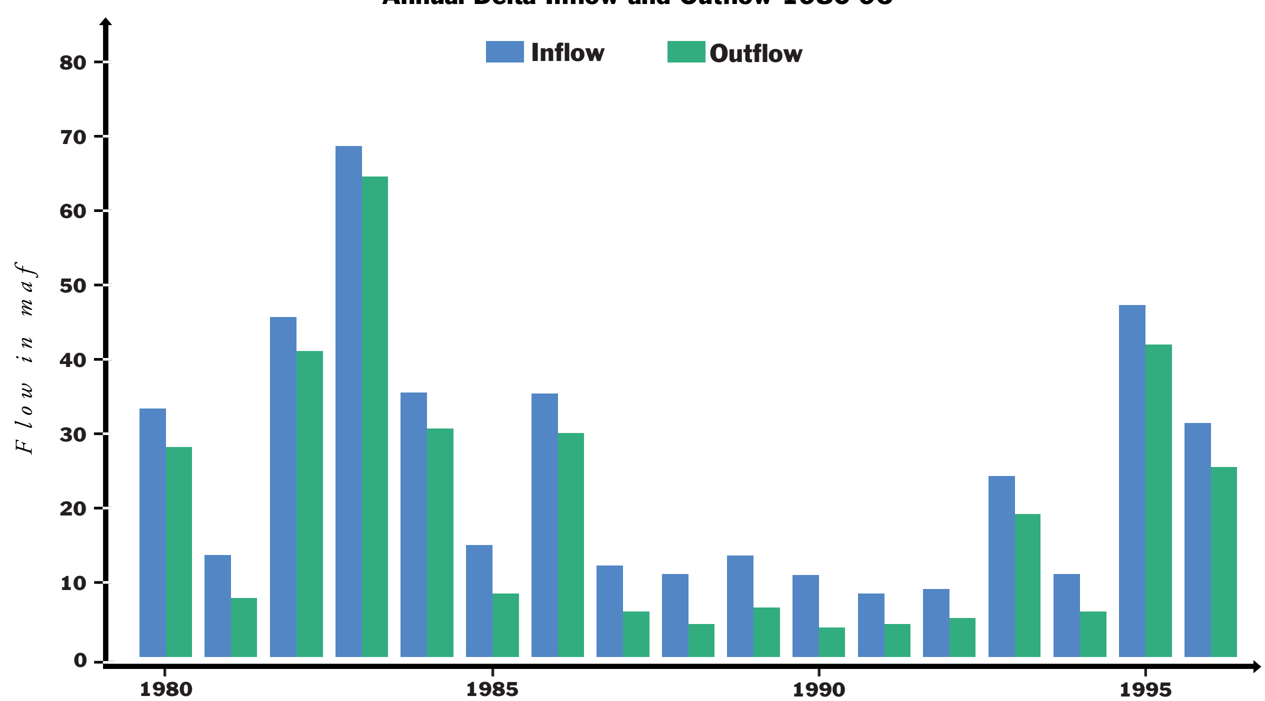
Delta outflow is the calculated amount of water flowing past Chipps Island at the western edge of the Delta into Suisun Bay. The magnitude of Delta outflow controls salt water intrusion from the ocean into the estuary. The magnitude of Delta outflow also influences the distribution of many estuarine fishes and invertebrates. Generally, the greater the outflow, the farther downstream estuarine fish and invertebrates occur. The relationship between Delta outflow and abundance of fish and invertebrates is much less clear. Some species, such as longfin smelt and juvenile splittail, show strong correlations between abundance and Delta outflow. The effects of outflow on species can vary depending on the time of year volume of outflow.

Suisun Bay, the first bay below the Delta, receives fresh water inflow that contributes dissolved nutrients needed to support estuarine food chains. Adjacent to Suisun Bay is Suisun Marsh, which includes about 58,600 acres of diked managed wetlands, tidal marsh, and adjacent grasslands, 29,500 acres of waterways, and a buffer zone of 27,900 acres of varying land use. Suisun Marsh is one of the largest contiguous brackish water marshes in the United States. Nearly half of the waterfowl and shorebirds migrating on the Pacific flyway pass through the Bay-Delta each year, using the Suisun marsh and other Delta wetlands as feeding and resting stations.

Fresh water outflow from the Delta passes through Suisun Bay and through the Carquinez Straits, entering San Pablo Bay, and eventually reaching the Golden Gate. By comparison, there is limited fresh water outflow and tidal circulation at the southern end of San Francisco Bay. Fresh water outflow to the South Bay comes from local tributaries such as Coyote Creek and the Guadalupe River. San Pablo Bay and the South Bay both offer shallow water habitat. National wildlife refuges—the San Pablo Bay NWR and the San Francisco Bay NWR—occupy parts of the shoreline in these areas. See Figure 4-12 for a location map of the Bay-Delta.

FIGURE 4-11

Annual Delta Inflow and Outflow 1980-96[a]



[a] 1983 was the wettest year in Northern California in this century.

FIGURE 4-12

Bay-Delta Estuary

The Delta is characterized by miles of meandering waterways and leveed islands used mainly for agricultural purposes.

Delta Fish Species of Special Concern. About two-thirds of California's salmon migrate through the Delta, including species having commercial importance (fall-run chinook salmon), as well as listed or candidate species (winter-run chinook, spring-run chinook, and steelhead trout). Resident fish species of special concern include Delta smelt (listed as threatened under both the State and federal ESAs) and splittail (proposed for federal ESA listing). Habitat needs of anadromous and resident Delta species of special concern were reflected in actions taken in the Bay-Delta Accord and in SWRCB's Order WR 95-6. The accord's provisions for coordination of CVP and SWP operations in the Delta with the presence of fish species of concern have been reflected in actions by the CALFED Operations Group to reduce Delta exports at times when monitoring indicated that significant numbers of certain fish species were present in the southern Delta. Day-to-day management of CVP and SWP Delta operations under near real-time conditions requires extensive data collection and monitoring support. The Interagency Ecological Program, a cooperative effort of nine State and federal agencies (DWR, DFG, SWRCB, USBR, USFWS, EPA, NMFS, USACE, and USGS), acquires and disseminates near real-time fish distribution and abundance

Delta smelt, native to the Bay-Delta, have a one year life span and relatively low reproductive rate, making their population abundance sensitive to short-term habitat changes.

data used by the CALFED Operations Group.

Populations of native species of special concern are affected by a variety of factors, many of which are not related to Delta outflow. One nonflow factor now receiving more attention is competition from introduced aquatic species (see Chapter 2 for a description of the National Invasive Species Act of 1996). Introduction of non-native species into an ecosystem can alter the pre-existing balance achieved among the native species. Native species' populations can be reduced, for example, when introduced species out-compete the native species for food or otherwise alter the food chain, or when introduced species prey upon native species.

In the Bay-Delta, new introductions are occurring in a system that already has numerous introduced species. Researchers estimate that the Bay-Delta is now home to at least 150 introduced plant and animal species, some of which were introduced deliberately (planting of game fish species such as striped bass) and others whose arrival was accidental (discharge of invertebrates in ship ballast water). The Asian clam, for example, was first detected in the Bay in 1986 and has now become the most abundant mollusk in the northern part of the Bay. This clam is a voracious feeder on the phytoplankton which supports other aquatic species. The zebra mussel—which has caused millions of dollars of damage in the Great Lakes states—has not yet been detected in the Delta, but experts believe that it may be only a matter of time before the mussel arrives. Invasive plant species in the Delta include *Egeria densa* and *Arundo Donax* (giant reed). Hydrilla, another well-known invasive aquatic plant, is now found in Clear Lake in Northern California, and control measures are being taken to eradicate it there, to prevent its spread to Delta waterways.

The Asian clam was first detected in the San Francisco Bay in 1986. By the early 1990s, it was the most abundant mollusk in the northern part of the Bay.

Much of the land in the Suisun Marsh is owned and managed by private gun clubs for duck hunting. DFG manages a wildlife area on Grizzly Island.

Quantifying Delta Outflow Requirements. SWRCB Order WR 95-6 established numerical objectives for salinity, river flows, export limits, and Delta outflow. DWRSIM operations studies were used to translate these numerical objectives into Delta outflow requirements for average and drought year scenarios. The studies computed outflow requirements of approximately 5.6 maf in average years and 4.0 maf in drought years.

Wetlands

The wetlands component of environmental water use is based on water use at freshwater managed wetlands, such as federal national wildlife refuges and State wildlife management areas. The following text reviews the status of wetland acreage in California and wetland management programs, then discusses quantification of water demands and supplies for wetlands.

In general, wetlands can be divided into saltwater and brackish water marshes (usually located in coastal areas) and freshwater wetlands (generally located in inland areas). Five areas of California contain the largest remaining wetlands acreage in the State—the Central Valley, Humboldt Bay, San Francisco Bay, Suisun Marsh, and Klamath Basin. The majority of the State's wetland protection and restoration efforts are occurring in these areas. Nontidal wetlands usually depend on a supplemental water supply, and protecting or restoring them may create demands for freshwater supplies.

Wetlands Policies and Programs. Many programs and policies have been adopted by federal, State and regional agencies and private entities to protect and restore wetlands in California. Several of the more re-

California is a wintertime destination for migratory waterfowl on the Pacific flyway. Managed wetlands provide feeding, resting, and overwintering sites for the waterfowl.

cent wetland programs and policies are discussed below.

Ecosystem restoration is a large part of the CALFED program. CALFED's draft ERP plan proposes habitat restoration goals that include creating 64,000 acres of seasonal and perennial wetlands and 2,000 acres of riparian habitat, returning 37,000 to 57,000 acres to tidal action and enhancing 8,000 acres of existing seasonal wetlands. About 1,700 acres of wetland restoration projects were funded under the accord's Category III program in 1995 and 1996.

CVPIA required DOI to provide water supplies to the wetlands areas shown in Table 4-22. The Sacramento Valley refuges were to be provided with water supplies specified in a 1989 refuge water supply investigation prepared by USBR, and the San Joaquin Valley wetlands areas with supplies specified in USBR's San Joaquin Basin Action Plan/Kesterson Mitigation Action Plan. This water supply was to be provided in two increments—the first corresponding to the exist-

California Wetlands Conservation Policy

In 1993, a California wetlands conservation policy was established. The goals of the policy were to establish a framework and a strategy that would:

- Ensure no overall net loss and achieve a long-term net gain in the quantity, quality, and permanence of wetlands acreage and values in California in a manner that fosters creativity, stewardship, and respect for private property.
- Reduce procedural complexity in the administration of State and federal wetlands conservation programs.
- Encourage partnerships to make landowner incentive programs and cooperative planning efforts the primary focus of wetlands conservation and restoration.

The policy recommended completion of a statewide inventory of wetlands which would lead to the establishment of a formal wetland acreage goal. This inventory is in progress. The Resources Agency expects these policies to result in improved status for 30 to 50 percent of the State's wetlands by the year 2010. Based on an estimate of 450,000 acres of existing wetlands in the State, as much as 225,000 acres of wetland could be improved, restored or protected.

TABLE 4-22

CVPIA Refuge Water Supplies[a] (taf)

Refuge	*Level 2 Supply at Refuge Boundary*	*Level 4 Supply at Refuge Boundary*
Sacramento Valley Refuges		
Sacramento National Wildlife Refuge	46.4	50.0
Delevan National Wildlife Refuge	20.9	30.0
Colusa National Wildlife Refuge	25.0	25.0
Sutter National Wildlife Refuge	23.5	30.0
Gray Lodge Wildlife Management Area	35.4	44.0
Total for Sacramento Valley Refuges	**151.2**	**179.0**
San Joaquin Valley Refuges		
San Luis National Wildlife Refuge	19.0	19.0
Kesterson National Wildlife Refuge[b]	10.0	10.0
Volta Wildlife Management Area	13.0	16.0
Los Banos Wildlife Management Area	16.6	25.5
San Joaquin Basin Action Lands		
Freitas	5.3	5.3
West Gallo	10.8	10.8
Salt Slough	6.7	10.0
China Island	7.0	10.5
Grasslands Resource Conservation District	125.0	180.0
Mendota Wildlife Management Area	27.6	29.7
Merced National Wildlife Refuge	15.0	16.0
East Gallo	8.9	13.3
Kern National Wildlife Refuge	9.9	25.0
Pixley National Wildlife Refuge	1.3	6.0
Total for San Joaquin Valley Refuges	**276.1**	**377.1**
Total for all Refuges	**427.3**	**556.1**

[a] Table is excerpted from 1997 draft CVPIA PEIS.
[b] Kesterson NWR was merged with San Luis NWR subsequent to CVPIA enactment.

ing average annual deliveries that the wetlands had been receiving from drain water and other sources, and the second corresponding to the ultimate or optimum management levels of the wetlands. The first increment of water supply (Level 2) was to be provided by reallocation of CVP supplies. The second increment (Level 4) was to be acquired through purchases from willing sellers. DOI was to acquire all of the second increment of supply by 2002. USBR has operated the CVP to provide the Level 2 supplies, and has been making year-to-year short-term water purchases for the increments of Level 4 supply. USBR and USFWS have been studying conveyance alternatives (and groundwater extraction, in addition to surface water supply alternatives) associated with making these increased supplies available to the refuges.

CVPIA also required DOI to prepare a report by September 1997 to investigate methods of improving water supplies in the Central Valley for existing private wetlands and for 120,000 acres of new wetlands. The 120,000 acres came from wetland restoration objectives of a Central Valley Habitat Joint Venture report. USFWS's report is currently in preparation.

Additionally, the act required that financial incentives be made available to farmers within the CVP service area for flooding agricultural lands to provide waterfowl habitat. The incentives include cost-sharing for water purchases, pumping costs, facility construction (e.g., water control structures), and upgrades or maintenance to existing facilities. CVPIA caps the funding for this program at $2 million per year and the program terminates in 2002.

In 1986, the North American Waterfowl Management Plan was signed by the United States and Canada. The plan was updated in 1996 and Mexico became a signatory. NAWMP provides a framework for waterfowl management in North America through 2010; it includes numerical goals for waterfowl populations and for habitat protection, restoration, and enhancement. Implementing NAWMP is the responsibility of joint ventures in which governmental agencies and private organizations pool resources to address habitat needs.

There are four NAWMP joint ventures covering parts of California. A fifth joint venture is being considered in Southern California. The four existing joint ventures are described below.

The Central Valley Habitat Joint Venture, established in 1988, was the first California joint venture. CVHJV adopted six goals for the Central Valley:

- Protect 80,000 acres of wetlands through fee acquisition or conservation easement.
- Restore (and protect) 120,000 acres of former wetlands.
- Enhance 291,555 acres of existing wetlands.
- Enhance water-based habitat on 443,000 acres of private agricultural land.
- Secure 402,450 af of water for 15 refuges in the Central Valley.
- Secure CVP preference power for public and private lands dedicated to wetland management (i.e., provide access to low-cost power generated at CVP facilities).

In 1990, the Legislature authorized the Inland Wetlands Conservation Program administered by the Wildlife Conservation Board. This program carries out some CVHJV objectives by administering a $2 million per year program to acquire wetland habitat.

The Pacific Coast Joint Venture encompasses coastal wetlands, major rivers, and adjacent uplands from northern British Columbia to the northern edge of San Francisco Bay. In California, there are two focus areas with strategic plans outlining specific target areas and acreage objectives. Almost all the wetlands are coastal projects with little or no freshwater requirements. Objectives for the northern focus area (Del Norte and Humboldt counties) are:

- Maintain 22,000 acres of seasonal wet pasture in agricultural usage compatible with water-associated wildlife.
- Permanently protect an additional 10,500 acres of key wetlands through easements or fee acquisitions.
- Protect, restore, and enhance 10,100 acres of wetlands on existing public lands.
- Assist landowners to protect, enhance, and restore 5,000 acres through cooperative projects.

Objectives of the southern focus area (Mendocino, Sonoma, and Marin Counties excepting watersheds draining to San Francisco Bay) are:

- Permanently secure through fee acquisition or easements an additional 20,000 acres of coastal and interior wetlands, riparian habitats, and associated uplands.
- Restore 3,500 acres of reclaimed coastal and interior wetlands on private and public lands.
- Enhance 5,500 acres of coastal and interior wetlands and riparian habitats on public and private lands.

Approximately half of the acreage in the southern focus area is inland (nontidal) habitat requiring fresh water.

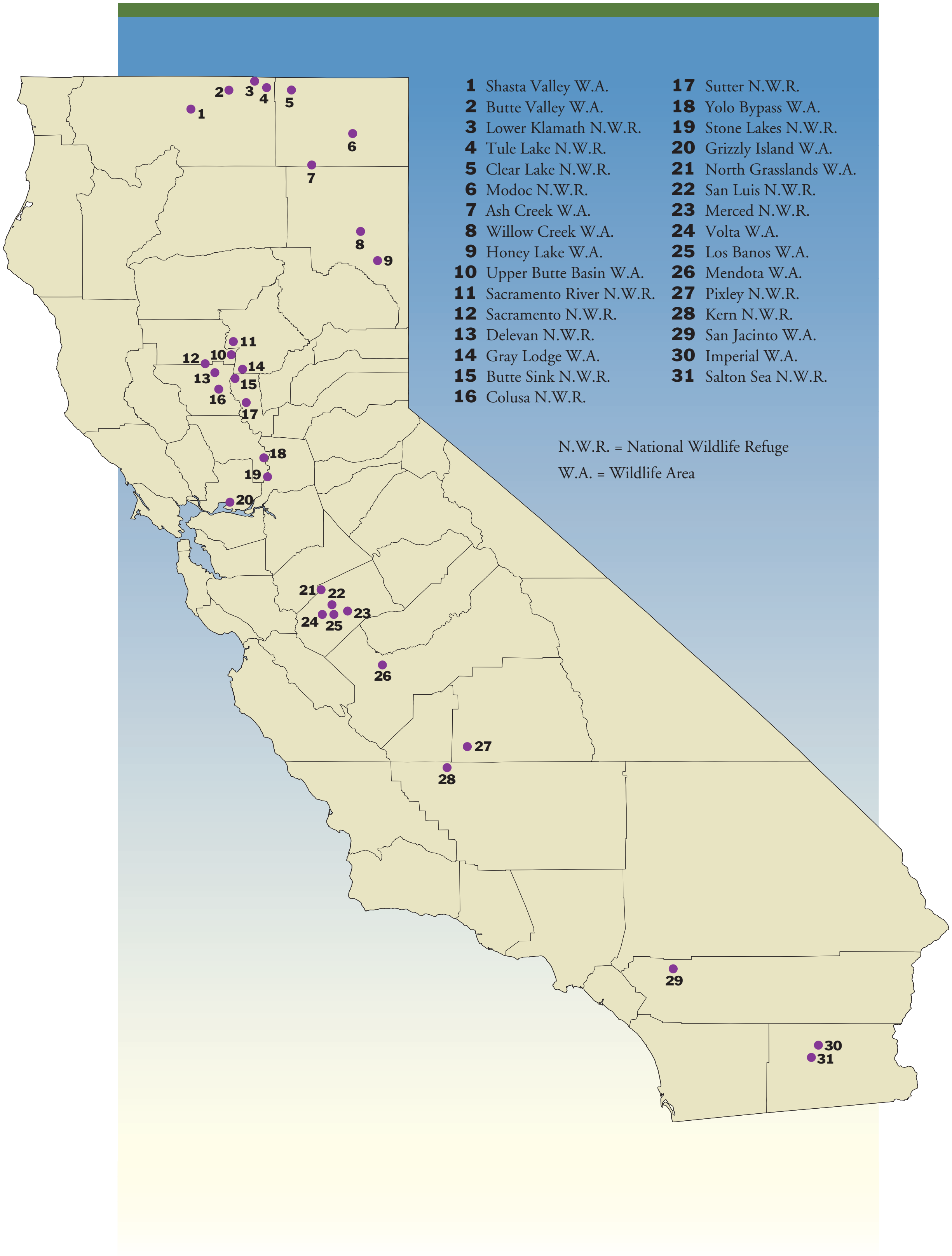
The Intermountain West Joint Venture encompasses parts of Canada and Mexico and all or part of eleven western states, including eastern California. The California action group has completed a working agreement and drafted plans for six focus areas. Acreage goals for acquisition, restoration, and enhancement have not been established.

The San Francisco Bay Joint Venture was established in 1995. Its management board is drafting an implementation strategy. Formal acreage goals and timelines for acquisition and restoration projects will be established. It is expected that many of the areas protected or restored by the SFBJV will be tidal areas with little or no fresh water requirement.

Refuge Water Supply Conservation Programs. In the spring of 1997, a refuge water supply interagency coordinated program task force was formed as an outgrowth of discussions in CALFED and CVPIA programs regarding the need to have best management practices for water conservation on wildlife refuges. The goal of the task force is to develop a common methodology for water management planning, including water conservation actions, for the federal, State, and private refuges covered in CVPIA's refuge water supply provisions. A draft document containing BMPs or efficient water use guidelines for the refuges is scheduled to be released for public review in 1998.

Wetlands Water Use. Bulletin 160-98 quantifies applied water needs only for managed wetlands, because other wetlands types such as vernal pools or coastal wetlands use naturally-occurring water supply (precipitation or tidal action). Managed wetlands are defined for the Bulletin as impounded freshwater and nontidal brackish water wetlands. Managed wetlands may be State and federal wildlife areas or refuges, private wetland preserves owned by nonprofit organizations, private duck clubs, or privately owned agricultural lands flooded for cultural practices such as rice straw decomposition. Figure 4-13 shows California's publicly owned wetlands. Some of the largest concentrations of privately owned wetlands are the duck clubs in the Suisun Marsh and the flooded rice fields in the Sacramento Valley. (Acreage of rice fields flooded to enhance decomposition of stubble remaining after harvest and to provide habitat for

FIGURE 4-13
Publicly-Owned Fresh Water Wetlands



overwintering waterfowl was identified by Department land use surveys.)

State and federal wetlands in the Central Valley are normally managed to support several types of wildlife use areas—permanent marsh, seasonal marsh, irrigated waterfowl food crops (such as millet, rice, or smartweed), and non-irrigated uplands. Each has different applied water requirements, as indicated in Table 4-23, which shows typical ranges for Central Valley wetlands. Table 4-24 shows wetlands water demands by region.

TABLE 4-23

Ranges of Applied Water on Central Valley Managed Wetlands (af/acre/year)

Type of Use	*Applied Water*
Permanent marsh	5-10
Seasonal marsh	2-10
Irrigated waterfowl food crops	1-4

Summary of Environmental Water Use

Table 4-25 shows base 1995 and forecasted 2020 environmental water use by hydrologic region. The large values in the North Coast Region illustrate the magnitude of demands for wild and scenic rivers in comparison to other environmental water demands.

Water Use Summary by Hydrologic Region

Tables 4-26 and 4-27 summarize California applied water use by hydrologic region. The tables combine the urban, agricultural, and environmental water use described in this chapter. These demands, together with the water supply information presented in Chapter 3, are used to prepare the statewide water balance shown at the beginning of Chapter 6 and the regional water balances shown in Chapters 7-9.

TABLE 4-24

Wetlands Water Use by Hydrologic Region (taf)

	1995		*2020*	
Region	*Average*	*Drought*	*Average*	*Drought*
North Coast	325	325	325	325
San Francisco Bay	160	160	160	160
Central Coast	0	0	0	0
South Coast	27	27	31	31
Sacramento River	632	632	632	632
San Joaquin River	230	230	240	240
Tulare Lake	50	50	53	53
North Lahontan	18	18	18	18
South Lahontan	0	0	0	0
Colorado River	39	38	44	43
Total (rounded)	**1,480**	**1,480**	**1,500**	**1,500**

TABLE 4-25

Applied Environmental Water Use by Hydrologic Region (taf)

	1995		*2020*	
Region	*Average*	*Drought*	*Average*	*Drought*
North Coast	19,544	9,518	19,545	9,518
San Francisco Bay	5,762	4,294	5,762	4,294
Central Coast	118	37	118	37
South Coast	100	82	104	86
Sacramento River	5,833	4,223	5,839	4,225
San Joaquin River	3,396	1,904	3,411	1,919
Tulare Lake	1,672	809	1,676	813
North Lahontan	374	256	374	256
South Lahontan	107	81	107	81
Colorado River	39	38	44	43
Total (rounded)	**36,940**	**21,240**	**36,980**	**21,270**

TABLE 4-26

California Average Year Water Use by Hydrologic Region (taf)

Region	1995				2020			
	Urban	*Agricultural*	*Environmental*	*Total (rounded)*	*Urban*	*Agricultural*	*Environmental*	*Total (rounded)*
North Coast	169	894	19,544	20,610	201	927	19,545	20,670
San Francisco Bay	1,255	98	5,762	7,110	1,317	98	5,762	7,180
Central Coast	286	1,192	118	1,600	379	1,127	118	1,620
South Coast	4,340	784	100	5,220	5,519	462	104	6,080
Sacramento River	766	8,065	5,833	14,660	1,139	7,939	5,839	14,920
San Joaquin River	574	7,027	3,396	11,000	954	6,450	3,411	10,820
Tulare Lake	690	10,736	1,672	13,100	1,099	10,123	1,676	12,900
North Lahontan	39	530	374	940	50	536	374	960
South Lahontan	238	332	107	680	619	257	107	980
Colorado River	418	4,118	39	4,570	740	3,583	44	4,370
Total (rounded)	**8,770**	**33,780**	**36,940**	**79,490**	**12,020**	**31,500**	**36,980**	**80,500**

TABLE 4-27

California Drought Year Water Use by Hydrologic Region (taf)

Region	1995				2020			
	Urban	*Agricultural*	*Environmental*	*Total (rounded)*	*Urban*	*Agricultural*	*Environmental*	*Total (rounded)*
North Coast	177	973	9,518	10,670	212	1,011	9,518	10,740
San Francisco Bay	1,358	108	4,294	5,760	1,428	108	4,294	5,830
Central Coast	294	1,279	37	1,610	391	1,223	37	1,650
South Coast	4,382	820	82	5,280	5,612	484	86	6,180
Sacramento River	830	9,054	4,223	14,110	1,236	8,822	4,225	14,280
San Joaquin River	583	7,244	1,904	9,730	970	6,719	1,919	9,610
Tulare Lake	690	10,026	809	11,530	1,099	9,532	813	11,440
North Lahontan	40	584	256	880	51	594	256	900
South Lahontan	238	332	81	650	619	257	81	960
Colorado River	418	4,118	38	4,570	740	3,583	43	4,370
Total (rounded)	**9,010**	**34,540**	**21,240**	**64,790**	**12,360**	**32,330**	**21,270**	**65,960**

4A

Urban and Agricultural Water Pricing

This appendix is provided as background to respond to interest expressed by Bulletin 160-98 reviewers in water pricing information. Water prices in California vary widely, as discussed below. The more than 2,800 local agencies in California that provide water service establish their prices based on factors specific to their individual service areas, and those prices are generally reviewed by agencies' elected or appointed boards of directors, or by the California Public Utility Commission. Public agencies are not permitted to make a profit from their water sales, and the profits that privately owned water purveyors are allowed to make are established by the PUC.

Water Retail Pricing

Many factors influence the prices charged by water agencies. For public water agencies, the types of charges they may levy depend upon the legislation under which they were created. Table 4A-1 shows types of California water supply agencies. Descriptions of the general powers of the public agencies shown in the table can be found in DWR's Bulletin 155-94, *General Comparison of Water District Acts*. Investor-owned utilities' water rates are set by the California Public Utilities Commission. Privately owned mutual water companies set rates for their members.

TABLE 4A-1
Types of Local Supply Water Agencies in California[a]

Type	*Ownership*	*Number*
County Service Area	Public	880
Mutual Water Company	Private	801
Community Services District	Public	309
Investor-Owned Water Utility	Private	195
County Water District	Public	178
Water District	Public	157
Irrigation District	Public	97
Public Utility District	Public	52
Flood Control and Water Conservation District	Public	41
County Water Works District	Public	40
Municipal Water District	Public	40
Water Agency or Water Authority	Public	31
Water Conservation District	Public	13
Water Storage District	Public	8
Municipal Utility District	Public	5
Water Replenishment District	Public	2
Metropolitan Water District	Public	1
Total		**2,850**

[a] Water supply may also be provided by local agencies having other purposes (e.g., reclamation districts).

Source: Department of Health Services and State Controller's Office data, 1994-96.

Acquisition and Delivery Costs

Acquisition costs are costs associated with obtaining water from a source. These costs may vary greatly from one source to another. Some water agencies have developed their own supply sources, some purchase water wholesale from larger agencies, and some have a mix of their own supplies plus wholesale purchases. Other costs include transportation and local delivery charges and water treatment costs. Supplies delivered for urban use require treatment, which is becoming an increasingly greater component of total cost as more stringent drinking water quality regulations are put into place. Compliance with surface water filtration and information collection requirements of the Safe Drinking Water Act, for example, is a substantial cost item for many water agencies.

Some water agencies use water rates to fully recover the costs of acquiring, treating, and delivering supplies, others use a combination of water rates and local property taxes. Another important consideration is whether a water agency sets its rates to reflect short-term or long-term costs. This is significant if a water agency's system is currently operating at capacity and major system improvements are needed. In this case, the water agency may have to increase rates to reflect the higher marginal costs of future system expansion.

During droughts, the rates water agencies charge may vary depending on supply availability. Agencies may have to acquire water from outside sources to meet service area needs or may have to construct interties or other conveyance system improvements to bring purchased supplies to their system. Many water agencies adopted higher rates to fund programs to encourage water conservation during the 1987-92 drought, and several implemented drought penalty rates intended to reduce water use drastically.

Characteristics of Service Area

A water agency's costs will be affected by the mix of residential, commercial, industrial, governmental, and agricultural users within the service area because the cost of service to different classes of users is likely to be different. If a water agency serves a heavily populated area with many connections per square mile, the average fixed costs per customer will tend to be less. Conversely, if the purveyor serves a sparsely populated area, average fixed costs of serving each customer will normally be high. Because of pumping costs, changes in elevation within a service area can also affect delivery costs.

Rate Structure

Water rates are the primary source of income for most water agencies. Although rates can be structured many ways, they typically include fixed charges, consumption-based charges, or both.

Fixed charges recover some or all of costs incurred regardless of the amount of water used, such as debt service incurred from project construction. Fixed charges are typically used by water agencies that do not meter consumption. Examples of fixed charges for metered urban water agencies include billing and administrative charges (service charges), lifeline charges for a minimum level of service, readiness to serve charges, and fire protection charges. Agricultural fixed charges (often called water availability or standby charges) can be levied on a per acre or connection basis. Fixed charges which are levied on a per acre or parcel basis will likely be affected by Proposition 218, discussed in more detail in Chapters 2 and 6.

Consumption-based charges are set on a per unit volume basis so the total charge varies with the user's consumption. These charges typically recover variable costs of water deliveries (water purchases, treatment, and pumping). As with fixed rates, there are several forms of consumption-based rates. One form is the constant charge, which is the same unit price for all units of water consumed. Another is block rates, which decrease (declining block) or increase (increasing block) with water consumption. A declining block rate sets a reduced price per unit for increased usage. Increasing block rates set increasing prices per unit for increased usage. Constant and increasing block rates are the predominant urban rate structures currently used in California. Some forms of declining rates are still used in urban areas, especially in communities using lower water rates as an incentive for industry to locate in their area. Some agencies use declining block rates and other incentives to encourage use of recycled water in lieu of potable supplies. Agricultural water agencies levy consumption-based charges based upon either the actual amount of water delivered or on the number of irrigated acres (charges may vary depending upon the crop type).

Fixed charges and consumption-based charges typically account for most of a water agency's total revenues. Revenues can also be obtained from assessments, or taxes, levied upon lands in accord with benefits received from an agency's actions. Assessments recover a portion of an agency's fixed costs, and can be levied either on lands which directly benefit from water deliveries (for example, land receiving irrigation water) or on lands which indirectly benefit from water deliveries (adjoining lands which may benefit from groundwater recharge resulting from the deliveries).

Cities may charge for sewers and sewage treatment based on water use. In some cities, the sewer charges are included in monthly service charges and commodity rates paid by the water users. Other cities charge for sewers based on water use, but keep the sewer charges separate from the water charges.

Urban Retail Water Costs

Since 1990 there have been a few statewide surveys of urban retail water costs in California. One, conducted by the Department in 1991, included about 70 communities. The results of this survey are described in the Department's Bulletin 166-4, *Urban Water Use in California*. DHS conducted another survey in 1990, and three others were conducted by a private consulting firm in 1993, 1995, and 1997. (The 1993-1997 surveys were based on an assumed monthly consumption of 1,500 cubic feet of water per connection, an amount much lower than that used by many households. This assumption limits the usefulness of the survey data.) At a statewide level of coverage, there are no recent retail pricing data based on actual water use amounts.

In 1994, the accounting firm of Ernst & Young conducted a national water rates survey which MWDSC summarized in its 1995 Integrated Resources Plan. That survey showed that the national average for retail urban water supply was almost $600/af. MWDSC's average was about $625/af; San Francisco's was about $560/af; and Oakland's was almost $700/af. (Other urban areas had higher costs. Indianapolis was about $725/af; Houston was almost $900/af, and Nashville was more than $1,100/af.)

Impacts of Retail Prices on Water Use

Price elasticity studies are used to characterize price responsiveness—the degree that water users increase or decrease use in response to a change in water price. Economists define price elasticity of demand as the ratio of the percentage change in quantity of water used to the percentage change in the price of water.

When faced with a significant water price increase, urban water users may react in one of three ways:

- They may use substantially less water. In this case, water users are sensitive to price changes, and demand is defined to be elastic (its absolute elasticity value is equal to or greater than one). For example, if a 10 percent increase in price caused a 10 percent reduction in demand, economists would define demand as elastic.
- They may use a little less water. In this case, water users are not very sensitive to price changes, and demand is said to be inelastic (absolute elasticity value is less than one). For example, if a 10 percent price increase caused a 5 percent reduction in demand, demand would be defined as inelastic.
- They may continue to use the same amount as before. In this case, the water users are completely insensitive to price changes, and demand is said to be perfectly inelastic (elasticity value is equal to zero).

A 1989 EBMUD study, for example, estimated price elasticity of demand for its residential water supply to be -0.202 from 1981 through 1987. This means that a water price increase of 10 percent could be expected to lower the amount of water use by about 2 percent. The demand for water in this case was inelastic—residential water users were found to be relatively insensitive to price changes. This has been the case for most studies of residential water demand.

Factors that can affect elasticity include climate, housing type, water users' income, percentage share of water bills in users' budgets, water rate structure, water conservation measures and education, and users' preferences regarding water use (some users may prefer to irrigate large turf areas regardless of cost). Table 4A-2 provides a survey of recent literature on urban water price elasticities of demand. These studies were performed with statistical modeling which employed historical water use, water price, and demographic and climatic data.

Elasticity estimates derived for one geographic area are not necessarily representative of another area because of these many potential variables. It is generally not correct to take a value of residential price elasticity estimated for one community during one period of time and to assume that it is applicable to another community, or for another period of time. Only by carefully examining the factors described above can elasticities developed under one set of circumstances be reasonably used for estimating elasticities under other circumstances.

For Bulletin 160-98, the Department contracted

TABLE 4A-2

Urban Water Demand Price Elasticity Studies

Author(s)	*Study Date*	*Study Area*	*Type of Demand*	*Estimated Elasticity*	*Range of Study Water Prices*	*Equivalent Prices ($/af)[a]*
Moncur	1987	Honolulu, Hawaii	Short-term residential Long-term residential	-0.265 -0.345	$0.22 - $0.36 /1,000 gal (1983 dollars)	$72 - $117
Metzner[a]	1989	San Francisco	Long-term residential	-0.25	$0.73 - $0.78 /100 cu ft (1995 dollars)	$318 - $340
Weber	1989	EBMUD	Long-term residential	-0.01 to -0.25	$0.24 - $0.94 /100 cu ft (1989 dollars)	$105 - $409
Nieswiadomy[b] & Molina	1989	Denton, Texas	Long-term residential	-0.55 to -0.86	$0.27 - $0.56 /1,000 gal (1967 dollars)	$88 - $183
Billings & Day	1989	Tucson, Arizona	Long-term residential	-0.72	$6.60 - $11.20 monthly bills 1974 -1980 (1974 dollars)	$7 - $11 monthly bills
MWDSC	1990	South Coast Region	Long-term single-family residential Summer Winter	 -0.29 to -0.36 -0.03 to -0.16	Not Available	Not Available
Schneider & Whitlach	1991	Columbus, Ohio	Short-term residential Long-term residential Short-term total urban Long-term total urban	-0.262 -0.110 -0.504 -0.123	Not Available	Not Available
Renwick et al.	1996	8 California cities	Long-term single-family residential	-0.16	$0.47-$4.25 /100 cu ft	$205-$1,851

[a] Water rate data was unavailable from the study author. The Department retrieved the historical data and inflated the prices to 1995 levels for display purposes only.

[b] Study was for summer months only and was a five-year period of recently adopted increasing block rates. Adjusted R^2 for models which produced -0.86 and -0.55 elasticities was only 0.26 and 0.11, respectively.

with University of California researchers for an evaluation of the effects of water pricing and non-pricing demand reduction actions (e.g., public education, rationing, subsidies for adoption of more efficient water use technologies) on urban residential water use. The study covered single-family residential use during 1989 to 1996, a time period incorporating the recent drought and allowing evaluation of actions taken by water purveyors to reduce residential water use during the drought. Eight water retailers whose service areas represent 24 percent of California's population were included—San Francisco PUC, Marin MWD, Contra Costa WD, East Bay MUD, City of San Bernardino, City of Santa Barbara, Los Angeles DWP, and City of San Diego. All of these agencies experienced price increases over the study period and all used

TABLE 4A-3

DWR Survey of 1996 Agricultural Surface Water Costs[a]

Region	*1996 Total Deliveries (taf)*	*1996 Costs ($/af)*			*Water Rates Basis (number of agencies)*				
		Weighted Average	*Max.*	*Min.*	*By Acre*	*By Crop & Acre*	*By af Used*	*By Acre & af Used*	*Total*
North Coast	80	10	12	2	2	0	1	0	3
San Francisco Bay[b]	—	—	—	—	—	—	—	—	—
Central Coast	37	128	533	87	0	0	2	2	4
South Coast	92	373	604	131	0	0	1	7	8
Sacramento River	1,275	12	32	2	1	4	1	2	8
San Joaquin River	1,339	22	238	6	2	0	1	4	7
Tulare Lake	2,672	42	161	9	1	0	4	6	11
North Lahontan[b]	—	—	—	—	—	—	—	—	—
South Lahontan	18	61	61	61	0	0	1	0	1
Colorado River	3,403	13	14	8	2	0	0	2	4
Statewide	**8,916**	—	—	—	**8**	**4**	**11**	**23**	**46**

[a] Average retail costs to the farmer
[b] No responses

non-pricing demand reduction actions during the study period. Price elasticity was estimated to be -0.16 (meaning that a 10 percent price increase would result in a 1.6 percent demand reduction) over a range of marginal prices of $0.47 to $4.25 per hundred cubic feet, showing that residential demand was price inelastic over this range.

The urban water demand forecast used for Bulletin 160-98 assumed single-family residential price elasticities of -0.1 for winter months and -0.2 for summer months. Studies of urban water pricing to date indicate that the role of pricing by itself in achieving demand reduction is small. The plot of urban water production over time shown in Figure 4-4 illustrated the strong response of water use to the 1987-92 drought. Actions taken by water agencies during the drought to encourage demand reduction—including public education programs, voluntary rationing, rebates for plumbing retrofits—decreased residential water use. However, water use throughout the State is rebounding to earlier levels, even after significant price increases by some agencies. For example, Contra Costa WD increased its average water rates substantially to finance construction of Los Vaqueros Reservoir. Between 1980 and 1997, CCWD's average water price increased by about 217 percent (adjusted for inflation). Its use per residential unit declined by 9 percent, much of which is likely due to plumbing retrofit and building code requirements for new plumbing, and public education.

Agricultural Water Costs

In December 1996, the Department mailed water cost surveys to more than 60 agricultural water agencies in California. This survey was conducted to determine the range of average agricultural retail surface water costs in the State and to obtain information on types of water charges being used. Table 4A-3 summarizes the results of this survey by hydrologic region. Many responding agencies based their charges on both water use and number of acres irrigated. The information is presented here to illustrate the variability of prices based on local circumstances.

Agricultural groundwater costs vary considerably throughout California. Factors influencing these costs include depth to groundwater, water quality, and well yields. Many groundwater users are self-supplied, meaning that individual water users pump their own supplies rather than receiving them from a water agency. Bulletin 160-93 showed general ranges of agricultural groundwater production costs. The Department does not have sufficient new data to accurately update those general cost ranges for Bulletin 160-98.

Impacts of Price on Agricultural Water Use

Price elasticity of demand for agricultural water is a measure of farmers' responsiveness to changes in the price of water. Researchers have used a variety of models (programming and econometrics) to estimate the agricultural water use price elasticity in different parts of the country, and have concluded that demand for irrigation water is generally price inelastic, within price ranges typical for agricultural water use. Obviously, there is no other commodity that can be substituted for the water needed to grow crops. As Table 4A-4 illustrates, water costs are typically a relatively small percentage of the total cost of producing most crops. The Central Valley Production Model was used to estimate agricultural price elasticity in the Central Valley. CVPM price elasticity estimates for irrigation water demand are based on the level of production of various crops. CVPM also allows for changes in cropping patterns as water becomes more scarce, more expensive, or both.

Results of CVPM studies are summarized in Table 4A-5. Surface water prices were increased for the study by different increments, and groundwater costs increased as a result of changes in pumping depths. Both short- and long-term elasticities were estimated. In the short-term study, it was assumed that farmers did not have enough time to adjust to increases in water costs, while in the long-term farmers could switch to more efficient irrigation technologies.

The values in the table are estimates of a farmer's ability to respond to water price changes. For example, if surface water prices increase by 10 percent in the Sacramento Valley, the demand for surface water will decline by 3.2 percent. The model runs indicated that demand for irrigation water was price inelastic over the price ranges analyzed. Where groundwater is available in the Central Valley, farmers may increase their groundwater use if pumping costs are less than the costs of their surface water supplies.

TABLE 4A-4

Average Water Costs as a Percent of Total Production Costs for Selected Crops in the Tulare Lake Region[a]

Crop	*Water Costs as a Percent of Total Costs*
Irrigated pasture	36
Alfalfa hay	19
Barley	16
Dry beans	14
Wheat	14
Cotton	12
Sugar Beets	12
Safflower	11
Dry Onions	9
Almonds	6
Pistachios	6
Processing tomatoes	6
Wine grapes	5

[a] Data from output of the Department's Central Valley Net Crop Revenue Model.

CVPIA Tiered Pricing

Section 3405(d) of CVPIA required that new, renewed, or amended contracts for project water incorporate an inverted block rate pricing structure specified in the act. The first rate tier applied to a quantity of water up to 80 percent of the contract total. The second rate tier applied to the quantity of water from 80 percent to 90 percent of the water under contract, and was to be halfway between the rate for the first tier and the third tier. The third tier applied to the quantity of water beyond 90 percent of the contract total, and was to be not less than USBR's full cost rate. USBR's municipal and industrial customers are already charged the full cost rate, which includes cost of service, principal and interest on facility construction costs, and CVPIA Restoration Fund charges.

As noted in Chapter 2, all of USBR's contract renewals to date have been interim renewals, since the PEIS required by the act has not yet been completed. No long-term renewal contracts can be executed until USBR completes the PEIS, which is now expected to occur in 1999. Through 1996, interim contracts for project water supply represented about 16 percent of project water under contract.

In its 1998 public draft PEIS, USBR used CVPM to estimate potential impacts of implementing tiered pricing as set forth in the act. USBR estimated that implementing tiered pricing would reduce average year CVP applied irrigation water in the CVP service area

TABLE 4A-5

Price Elasticities for Surface Water Irrigation Demand

Region	*Short-Term Elasticity*	*Long-Term Elasticity*	*Range of Water Prices ($/af)*
Sacramento River	-0.24	-0.32	20 - 240
San Joaquin River	-0.20	-0.30	20 - 240
Tulare Lake	-0.18	-0.24	20 - 240

by 266 taf from CVPIA's assumed no-action condition. This amount took into consideration the shift from CVP water use to groundwater use, in those areas having access to groundwater supplies. (The estimate assumed that USBR's ability to pay policy for irrigation remained in effect for principal on capital and Restoration Fund charges, at an estimated payment capacity of $11/af north of the Delta and $70/af south of the Delta.)

USBR also evaluated alternatives to the tiered pricing specified in the act, including an analysis which assumed that ability to pay provisions were not in force. This approach would reduce applied irrigation water by an additional 25 taf in an average water year. The greatest reduction in applied irrigation water use occurred in USBR's alternative which exceeded the requirements of the statute by applying full cost pricing to the first 80 percent of contract water supply, 110 percent of full cost pricing to the second tier, and 120 percent of full cost pricing to the last 10 percent of contract water supply. The draft PEIS estimated that this alternative would reduce applied irrigation water by about 570 taf in an average year.

After USBR completes the CVPIA PEIS, long-term contract renewals can begin. The effects of tiered pricing on CVP water use will be manifested over time, as more contracts are renewed. The relationship of CVP tiered pricing to CVP water use, however, cannot necessarily be generalized to price/water use relationships for agricultural users served from non-USBR sources. Agricultural water users served by the SWP, local water projects, and self-supplied sources already pay full cost rates for their supplies.

Comparing Agricultural and Urban Water Costs

Generally, agricultural water supply costs are lower than urban costs. Much of the State's earliest large-scale water development was for agriculture, and the irrigation works were constructed when water development was inexpensive by present standards. Also, there are basic differences in the delivery systems providing agricultural and urban water supplies. The price of water is determined by the cost of water at the source (from a reservoir or at the Delta, for example) plus the costs of using the facilities associated with conveying, storing, treating, and delivering the water to the final users. Some contracts for agricultural supplies have allowed agricultural users to pay a lower price for water supplies in return for accepting supplies with a lower level of reliability. Typically this was achieved by deficiency provisions incorporated in the water supply contracts.

Both urban and agricultural water agencies must pay transportation costs incurred to bring the water supplies to their service areas. However, agricultural agencies are often closer to the surface water sources and in many cases are able to rely on gravity-operated conveyance and distribution systems, avoiding energy costs associated with pressurized pipelines. Urban water supplies often travel through hundreds of miles of canals or pipelines, adding considerably to the transportation costs. For example, by 2000, power costs to deliver SWP water to the San Joaquin Valley service area are estimated to be about $15/af. Power costs to deliver the same acre-foot of SWP water to the South Bay, Central Coast, and Southern California service areas are estimated to be about $34, $78, and $87, respectively.

Urban water systems have additional delivery costs compared to agricultural systems. For example, urban water users must pay for terminal storage and pressurization of water. Monitoring and treating water for public health protection is expensive, and costs are expected to increase as a result of more stringent drinking water standards. Most urban water systems also incur substantial costs to install and read meters, and to prepare billings.

4B

BMP Revisions and Water Savings Assumptions

Table 4B-1 provides a synopsis of revisions to urban water conservation BMPs, as adopted by CUWCC in September 1997.

Table 4B-2 summarizes BMP water savings assumptions specified in the Urban MOU. These assumptions served as the basis for urban water use study conservation savings calculations, according to the following general formula:

$$S_{c,w,t} = U_{w,t} * R_{c,w} * P_{c,w,t}$$

where

$S_{c,w,t}$ = water savings resulting from the implementation of conservation measure *c*, in water use category *w*, at time *t*, expressed in gallons per day

$U_{w,t}$ = base year water use in water use category *w* at time *t*, expressed in gallons per capita per day

$R_{c,w}$ = reduction in water consumption resulting from the implementation of conservation measure *c*, in water use category *w*, expressed as a proportion of base year water use

$P_{c,w,t}$ = population affected by conservation measure c, in water use category *w*, at time *t*

TABLE 4B-1

BMP Revisions

Changes to Existing BMP Definitions, Implementation Schedules, Coverage Requirements, and Reporting Requirements Contained in Exhibit 1 of the MOU

BMP Number	*BMP Name*	*Changes to BMP Definition*	*Changes to Implementation Schedule*	*Changes to Coverage Requirement*	*Changes to Reporting Requirement*
1	Water Survey Programs for Single-Family Residential and Multifamily Residential Customers	Removes requirement to specifically target top 20% of residential water users. Allows agencies to develop targeting and marketing approaches tailored to their service areas. Specifies minimum audit elements. Requires agencies to develop database to track program.	Extends the implementation schedule 10 years from the date the BMP is revised or the date an agency signs the MOU, whichever is later.	Replaces the requirement that 70% of the top 20% of residential customers accept an audit by September 1, 2001, with the requirement that 15% of residential customers accept an audit within 10 years of the date of implementation for the agency.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.
2	Residential Plumbing Retrofit	Adds requirement that agencies maintain device distribution programs at levels sufficient to distribute retrofit kits to not less than 10% of residential accounts each reporting period until coverage requirement is met. Allows agencies to use mass distribution methods as appropriate. Allows agencies to develop targeting and marketing approaches tailored to their service areas. Requires agencies to develop data base to track program.	Replaces the requirement that agencies realize the coverage requirement by September 1, 2001, with the requirement that they maintain the program at specified level until they can demonstrate coverage requirement is met.	Replaces the requirement that 75% of single-family and 80% of multifamily residences constructed prior to 1980 are retrofitted with the requirement that 75% of single-family and multifamily residences constructed prior to 1992 are retrofitted.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.

TABLE 4B-1

BMP Revisions

Changes to Existing BMP Definitions, Implementation Schedules, Coverage Requirements, and Reporting Requirements Contained in Exhibit 1 of the MOU (continued)

BMP Number	*BMP Name*	*Changes to BMP Definition*	*Changes to Implementation Schedule*	*Changes to Coverage Requirement*	*Changes to Reporting Requirement*
3	System Water Audits, Leak Detection and Repair	Replaces requirement that agencies conduct a complete system audit every three years with requirement that agencies conduct annual pre-screen audits and conduct full system audits only if indicated by the pre-screen audit.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later.	No change.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.
4	Metering with Commodity Rates for All New Connections and Retrofit of Existing Connections	Adds requirement that agencies assess feasibility of program to retrofit mixed-use metered accounts with dedicated irrigation meters.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later. Extends date that coverage requirement must be met from September 1, 2001, to 10 years from the date the BMP is revised or the date an agency signs the MOU, whichever is later.	No change.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.

TABLE 4B-1

BMP Revisions

Changes to Existing BMP Definitions, Implementation Schedules, Coverage Requirements, and Reporting Requirements Contained in Exhibit 1 of the MOU (continued)

BMP Number	*BMP Name*	*Changes to BMP Definition*	*Changes to Implementation Schedule*	*Changes to Coverage Requirement*	*Changes to Reporting Requirement*
5	Large Landscape Conservation Programs and Incentives	Adds requirement that agencies develop water use budgets for accounts with dedicated irrigation meters. Removes requirement to specifically target landscapes of 3+ acres for audits. Continues to require audits for customers without landscape water use budgets. Continues to require customer incentive programs. Allows agencies to develop targeting and marketing approaches tailored to their service areas. Requires agencies to develop database to track program.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later. Allows agencies 10 years from date BMP implementation is to be underway to meet coverage requirement. Allows agencies four years to develop water use budgets for dedicated irrigation meter accounts.	Removes requirement that agencies offer audits to 100% of accounts with 3+ acres of landscape by September 1, 2001. Adds requirement that agencies provide landscape audits to 15% of mixed-use, non-residential accounts within 10 years from date BMP implementation is to be underway for agency. Adds requirement that agencies offer audits to not less than 20% of mixed-use, non-residential accounts each reporting period. Allows agencies to satisfy audit requirements by implementing a mixed-use meter retrofit program or a program to develop landscape water use budgets for accounts with mixed-use meters.	Requests data on the number of accounts with dedicated irrigation meters, and number of water budgets established during reporting period. Otherwise, requests similar types and amounts of information as currently being collected in CUWCC annual reports.

TABLE 4B-1

BMP Revisions

Changes to Existing BMP Definitions, Implementation Schedules, Coverage Requirements, and Reporting Requirements Contained in Exhibit 1 of the MOU (continued)

BMP Number	*BMP Name*	*Changes to BMP Definition*	*Changes to Implementation Schedule*	*Changes to Coverage Requirement*	*Changes to Reporting Requirement*
6 (New)	High-Efficiency Washing Machine Rebate Programs	Adds requirement that agencies offer maximum cost-effective customer rebate for high-efficiency washing machines if energy service provider in service area is also offering rebates.	N/A	N/A	N/A
7	Public Information Programs	Adds requirement that agencies conduct public awareness surveys every three years to assess conservation attitudes and guide program design.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later.	No change.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.
8	School Education Programs	No substantive changes.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later.	No change.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.
9	Conservation Programs for Commercial, Industrial, and Institutional Accounts	Replaces audit requirement with a two track approach. An agency can choose either to implement an audit program for CII customers, or to meet a water savings performance target for the CII sector. Requires CUWCC to develop long-term CII ULFT implementation targets based on findings of CUWCC CII ULFT water savings study within one year of BMP adoption.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later. Allows agency 10 years from date BMP implementation is to be started to begin meeting coverage requirement.	Requires either 10% of commercial, industrial, and institutional accounts to accept an audit within 10 years or a reduction in water use by commercial, industrial, and institutional accounts by an amount equal to 10% of the use by the top 10% of accounts.	Requires agencies to substantiate either completed audits or water savings estimates. Requests substantially more information on program design and implementation than what is currently being collected through CUWCC annual reports.

TABLE 4B-1

BMP Revisions

Changes to Existing BMP Definitions, Implementation Schedules, Coverage Requirements, and Reporting Requirements Contained in Exhibit 1 of the MOU (continued)

BMP Number	*BMP Name*	*Changes to BMP Definition*	*Changes to Implementation Schedule*	*Changes to Coverage Requirement*	*Changes to Reporting Requirement*
10 (New)	Wholesale Agency Assistance Programs	Defines wholesale agency support roles in terms of financial, technical, and programmatic assistance to retail agencies implementing BMPs.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later.	Requires wholesalers to justify financial, technical, and programmatic support levels.	Requires additional reporting by wholesale agencies over what is currently being collected through CUWCC annual reports.
11	Conservation Pricing	Retains current definitions of non-conserving and conserving rate structures. Adds requirement that CUWCC undertake a study to empirically assess the affect of rate structure on customer water use patterns and quantities, and to specifically examine the relationship between customer demand and the proportion of agency revenue requirement recovered through commodity charges, fixed charges, and other service charges.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later.	No change.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.
12 (formerly BMP 14)	Conservation Coordinator	No substantive change.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later.	No change.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.

TABLE 4B-1

BMP Revisions

Changes to Existing BMP Definitions, Implementation Schedules, Coverage Requirements, and Reporting Requirements Contained in Exhibit 1 of the MOU (continued)

BMP Number	*BMP Name*	*Changes to BMP Definition*	*Changes to Implementation Schedule*	*Changes to Coverage Requirement*	*Changes to Reporting Requirement*
13	Water Waste Prohibition	No substantive change.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later.	No change.	Requires similar types and amounts of information as currently being collected in CUWCC annual reports.
14 (formerly BMP 16)	Residential ULFT Replacement Programs	Removes reference to CII ULFT replacement requirements; otherwise no substantive change.	Makes implementation schedule relative to the date the BMP is revised or the date an agency signs the MOU, whichever is later. Allows agency 10 years from date implementation is to commence to meet coverage requirement.	No change.	Requests similar types and amounts of information as currently being collected in CUWCC annual reports.

TABLE 4B-2

BMP Water Savings Assumptions

BMP Number	*BMP Name*	*MOU Savings Assumptions*		*Urban Water Use Study Modeling Assumptions*
		Coverage Requirement	*Reduction Factor*	
1	Water Survey Programs for Single-Family and Multifamily Customers	15% of residential accounts.	*Pre-1980 Construction* Shower head replacement: 7.2 gpcd Toilet retrofit: 1.3 gpcd Landscape Audit: 10% of outdoor use *Post-1980 Construction* Shower head replacement: 2.9 gpcd Toilet retrofit: 0 gpcd Landscape Audit: 10% of outdoor use	Modeled based on MOU savings assumptions.
2	Residential Plumbing Retrofit	75% of single-family and multifamily residences.	*Pre-1980 Construction* Shower head replacement: 7.2 gpcd Toilet retrofit: 1.3 gpcd *Post-1980 Construction* Shower head replacement: 2.9 gpcd Toilet retrofit: 0 gpcd	Modeled based on MOU savings assumptions.
3	System Water Audits, Leak Detection, and Repair	Maintain active distribution system auditing program and repair system leaks when cost-effective.	Unaccounted water losses assumed to be no more than 10% of total water into the suppliers' system.	Not modeled because statewide average unaccounted water loss currently meets the MOU target value.
4	Metering with commodity rates for all new connections and retrofit of existing connections	100% of unmetered accounts to be metered and billed by volume of use.	20% reduction in demand by retrofitted accounts.	Modeled based on MOU savings assumptions.
5	Large Landscape Conservation Programs and Incentives	ET_o - based water use budgets for 90% of accounts with dedicated irrigation meters; irrigation water use surveys for 15% of CII accounts with mixed use meters.	15% reduction in irrigation water demand for surveyed landscapes.	Not modeled due to insufficient base year data on landscape water use and acreage.
6	High-Efficiency Washing Machine Rebate Programs	Cost-effective customer incentive for the purchase of high-efficiency washing machines to be offered if incentives are being offered by local energy provider or wastewater utility.	Not quantified at this time.	Not modeled due to "not quantified" status in MOU.

TABLE 4B-2

BMP Water Savings Assumptions (continued)

BMP Number	*BMP Name*	*MOU Savings Assumptions*		*Urban Water Use Study Modeling Assumptions*
		Coverage Requirement	*Reduction Factor*	
7	Public Information Programs	Maintain an active public information program to promote and educate customers about water conservation.	Not quantified.	Not modeled due to "not quantified" status in MOU.
8	School Education Programs	Maintain an active school education program to educate students in agencies' service areas about water conservation and efficient water uses.	Not quantified.	Not modeled due to "not quantified" status in MOU.
9	Conservation Programs for Commercial, Industrial, and Institutional Accounts	10% of CII customers to accept a water use survey or reduce water use by CII customers by an amount equal to 10% of baseline CII water use.	*Commercial Water Use* 12% reduction in water use (gallons per employee per day) occurring from 1980-2000.	Modeled based on MOU savings assumptions.
			Industrial Water Use 15% reduction in water use (gallons per employee per day) occurring from 1980-2000.	Modeled based on MOU savings assumptions.
10	Wholesale Agency Assistance Programs	Report on cost effectiveness of each BMP the agency is potential obligated to support, agency avoided cost per acre-foot of new water supplies, monetary value of financial incentive and resources provided to retail members to assist or support BMP implementation, and amount of verified water savings achieved by each wholesaler-assisted BMP.	Not quantified.	Not modeled due to "not quantified" status in MOU.
11	Conservation Pricing	Maintain rate structure consistent with the definition of conservation pricing specified in the MOU.	Not quantified.	Although not quantified by the MOU, this BMP was modeled on the basis of DWR water price forecasts and recent studies of urban water price elasticity in California.

TABLE 4B-2

BMP Water Savings Assumptions (continued)

BMP Number	*BMP Name*	*MOU Savings Assumptions*		*Urban Water Use Study Modeling Assumptions*
		Coverage Requirement	*Reduction Factor*	
12	Conservation Coordinator	Maintain and staff the position of conservation coordinator and provide support staff as necessary.	Not quantified.	Not modeled due to “not quantified” status in MOU.
13	Water Waste Prohibition	Adopt water waste prohibitions consistent with the provisions specified in the MOU for this BMP.	Not quantified.	Not modeled due to “not quantified” status in MOU.
14	Residential ULFT Replacement Programs	Savings to equal or exceed water savings achievable through an ordinance requiring the replacement of high water using toilets with ULFTs upon resale.	At least as effective as requiring toilet replacement at the time of resale. (Exhibit 6 of the MOU presents a detailed methodology for estimating savings).	Modeled based on MOU savings assumptions.

4C

Normalizing Urban Water Use Data

Some of the public comments the Department received on the draft Bulletin 160-98 dealt with how normalized urban water use data were developed and why normalized data differed from actual water production data. This appendix is provided to address those comments.

Bulletin 160-98 estimates of urban water use begin with raw data from the Department's survey of public water systems. This survey provides local agencies' annual water production which, when combined with population data, can be shown as agency per capita water production. For each of the Bulletin 160 DAUs (or in some cases, PSAs) representative water purveyors are selected, and their production data are quality-controlled to fill in missing data points, check production numbers, and resolve inconsistencies in the data.

Figure 4-4 in Chapter 4 showed how average statewide urban water production has varied over time. Information used to prepare the figure came from the public water systems surveys. Figure 4C-1 shows sample data for 12 cities or water agencies, to illustrate geographic variability in production, together with statewide average water production. These plotted data do not include self-produced water, water that is developed by entities for their own use. Most self-produced water is developed by industrial users. The Department estimates quantities of self-produced water through periodic surveys of industrial water users.

Statewide, the residential sector accounts for over half of total urban water use. The landscape component of residential (and some commercial and institutional) use strongly influences year-to-year variations in urban use, reflecting availability of precipitation and other water sources. Landscape water use increases in dry years in most parts of the State, if water supplies are available, since less precipitation occurs. Regional variations in landscape water use reflect climatic differences and the extent to which available water supplies depend on local precipitation or on supplies from other sources.

FIGURE 4C-1

Sample Urban Water Production Data

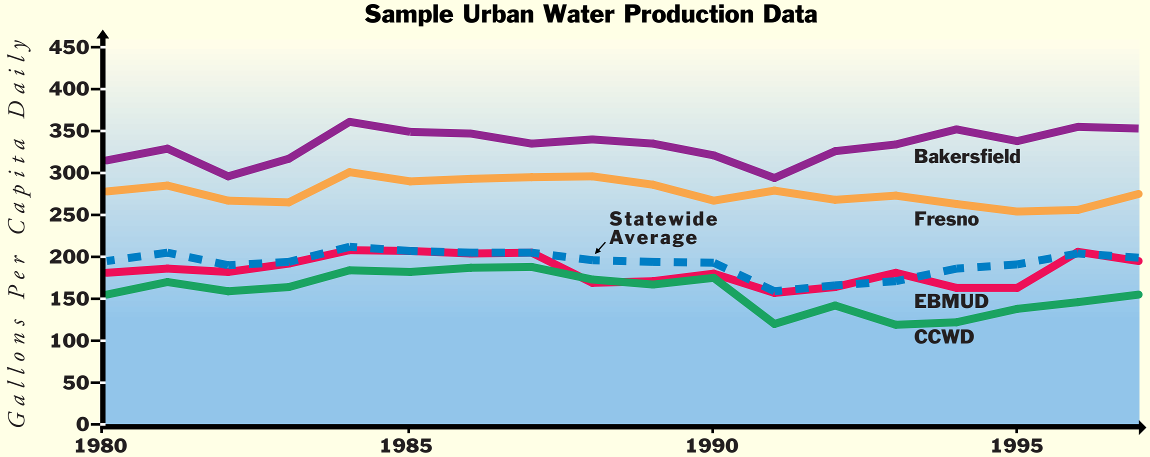


FIGURE 4C-1
(continued)

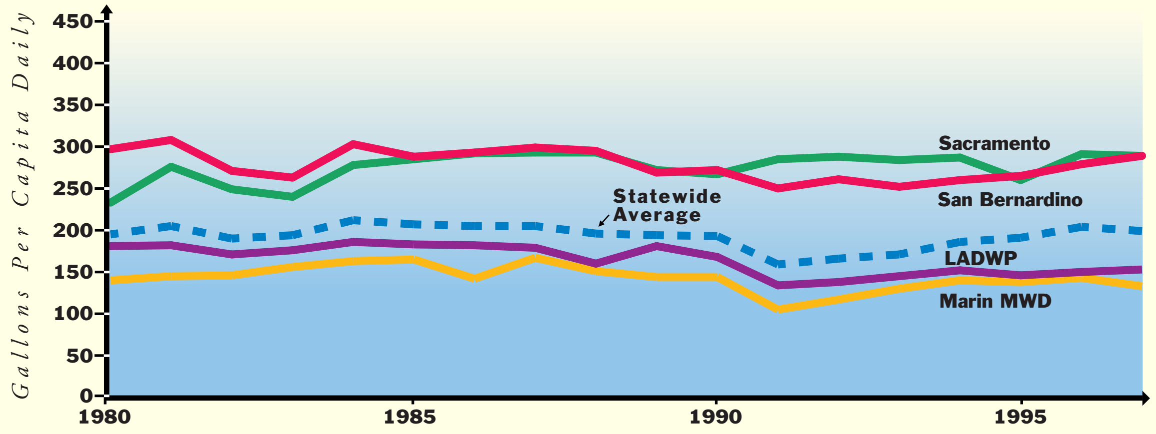
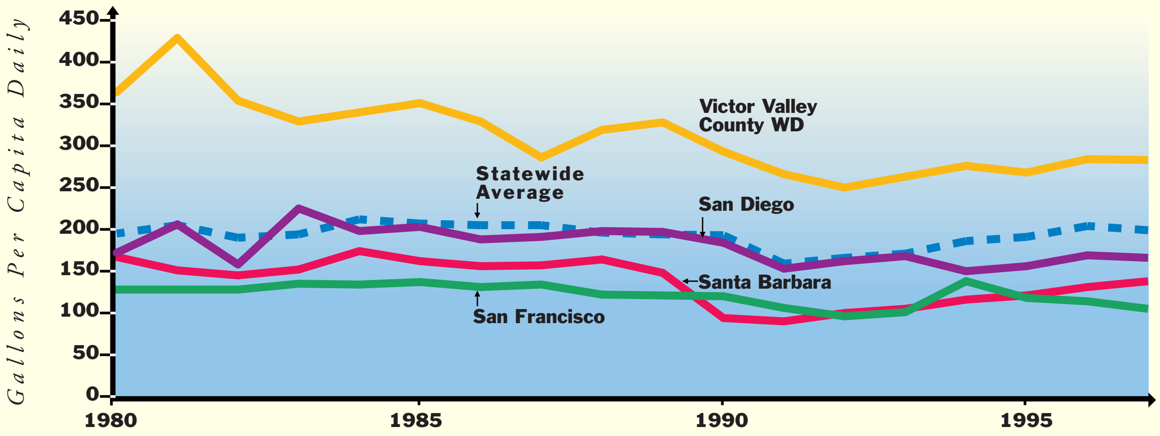


FIGURE 4C-1
(continued)



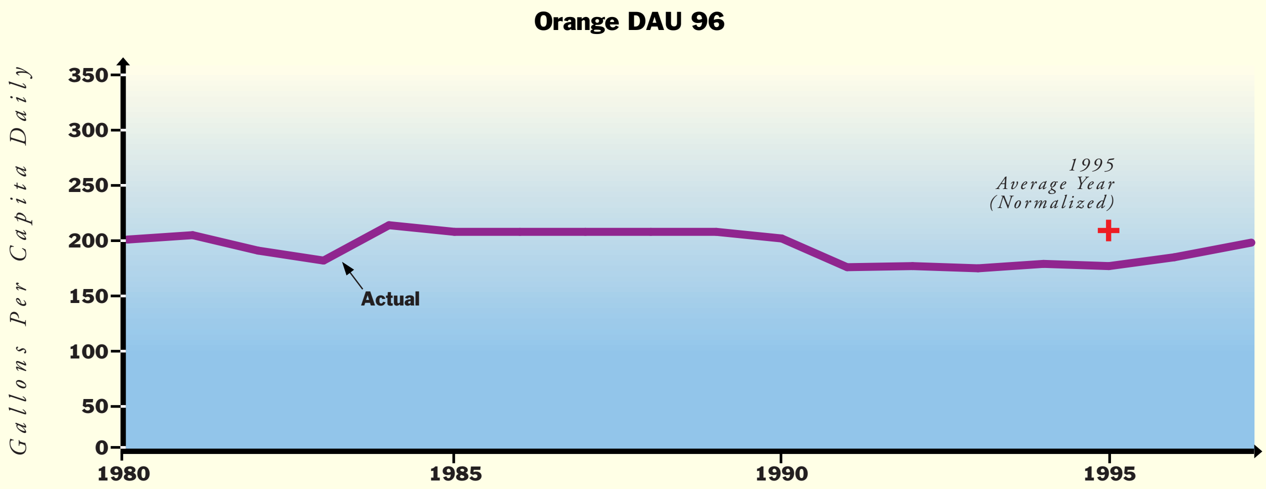
Addressing the impacts of the 1987-92 drought was a major consideration in reviewing the water purveyor data used for Bulletin 160-98. As shown in Figure 4-4, statewide average urban per capita water production declined during the drought years due to water rationing and other short-term restrictions in use, but then began to rebound. Capturing this rebound effect was important to estimating 1995 normalized urban use for Bulletin 160-98. As described in Chapter 4, the normalizing process is intended to remove water use irregularities due to droughts, extremely wet years, or other conditions. Calendar year 1995 was a wet year. Actual urban water production data for 1995 are thus lower than the Bulletin 160 normalized urban water use data.

Normalized urban water use is calculated for each DAU, except in the sparsely populated desert areas in southeastern California, where calculations are done at a PSA level. Recent production data from representative water purveyors are combined with normal water supplies and water use patterns to produce a composite per capita water production value for each DAU. Data for years during and immediately following the drought are removed from consideration due to the effects of water shortages of unprecedented severity and duration and a multi-year rebound in per capita water use. The composite per capita water production value is adjusted to account for self-produced water supplies, permanent effects of urban BMPs, and post-1990 changes to federal and State plumbing fixture standards to result in base year per capita water use.

The amount by which a normalized value differs from actual production data for a given year varies from DAU to DAU, as shown in Figure 4C-2 for some sample DAUs. (The 1995 statewide average normalized per capita urban water use was 229 gpcd, of which 9 gpcd represented self-produced water.) Normalized per capita water use data (water purveyor production plus self-produced water) are multiplied by the corresponding population to arrive at base 1995 normalized urban water use for each DAU. When DAU-level information is combined into hydrologic regions for Bulletin 160 water budgets, the "other" component of urban water use is added to the regional water budgets. This "other" component is small in comparison and includes recreation water use, energy production water use, and losses from major conveyance facilities. (With the addition of the "other" component, total 1995 normalized statewide average per capita water use is 244 gpcd.)

FIGURE 4C-2

Actual and Normalized Production Data



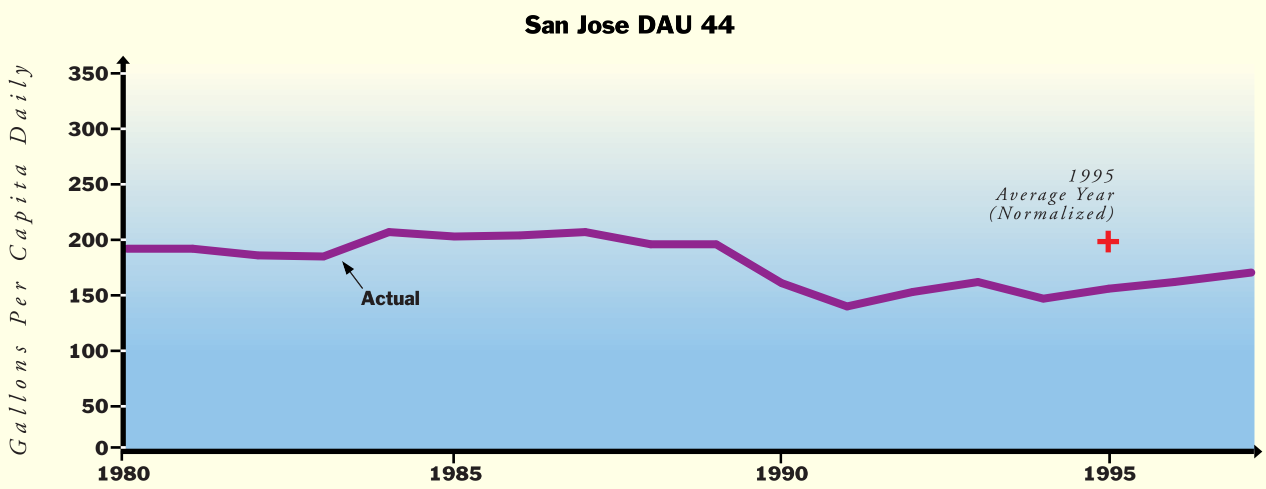
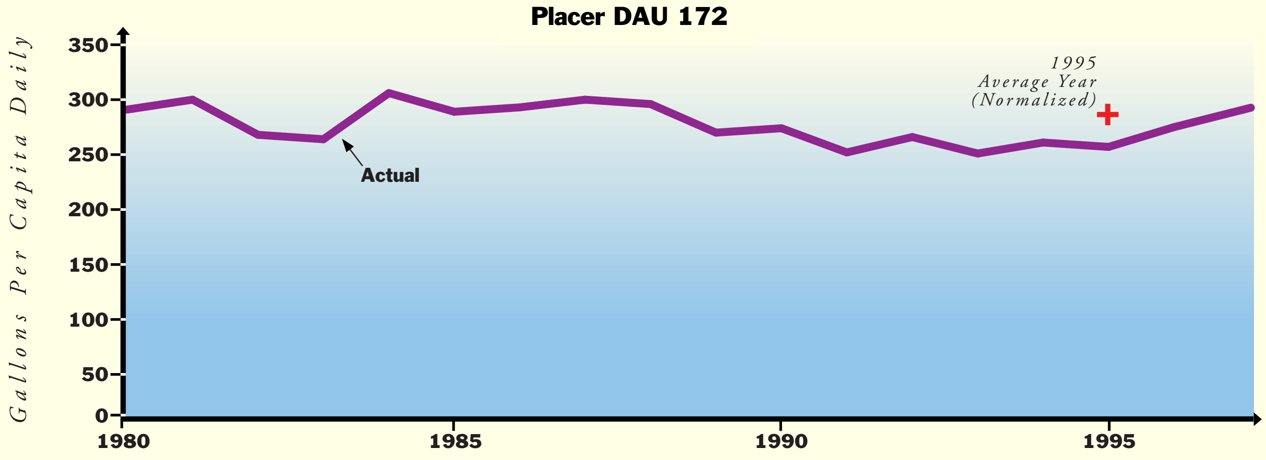
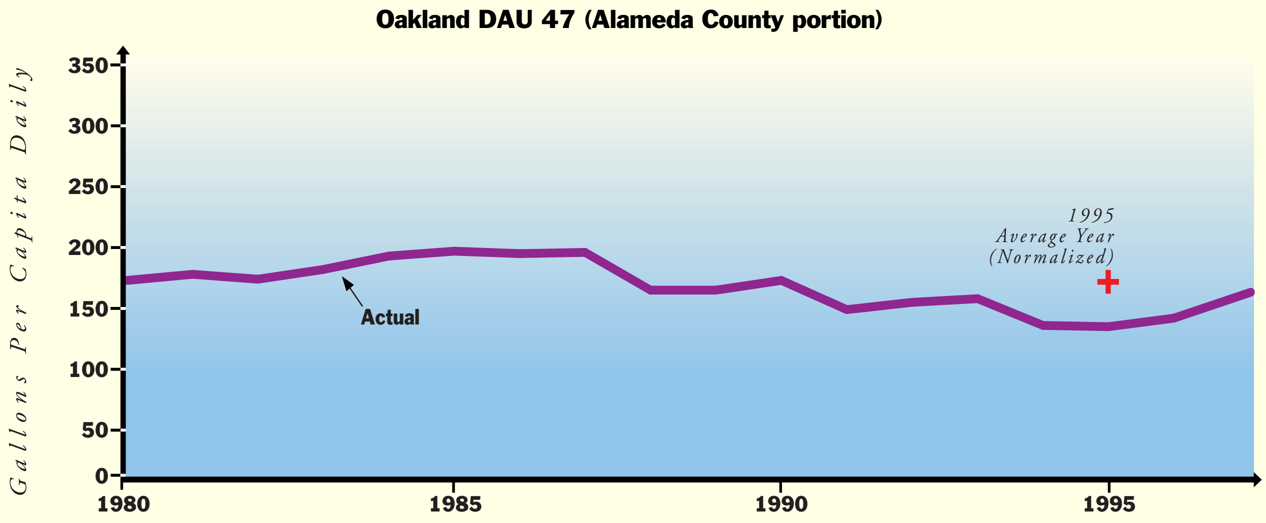
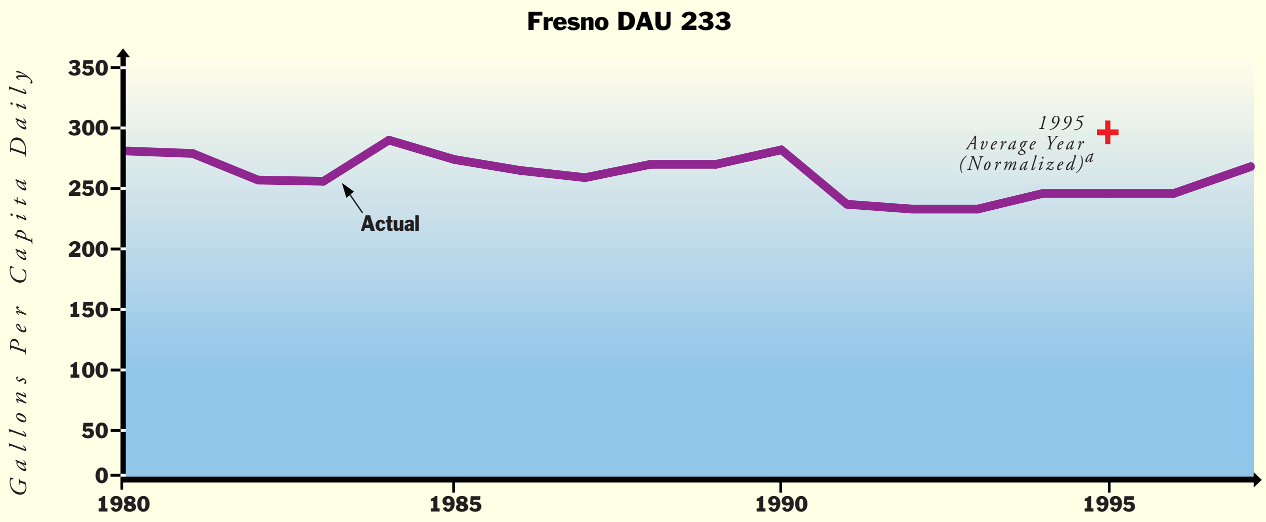


FIGURE 4C-2
(continued)







[a] Includes 29 gpcd self-produced industrial water use not accounted for in the plot of actual production data.

5

Technology In Water Management

This chapter highlights the present status and anticipated development of water management technologies. Review of water management technologies provides an important foundation for evaluating water management options described in later chapters of the Bulletin. For example, it is a common public perception that seawater desalting will solve most of California's future water problems. However, the current and reasonably foreseen state of desalting technology suggests that it will be used to meet relatively small, specialized needs due to its high cost. This chapter presents some case histories of selected technology applications and illustrates a few innovative examples.

Demand Reduction Technologies

Technological advances have improved urban and agricultural water use efficiency throughout the State. Future advances are expected to affect landscape irrigation, residential indoor water use, interior commercial, institutional, and industrial water use, and agricultural water use. Since the purpose of the Department's Bulletin 160 series is to assess water supply benefits, it is that aspect of demand reduction that the Bulletin addresses. Demand reduction technologies may provide additional benefits, such as reducing water treatment costs, reducing fish entrainment at water supply

The city of Santa Barbara's desalter was operated during the drought in 1992 and is now on standby status.

diversion structures, or reducing nonpoint source runoff. These other benefits are recognized in the Bulletin's options evaluation process, as described in Chapter 6.

Landscape Irrigation Technology

New irrigation control system technology can save water by setting irrigation cycles to account for changes in such factors as soil moisture and ET. New technology includes both retrofit devices and redesigned irrigation controllers.

Residential landscape irrigation systems often include sophisticated control devices such as electronic timers and electric solenoid-controlled valves. This increased sophistication does not always translate into water savings because homeowners often lack information on landscape plant water requirements. Consequently, many residential irrigation timers are permanently set to meet maximum summer season water requirements. A 1997 study by Utah State University showed that significant water savings could be achieved by retrofitting existing residential irrigation control systems with inexpensive (about $100) soil moisture-sensing devices. The devices are placed inline between the existing timer and valves and override a planned irrigation cycle when adequate soil moisture is available. Study results showed that the devices reduced landscape irrigation water use by an average of 10 percent. Follow-up questionnaires revealed that over 70 percent of the study participants observed that their lawns were as green or greener than before installation of the device.

New irrigation system controllers for the commercial, industrial, and institutional sectors are programmed for irrigation schedules based on normal year ET rates, and are adjustable to account for deviations from normal year ET. Some of the most advanced controllers can be automatically adjusted to current ET rates using telecommunication pager technology to access weather data from automated weather stations. Rainfall sensors represent an inexpensive method to automatically terminate irrigation controller programs during precipitation.

Residential Indoor Water Use Technology

Technological advances in residential indoor water use efficiency have come primarily from redesigning plumbing fixtures to meet new State and federal standards. Future efficiencies will come from improved fixtures and installation of more water-efficient home appliances. In addition, new technology to characterize residential water use may yield data allowing more accurate forecasts of components of urban water demand. This information would help allocate demand reduction program resources.

Previously, the breakdown of residential water use was estimated from water meter data and assumptions about the water use of various fixtures and appliances. However, a 1995 study in Boulder, Colorado, showed that detailed information on water use patterns could be gathered through analysis of data obtained from data loggers attached to residential water meters. The traces have sufficient detail to identify flow signatures of individual fixtures and appliances. The technique also provides information to differentiate between indoor and outdoor water use. Based on the success of the Boulder study, a larger study was organized by the American Water Works Association Research Foundation. The goal of this study is to collect information from 1,200 homes in 12 cities, for two 2-week periods—one period in the winter and another in the summer. The information will be sorted into its major end use components: toilets, showers, baths, faucets, dishwashers, washing machines, and leaks. Preliminary results are shown in Table 5-1. These data will be combined with information from a survey of study participants to construct a residential water use model. A final report on the study is scheduled for publication in 1999.

Plumbing Fixtures. State law requires all toilets sold or installed in California to use no more than 1.6 gallons per flush. These standards have pushed traditional gravity operated toilets to the limit of acceptable operation. The performance of gravity operated toilets is limited to the flow rate achieved through the bowl under the force of gravity, placing a limit on the potential for reducing the amount of water used in each flush.

Pressure-assisted toilets use pressurized flow, in conjunction with siphon action, to give acceptable

TABLE 5-1

Distribution of Residential Indoor Water Use

Component	*Average Use (%)*
Toilet	26
Washing Machines	23
Shower/Bath	20
Faucets	15
Leaks	13
Dishwasher	1
Other Uses	2

operation with less flushing water. The increased flow rate (more than 70 gpm compared to about 25 gpm for gravity designs) provides greater force to remove solids from the bowl and hastens the start of the siphon action. In addition, the surge of water from a pressure-assisted toilet is more effective at pushing waste through the drain line.

In the past, use of pressure-assisted technology was limited to the commercial sector due to high costs and increased noise. Current residential designs are less expensive than previous models and only slightly noisier than gravity toilets. Pressure-assisted toilets range in price from $220 to $815, compared to $65 to $575 for gravity toilets. Future residential designs may use 0.5 gallons or less per flush.

Washing Machines. Horizontal-axis washing machines (front loading washing machines) use significantly less water than traditional vertical-axis, central agitator machines. Rather than fully immersing the clothes, the tub of the washer rotates through a horizontal axis in alternating directions to lift and tumble the clothes through a pool of water. Recent studies show that these washers use about 25 to 35 percent less water than central agitator models.

Currently, horizontal axis washing machines produced by American manufacturers range in price from about $700 to $1,100. Models by some European manufacturers are considerably more expensive. Prices are expected to decrease to within about $200 of central agitator models as the market grows. A recent survey of appliance retailers showed the residential market for front loading washers could increase from about 2 percent at present to between 5 to 20 percent over the next five years.

Water Heaters. Hot water demand systems save water by either eliminating the need to drain cold water sitting in the pipe between the water heater and the plumbing fixture, or by reducing the distance between the heater and fixture. Demand systems are designed in two basic configurations: central storage tank and tankless systems. Central storage tank systems are based on traditional water heater and plumbing systems, modified with the addition of a valve to open a loop back to the hot water tank, and a pump to push the cold water back to the water heater while drawing hot water into the pipe. When hot water reaches the fixture, the loop closes and the hot water exits the fixture. Tankless systems, also known as instantaneous or on-demand water heaters, heat water only when needed. They can be located near the plumbing fixture to reduce the amount of cold water that must be displaced for hot water to reach the fixture. Because they do not store hot water, tankless systems save energy by eliminating standby losses.

Water savings depend on the amount of water to be displaced before hot water reaches the fixture (or the amount of water that would have been displaced, in the case of tankless systems). Measurements by the California Energy Commission show that about two times the pipe volume between the water heater and the fixture must be replaced before hot water reaches the fixture, due to heat lost to the pipe. A 1996 study of potential water savings in Southern California showed that hot water demand systems could save approximately 30 gpd per unit.

Interior CII Water Use Technology

Plumbing Fixtures. The water savings potential of 0.5 gpf toilets also applies to the commercial sector. In addition, while State law requires that urinals use no more than an average of 1.0 gpf, this water requirement could be further reduced or eliminated through the use of waterless urinals. Waterless urinals attach to

High efficiency horizontal axis washing machines are being used in commercial applications, but are just becoming available for home use. A check of large appliance dealers in 1998 showed that two brands of horizontal axis washers were commonly in stock, at prices ranging from $700 to $1,100. Comparable standard washers cost from $100 to $600 less. Some utilities are offering their customers rebates on the order of $100 to $150 for purchasing the horizontal axis machines.

standard plumbing stubs, but require no flushing water to operate.

Water savings from waterless urinals depends on the frequency of use and the flushing water requirement of the fixture that is replaced. A 1996 study in Southern California showed potential savings from about 11 gpd per fixture in office buildings to about 55 gpd per fixture in airports and movie theaters. In 1995, the U.S. Navy equipped sample bathroom facilities at the Naval Air Station North Island in San Diego with waterless urinals. The study found that replacement saved about 45,000 gallons of water per year, with a pay-back period of about 3 years. Based on the success of the trial, more than 200 waterless urinals were installed at the station. To date, the urinals remain in operation and perform well when maintained according to manufacturer recommendations.

Cooling Towers. The largest use of water in the industrial sector is for cooling. Water is used to cool heat-generating equipment, manufactured products, and food products and containers in canneries. The most water-intensive cooling method is once-through cooling, where water contacts and lowers the temperature of a heat source, then is discharged to waste. Recirculating cooling tower systems reduce water use by using the same water for several cycles.

The majority of cooling towers in California are recirculating evaporative systems, where the temperature of the cooling water is reduced through evaporation. As cooling water is recycled through the tower, the salt concentration increases. Salt build-up must be managed to avoid scaling on condenser tubes, which results in reduced heat transfer efficiency. Blowdown is the release of some of the circulating water to remove the suspended and dissolved solids left behind due to evaporation. Make-up water is added in place of the blowdown to reduce the total dissolved solids. Water savings can accrue by minimizing blowdown or by converting to a dry cooling process based on air heat exchangers.

Evaporative cooling towers are used by a wide range of industries.

Blowdown can be minimized by treating the recirculating water with sulfuric acid or ozone (to control scaling and biological fouling), by mechanical filtration of solids, and by the use of conductivity sensors and automatic valves to precisely control the blowdown/makeup process. Savings can be maintained through regular calibration of the conductivity sensors. A 1996 study conducted for MWDSC suggested that the majority of potential cooling tower water savings in Southern California could be realized through the addition and/or calibration of conductivity controllers. Water savings estimates ranged from about 400 to more than 900 gpd per site.

Air heat exchangers use fans to blow air past finned tubes carrying the recirculating cooling water. The Pacific Power and Light Company's Wyodak Generating Station in Wyoming uses dry cooling to eliminate water losses from cooling water blowdown and evaporation. The processed steam is condensed by routing it through finned carbon steel tubes as fans force air, at a rate of 45 million cubic feet per minute, through an 8 million square foot finned-tube surface. This technique results in a water requirement of 300 gpm, compared to about 4,000 gpm of make-up water for equivalent evaporative cooling.

Agricultural Water Use Technology

Future technological advances in irrigation systems and irrigation scheduling are expected to result in more efficient agricultural water use.

Irrigation Systems. Many terms are used in describing the performance of irrigation systems, but the two most important are DU and SAE, defined in Chapter 4. The accompanying sidebar defines several agricultural technology terms used throughout this section. Irrigation experts generally agree that an 80 percent DU is achievable by all irrigation systems and is an upper limit for existing systems. With today's systems, SAEs of more than 73 percent indicate under-irrigation, potentially resulting in a reduction of

Definition of Irrigation Terms

- Distribution Uniformity: A measure of the variation in the amount of water applied to the soil surface throughout an irrigated area.
- Seasonal Application Efficiency: The water beneficially used for ETAW and cultural practices divided by applied water.
- Intake Opportunity Time: The amount of time that applied irrigation water is in contact with the soil.
- Allowable Depletion: Depth of water needed to bring soil moisture to field capacity—a measure of how dry the soil is allowed to become before an irrigation is applied.
- Reference Evapotranspiration (ET_o): The ET of well-watered 4 to 6 inch tall turf.

crop production and an increase in soil salinization. Whether a gravity or pressurized system, a well-designed and well-managed irrigation system appropriate to a field's terrain, soil, crop, and flow constraints can achieve the maximum DU and result in high SAE, provided the irrigation water supply is of adequate quality and is available when needed at the proper rate of delivery.

Adoption of new irrigation technology to reduce applied water must result in a reduction of deep percolation, tailwater runoff, ET, or leaching requirement. Reduced deep percolation and tailwater runoff could be achieved by improving in DUs and irrigation management. Evapotranspiration could be reduced by minimizing losses from surface evaporation, or by intentional underirrigation with no loss in production or quality. Reducing the leaching requirement (the amount of water used to leach salts from the soil) is not a goal because insufficient leaching results in salinization of the soil, rendering it less productive and consequently reducing water use efficiency.

Gravity, or surface irrigation, systems use the soil surface to spread and move water on and over a field. The major types of gravity irrigation systems used in California—furrows, border-strip, and level basin—are discussed in the sidebar. The field is optimally rectangular, with the water entering the field from the highest side. The water moves over the surface of the soil, eventually covering the area intended for irrigation, and infiltrates the soil to replenish soil moisture. The rate of infiltration varies by soil type and time (a sandy soil has a much higher infiltration rate than a clay soil). All soils have a maximum infiltration rate at the beginning of irrigation. The longer the water is in contact with the soil, the more the infiltration rate decreases; in some soils it decreases to almost zero.

Important factors for achieving high DUs are intake opportunity time and soil infiltration rate. The IOT varies within an irrigated field. On furrow systems, the part of the field closest to the source of water usually has the highest IOT. For high DUs, the IOT within a field must have a high uniformity. In addition, soil will affect the DU. Different soils with the same IOT will have different infiltration rates. The more nonhomogeous the soil, the more soil infiltration rates will vary, resulting in a lower DU.

Irrigation timing, applying the correct amount of water, and having a high DU are important considerations for achieving high SAE. With most surface systems, the grower must decide how dry the soil can become (its allowable depletion) before an irrigation is applied. The grower's decision is based on the field, irrigation system design, crop, soil depth, and other factors. If the soil has an AD of 3 inches, irrigation should occur when the soil in the field has dried to that level. The amount of water applied over the field should be more than 3 inches, because water cannot be applied with a DU of 100 percent. Irrigating before reaching the AD could result in an over-application of water, and a lower SAE. Irrigating after reaching the AD might result in an under-application, and an overly high SAE, which is not desirable because plant stress may occur.

Pressurized, or piped, irrigation systems use pipelines and water emission devices to discharge water into a field and onto or under the soil surface. Water is pressurized using a pump and is usually passed through a filter to reduce the chance of clogging the emission devices. The water is distributed from a main pipeline system and sub-mains to lateral pipelines in the cropped field. Water flows from the emission devices as either a spray or a very small continuous stream. As the water meets the soil, it infiltrates to replenish soil moisture.

Pressurized systems are very different from surface systems. The performance of surface systems depends upon soil infiltration rates, IOT, and the amount of water applied. With pressurized systems, DU is constant and depends on the hardware design and maintenance. The DU will not change, unless pipeline leaks or clogging of devices occur, or winds distort the spray pattern. One of the most important design considerations for achieving high DUs is pressure regulation, as flow rates change with pressure. Excessive pressure variations in the design will result in a low DU.

The most important considerations for achieving high SAE with pressurized systems are applying the correct amount of water during an irrigation, and maintaining a high DU. Since a pressurized system can apply any amount of water with the same uniformity, the amount of water needed to replenish the crop root zone must be determined before the irrigation. Then the irrigation can be operated for the correct amount of time to apply the required water. The major types of pressurized irrigation systems used in California—sprinkler and micro-irrigation—are discussed in the sidebar.

Irrigation Scheduling. All irrigation systems require proper scheduling to achieve high SAEs. To develop an optimized irrigation schedule, the grower considers several factors: allowable or desirable crop water stress, the soil's water holding capacity within the crop root zone, water availability and/or delivery constraints, amount of effective rainfall, and application rate. With this information, along with soil moisture determinations, plant stress indices, and/or estimates of crop ET, a grower can develop a water budget schedule. The water budget compares crop ET with soil AD, allowing the grower to decide when and how long to irrigate.

Soil moisture is monitored many ways. Subsurface soil samples can be taken and visually inspected to estimate the moisture status. Soil moisture can be estimated with mechanical devices such as tensiometers or with electrical resistance devices such as gypsum blocks that rely on the change in electrical conductivity of water in the device. A neutron probe, another moisture-sensing device, measures the amount of neutrons reflected from water molecules in the soil.

Gravity (Surface) Irrigation Systems

Furrow Systems

Furrow is the most common gravity system, and is used for field crops, truck crops, trees, and vines. Channels or corrugations are cut or pressed into the soil of a field, usually one furrow between planted rows of crops. Efficient furrow systems have a slight grade, sloping from the head of the field where water enters the furrows to the bottom of the field. Water is delivered to the furrows using an earthen ditch and siphon tubes, gated pipe, or underground piping and above ground valves. In furrow systems, only the soil in the channel is wetted. Between 20 to 50 percent of the soil surface in a furrow irrigated field usually comes in contact with the irrigation water.

To irrigate sloping furrow systems efficiently, tailwater is allowed to run off the end of the furrows. A tailwater recovery system is needed to reapply this water, either on the same field or on another field. Efficient management requires a relatively high flow at the beginning of the irrigation, to get the water down the furrow quickly, then the flow is cut back to reduce tailwater. With furrow systems, high DUs can be achieved when the advance time (the time it takes the water to move from the top of the field to the end) is relatively short compared to the total time of irrigation.

Furrow systems can be designed and operated to achieve good SAEs for a range of ADs, except for very small ADs. The AD changes as the root zone changes. The early season irrigation of annual crops will not be as efficient as later season irrigations, because the early season AD would be small (shallow root depths), while the later season AD would be large (deep roots). Infiltration rates are typically higher soon after planting and lower later in the season.

Technologies and actions to optimize DUs and increase SAEs for furrow systems include:

- Dragging torpedoes (heavy metal cylindrical devices) within a furrow to smooth and compact the soil surface will decrease the advance time. This is most effective for early season irrigations, where the soil surface is rough due to tillage, and the soil intake rate is high.
- Shortening the length of the furrow will result in decreased advance time. (Shortening furrows increases the number of furrows, which can also result in less planted acreage and an increase in the cost of irrigation.)
- Laser leveling of fields to achieve a uniform slope, and a steeper slope (if practical), will decrease the advance time.
- Using surge irrigation, a technique where short term opening and closing of valves provides water to the furrows, resulting in the water "surging" down the furrow. (This technique is better suited to some soil types than others.) This technique will improve the uniformity of IOT in a furrow. It requires a surge valve designed for this application, and can easily be automated.
- Reducing the flow rate in each furrow after the water has reached the end of the furrow is essential to reducing the amount of tailwater produced.
- Using a properly planned and designed tailwater recovery system, along with efficiently using the captured tailwater on the same field or other irrigated fields.

Border-Strip Systems

Border-strip systems are generally used for alfalfa and pasture, but can be used on field crops and trees and vines. A field is divided into a number of strips, usually between 20 to

continued ...

100 feet wide. Low levees, or borders, divide each strip. Each strip has a slight slope from the head of the strip to the bottom, and ideally little or no slope between the sides. Water is delivered to each strip using an earthen ditch and siphon tubes, gated pipe, or underground piping and above ground valves. Usually all the soil surface in the strip, other than that in the borders, comes in contact with irrigation water.

A relatively large flow of water is directed into each strip during irrigation. The time it takes for the water to reach the end of the field is the advance time. When the water is between 60 to 90 percent of the way down the strip, the water is shut off, and the water already in the strip continues to move down the strip. The time it takes for the water to recede from the soil surface (from the top of the strip to the bottom) is the recession time. To achieve a high DU, the advance time must be very similar to the recession time, resulting in a uniform IOT over the strip. Generally, a border-strip system is designed and operated to have a small amount of tailwater, which requires a tailwater recovery system for reducing applied water. Border-strip systems can be designed to have a high DU and can achieve a high SAE, but only for a specific AD. Border-strip systems are well suited to crops with a constant deep root zone, such as alfalfa, pasture, trees, and vines.

Technologies and actions for border-strip systems to optimize DUs and increase SAEs include:

- Modify the advance rate to match the recession rate by adjusting the flow rate, changing border spacing, and using laser leveling to achieve a uniform slope and minimize cross slope.
- Use a properly planned and designed tailwater recovery system, and use the captured tailwater efficiently on the same field or on other irrigated fields.

Level Basin Systems

Level basin systems can be used on alfalfa, pasture, trees, vines, and field crops. The size of each basin is variable and depends upon soil infiltration rate and flow rate of water. Basins can vary from small (50 x 50 feet) to large (10 or more acres). There should be little or no slope within a basin. Earthen berms are built up on all sides of the basin. Water is delivered into each basin from pipelines and valves for smaller basins or from lined or unlined ditches with large gates. Normally, level basins are designed to have no tailwater. To achieve a high DU, the basin must be level, the flow of water must be high enough to cover the soil surface in a very short time (without any soil erosion from the flow), and the soil should be homogeneous.

Technologies and actions to optimize DUs and increase SAEs for level basin systems include:

- Use laser leveling to achieve a precise grade.
- Minimize soil variability within a basin. Large basins can be subdivided into smaller basins with uniform soil characteristics.

A side roll, wheel move sprinkler system.

Moisture content can also be estimated by dielectric sensors, devices that measure the dielectric content of a soil.

Plant stress indicator devices include pressure bombs and infrared thermometers. A pressure bomb is used to determine the turgor pressure within the cells of a plant's leaf, which provides information on the plant's moisture status. Infrared thermometers are hand-held devices used to measure plant canopy temperature. Plants can control water loss by regulating the stomatal openings in their leaves. Monitoring plant canopy temperatures with this device aids in determining if crop stress is occurring, and can indicate the status of soil moisture.

Crop ET estimates are developed using either evaporation pans or weather information. Class A evaporation pans are commonly used for measuring evaporation. The pans, constructed of galvanized steel or aluminum, are situated in the center of a large irrigated turf area. The pan station includes devices to measure rainfall, temperature, wind speed, and relative humidity. Evaporation is measured by monitoring the change in height of the water in the pan. The evaporation readings are multiplied by crop coefficients to estimate ET of a specific crop.

Many growers use automated weather station data for determining crop ET, such as the California Irrigation Management Information System. CIMIS is a

Pressurized (Piped) Irrigation Systems

Sprinkler Systems

Sprinkler systems are the most common type of pressurized systems and can be used for almost all crops. There are many different sprinkler head designs with flow rates that can vary from 10 gpm to less than 1 gpm. The spacing of the sprinkler heads in the field depends upon the flow rates and the radius of the area where the spray contacts the soil. To achieve high DUs, systems for field and truck crops are designed to space sprinkler heads close enough so that there is the proper amount of overlap of their wetted areas. Sprinkler systems for tree crops do not generally depend on overlap.

To achieve high DUs, a system must be designed to have minimal pressure variation, which ensures uniform flow rates from the sprinkler heads. Sprinkler nozzles must be maintained, because clogged or partially clogged nozzles lower DU, and worn nozzles will change flow rates, resulting in larger variations in pressure in the system. The application rate must be the same or less than the soil's infiltration rate. There are many variations in sprinkler systems used in California.

Permanent Systems. Permanent systems use underground pipelines. Risers connect to an underground lateral, usually with a sprinkler head attached less than a foot from the surface. These systems are commonly used for orchard irrigation (under tree), but when connected to taller risers they can be used for vines.

Solid Set Systems. Solid set systems use above ground aluminum pipelines, usually in 30 foot sections. Short risers connect the aluminum laterals to sprinkler heads. With a solid set system, the irrigation system covers a complete field. The system may stay in the field for the whole growing season, and be removed before harvest, or may be used only for germination or transplant establishment of vegetable crops. These systems are used mainly for field and truck crops.

Hand Move Systems. Hand move systems are similar to the solid set systems, using the same aluminum pipelines, but do not normally cover a whole field. After an irrigation, the sprinkler laterals are disconnected from the sub-mains, and moved by hand to the next location in the field. After each irrigation, the laterals are systematically moved to the next location. These systems are usually designed for each part of the field to receive irrigation water every 7 to 14 days. These systems are used on field crops, truck crops, and orchards.

Wheeled Systems. Wheeled systems have the lateral, risers, and sprinkler heads all mounted on wheels that can be moved throughout the field during the irrigation season. Side roll systems are designed to be stationary during the irrigation. After the irrigation, they are moved (using an on-board engine) to the next location.

Linear Move Systems. Linear move systems have the lateral, risers, and sprinklers mounted on pipes between large wheeled towers. The system continuously travels down the field during irrigations. The water is usually supplied to the system via a canal parallel to the travel of the system.

Center Pivot Systems. Center pivot systems are similar in structure to linear move systems, except instead of the lateral traveling down the field, it travels in a circle in the field. One end of the lateral is fixed in the middle of the field, where the water enters the lateral. The entire lateral rotates around this pivot (which is usually a well), and continuously moves during irrigations.

Low-Energy Precision Application Systems. LEPA systems are similar to linear move sprinkler systems, except that they have drop tubes from the lateral to the soil surface instead of sprinkler heads. These systems are used in fields that have furrows, sometimes with small checks or dams in the furrow. The LEPA system travels perpendicularly to the furrows, and drop tubes emit water uniformly into the furrows.

continued...

Technologies and actions for sprinkler systems to optimize DUs and increase SAEs include:

- Minimize pressure variation within the system. Design sprinkler heads, nozzles, and spacings for the proper amount of overlap in spray. Ensure that application rates are lower than the soil infiltration rate, and that filtration is adequate. The sprinkler system must be properly maintained.
- To avoid spray losses, avoid irrigation during windy conditions, and ensure that pressures and nozzles are compatible to avoid misting.
- Where appropriate, use flow control nozzles.

Micro-Irrigation (Low Volume) Systems

Use of these systems increases each year. In many areas with trees and vines, they are the predominant method of irrigation. Low volume systems have many of the same components of sprinkler systems: pressurized water sources, filters, main pipelines, sub-mains, and laterals. The main difference is the devices that emit the water to the soil. These emit water at a very low flow rate (from 0.5 to 10 gallons per hour). There are two types of devices used, drip and micro-spray. With drip devices (emitters), water flows out as a constant stream (0.5 to 2 gallons per hour) directly to the soil. With micro-spray, the devices (spray heads) produce a spray (4 to 20 gallons per hour) over the soil surface. Other key differences between micro-irrigation systems and sprinkler systems are that the entire main and sub-main pipelines are usually underground rigid plastic pipe, the laterals are flexible plastic hose, and the filters are designed to remove much smaller particles to prevent clogging. Emitter and spray heads use small orifices, channels, or nozzles to regulate flow rates, and are subject to clogging by particulate matter and biological growth.

Drip system emitters are usually spaced 2 to 5 feet apart. Drip systems can be buried or placed on the soil surface. Emitter spacing is based upon the soil type being irrigated, with sandier soils needing a closer spacing, and clay soils using the greatest spacing. Drip systems are mostly used for orchards and vines, strawberries, and nurseries, but their use is increasing for vegetable crops. In these systems, the emitters are spaced much closer and are installed 8 to 18 inches below the soil surface.

Micro-spray systems use small plastic sprinklers or jets that spray water over the soil surface, creating a wetted area 12 feet or more in diameter. The droplet sizes are small compared to a sprinkler system, and the application rate is low. Micro-spray heads are connected to plastic lateral hoses, usually one hose per row of trees. These systems are not designed to wet the entire soil surface like a typical sprinkler system. These systems are used almost exclusively in orchards.

Drip and micro-spray systems can achieve high DUs if pressure variation is minimized. Because of the small nozzles and emitter pathways, partial or full clogging is always a potential problem, and can significantly reduce DU. These systems require regular maintenance to reduce clogging, including frequent flushing of pipelines and lateral hoses, and addition of chemicals (such as chlorine and acids) to kill bacteria and other biological growth and to reduce scale buildup. The systems require filtration and the filters need regular maintenance to ensure that they operate as designed.

Achieving a high SAE with these systems is dependent on maintaining a high DU and on proper irrigation scheduling. One advantage to these systems is that irrigation scheduling is more easily controlled than most sprinkler and surface systems. Flow can be started and stopped easily (providing the water delivery system can accommodate this), and they are easier to automate, even to the extent of using remotely sensed field information for making irrigation timing decisions.

Technologies and actions for optimizing DUs and increasing SAEs of micro-irrigation systems include:

- Ensure that pressure variation within the system is minimized, the filtration system is adequate, and prevent emitter clogging.
- Perform regular inspections of filters, emitters/spray heads, pressure levels, and tubing/pipelines, and provide regular maintenance, including filter cleaning and hose/pipeline flushing.
- Where appropriate, use pressure compensating emitters or microsprinklers.

repository of climatological data collected at 93 computerized weather stations throughout the State. CIMIS was developed by the Department and the University of California at Davis, and has been in operation since 1985. Weather data are collected daily from each weather station site and automatically transmitted to a central computer in Sacramento. Currently, the CIMIS computer receives over 25,000 requests for ET data annually, representing approximately 75,000 end users. The weather data (solar radiation, temperature, relative humidity, and wind speed) are used with a modified Penman equation to calculate ET_o. ET_o is used in irrigation scheduling to estimate plant ET, by multiplying ET_o by the appropriate crop or landscape coefficients.

Regulated deficit irrigation is a technique to reduce crop ET. Irrigation is reduced during a specific stage of the crop's growth, resulting in some crop stress at the time, but with little or no negative effects on production, quality, or on future growth. Research has shown that this management technique may be applied to some tree crops such as pistachios, almonds, and olives. This irrigation strategy may have its greatest value in drought situations, where a grower may be forced to under-irrigate.

Water Treatment Technologies

As discussed in Chapter 3, water quality is a critical factor in determining the usability and reliability of any particular water source. Traditional public health practices emphasize the need to use best available quality sources for municipal supplies and to implement source protection measures to maintain high quality raw water sources. Where raw water supplies are of less than pristine quality, greater reliance must be placed on treatment technology. Water recycling and desalting are becoming larger components of potential future supplies, especially for urban areas. To transform these lower quality raw water sources into reliable water supply options, the basic water treatment technologies described in this section are used. Application of these technologies to specific options (such as treating contaminated groundwater) is also outlined.

Description of Water Treatment Technologies

Activated Carbon Adsorption. Treatment by activated carbon adsorption is most applicable to organic contaminants. By bringing contaminated water in contact with activated carbon in granular or powdered form, the contaminants are adsorbed onto the carbon.

An evaporation pan with weather station in the background.

The process may be accomplished by batch, column, or fluidized-bed operations. Spent carbon may be regenerated or may be disposed of in accordance with regulatory requirements. In addition to the traditional use of activated carbon for taste and odor control and dechlorination, carbon adsorption is widely used for removal of volatile organic chemicals and synthetic organic chemicals.

Granular activated carbon adsorption is a unit process with a proven ability to remove a broad spectrum of organic chemicals from water. EPA considers GAC adsorption as the best available technology for removal of VOCs and SOCs. Powdered activated carbon has traditionally been used to control taste and odor in water, and is also used for removal of certain SOCs, especially pesticides. PAC, in combination with conventional water treatment technology, can provide acceptable levels of pesticide removal in surface waters. A typical application of PAC would be for seasonal removal of pesticides found in municipal treatment plant raw water supplies during wet weather. Some limitations to use of PAC include the potential need for large doses of carbon to achieve desired levels of treatment, and the resultant high sludge production.

Air-Stripping. This treatment technique removes VOCs from contaminated water. Countercurrent air-stripping in a packed tower is the most common process. The conventional configuration of a unit consists of a tower with water inflow at the top and air inflow at the bottom. The tower is filled with small diameter random packing. As clean air moves upward, the VOCs transfer from the water phase into the air phase. Treated water exits from the bottom, and the air containing VOCs is discharged from the top of the tower, either into the atmosphere or into a gas treatment system.

Since air-stripping transfers contaminants to the atmosphere, they must take into consideration allowable VOC emissions. In some parts of the State, such as in the South Coast Air Quality Management District, emissions are strictly regulated and additional treatment to reduce emissions to acceptable levels is needed. GAC adsorption may be used with air-stripping to control emissions from a packed-tower aeration system.

The closed-loop air-stripping process is an innovative extension of the traditional air-stripping technology. The closed-loop air-stripping process combines air-stripping with an ultraviolet photo-oxidation

This air stripping system at McClellan Air Force Base in Sacramento is being used to clean groundwater contaminated with solvents.

process to control VOC emissions. In this process, exhaust air is irradiated with UV radiation in a photo-oxidation chamber, and VOCs are destroyed. The end products are carbon dioxide, hydrochloric acid, and ozone. The treated air is recycled to the PTA unit.

Advanced Oxidation. In contrast to GAC or air-stripping, advanced oxidation processes can destroy organic contaminants rather than transferring them from one medium to another. Examples of AOPs include treatment with UV, ozone/hydrogen peroxide, and ozone/UV. AOPs provide more powerful oxidation and at faster rates than conventional oxidants such as chlorine. As a result, they can remove compounds which are not treatable with conventional oxidants. These oxidants can also reduce disinfection by-products created by processes such as chlorination. To date, much AOP work has focused on removing low-molecular weight solvents such as TCE and PCE from contaminated groundwater, and on reduction of DBPs.

Membrane Technologies. Membrane technologies include reverse osmosis, electrodialysis, microfiltration, ultrafiltration, and nanofiltration. RO, MF, UF, and NF are pressure-driven processes of barrier separation; electrodialysis employs electrical potential as the driving force. Membrane processes have been used for desalting, removal of dissolved organic materials, softening, liquid-solid separation, pathogen removal, and heavy metals removal. Other promising membrane technologies are membrane phase-contact processes. These processes are not pressure driven but remove contaminants by extraction into another phase, as do air-stripping and solvent extraction.

RO membranes permit water to flow through them while rejecting the passage of dissolved contaminants. This is based on the natural osmotic process where water passes through a semipermeable membrane from a solution of higher concentration to a lower one. In RO, a pressure greater than osmotic pressure is applied to the contaminated water. Water passes through the membrane but contaminants are retained. RO systems using newer membranes operate at about 250 psi for desalting brackish groundwater and up to 1,000 psi for seawater desalting.

Electrodialysis induces contaminant ions to migrate through a membrane, removing them from the water. In an electrodialysis unit, contaminated water is pumped into narrow compartments separated by alternating cation-exchange and anion-exchange membranes, selectively permeable to positive and negative ions. A variation of this process is called electrodialysis reversal. In electrodialysis, the electrical current flow is always in the same direction. In EDR, the electrical polarity is periodically reversed, which reverses ion movement and flushes scale-forming ions from the membrane surfaces.

MF, UF, and NF operate similarly to RO, but at lower pressures. More stringent drinking water regulations coupled with diminishing sources of pristine waters have stimulated interest in the use of membrane technologies in drinking water treatment. The use of low-pressure membrane filtration for municipal water treatment is a relatively new concept in the water industry, which has traditionally used membranes for removing salts or organic materials. MF operates at pressures ranging from 20 to 100 psi and is capable of removing micron-sized (10^{-6} m) materials. Colloidal particles are physically rejected by MF membranes. UF operates at pressures ranging from 3 to 150 psi and is capable of removing materials that are on the order of a nanometer in size (10^{-9} m) from water. Dissolved inorganic contaminants are not retained by MF and UF membranes. One of the most novel applications of low-pressure membrane technology is the removal of microorganisms such as coliform bacteria, viruses, *giardia,* and *cryptosporidium* from drinking water sources without using chemicals for primary disinfection. The efficiency of low-pressure membranes in removing particles from untreated water supplies has been well documented. MF and UF have shown to be capable of consistently reducing turbidities to less than 0.1 NTU, regardless of the influent turbidity level.

NF operates at pressures ranging from 150 to 300 psi and has characteristics between those of RO and MF. The capital cost of an NF plant is typically high compared to conventional treatment plants because of the cost of membranes and high-pressure equipment. Pilot and bench-scale studies have demonstrated that nanofiltration is effective in removing DBP precursors and SOCs such as pesticides. NF is also frequently used for water softening applications.

Ion-Exchange. The process passes contaminated water through a packed bed of anion or cation resins. The resin type is selected based on the contaminant to be removed. The treatment process exchanges ions between the resin bed and contaminated water. By displacing ions in the resin, contaminant ions become part of the resin and are removed from process water. During the ion-exchange process, the exchange capacity of the resin becomes depleted and needs regeneration to become effective. Sodium chloride brine is used to regenerate the resin. Ion-exchange is widely used for removing nitrates in groundwater and for removing some metals. It may also be used for water softening. Its effectiveness in removing radionuclides is being investigated in a number of full scale applications.

Chemical Precipitation. Chemical precipitation is used for removing heavy metals from water. The contaminants are precipitated from solution and removed by settling. There are several types of chemical addition systems including ones using carbonates, hydroxides, and sulfides. The carbonate system uses soda ash and pH adjustment. The hydroxide system is most widely used for removing inorganics and metals. The system uses lime or sodium hydroxide to adjust the pH upward. The sulfide system removes most inorganics (except arsenic). The disadvantage is that sulfide sludges are susceptible to oxidation to sulfate when exposed to air, resulting in resolubilization of the contaminants.

Biological Treatment. Biological treatment uses microorganisms to remove contaminants in water through metabolic processes. The process can be a suspended growth system, where the microorganisms and nutrients are introduced in an aeration basin as suspended material in a water-based solution, or a fixed-film system where the microorganisms attach to a medium which provides inert support. Biological treatment is used in municipal wastewater treatment and for treating water containing organic compounds such as petroleum hydrocarbons. Biological treatment is often used for remediation of leaking fuel tank sites, either above ground, or *in situ*.

Disinfection. This treatment inactivates pathogens in water. The most common disinfection process is chlorination, often used to treat wastewater and drinking water. Two relatively new disinfection processes applied in water recycling include UV radiation and ozonation. UV has recently been approved by the DHS for disinfecting recycled water. UV has been shown to be as effective as chlorine or ozone in reducing coliform bacteria and is more effective at virus removal. UV has the potential to be more cost effective than chlorine disinfection, and eliminates the DBPs and handling hazards associated with chlorination.

Innovative Treatment Technologies. Many innovative technologies are being used to treat contaminated groundwater at hazardous waste sites. These technologies typically combine basic processes with a few special techniques. In the future, these technologies may see broader application in groundwater recovery projects. Some examples of these technologies, primarily those applied at pilot or full scales, are covered below.

The EnviroMetal Process, a proprietary technology, treats groundwater *in situ* using reactive metal (usually iron) to enhance the abiotic degradation of dissolved halogenated organic compounds. A permeable treatment wall of the coarse-grained reactive metallic media is installed across a plume of contaminated groundwater, breaking down contaminants as they migrate through the aquifer. This technology has received regulatory approval for use in at least two industrial facilities in California for treating shallow plumes with elevated levels of VOCs.

Integrated vapor extraction and steam vacuum stripping removes VOCs, including chlorinated hydrocarbons, in groundwater and soil. The integrated system has a vacuum countercurrent stripping tower that uses low-pressure steam to treat contaminated groundwater, and a soil vapor extraction process to treat the soil. The stripper and the soil vapor extraction systems share a GAC unit to decontaminate the combined vapors. The technology has been used to treat TCE-contaminated groundwater and soil.

Steam-enhanced extraction uses injection wells to force steam through the soil to enhance vapor and liquid extraction thermally. The process extracts volatile and semivolatile organic compounds from contaminated soil and groundwater. The recovered contaminants are condensed or trapped by activated carbon filters. After treatment is complete, subsurface conditions are suitable for biodegradation.

Subsurface volatilization and ventilation technology uses a network of injection and extraction wells to treat subsurface organic contamination through soil vapor extraction and *in situ* biodegradation. A vacuum pump extracts vapors while an air compressor injects air in the subsurface. In most sites, extraction wells are placed above the water table and injection wells are placed below the groundwater level. Because it provides oxygen to the subsurface, the process can enhance *in situ* bioremediation.

The PACT wastewater treatment system is a proprietary technology that combines biological treatment and PAC adsorption to contaminated water. Microorganisms and PAC contact wastewater in an aeration tank. The biomass removes biodegradable organic contaminants, and PAC enhances adsorption of organic compounds. PACT systems treating up to 53 mgd of wastewater are in operation. This process is applicable to groundwater contamination from hazardous waste sites.

Capacitive deionization desalting is an experimental process being researched at Lawrence Livermore National Laboratory. It involves passing water through electrodes made of carbon aerogel and generating a small voltage differential between alternating positive and negative electrodes, thus drawing ions out of the solution. The ions are removed by electrostatic attraction and are retained on the electrode until the polarity is reversed. The ions are then captured with a small amount of water. Other dissolved materials such as trace metals and suspended colloids are removed by electrodeposition and electrophoresis. The process has been operating in a laboratory for over two years. Sodium chloride, sodium nitrate, and ammonium perchlorate solutions have been tested with excellent results. Electrode life has been acceptable in the laboratory, with electrodes operating for more than two years with little degradation. The electrodes appear to be regenerable with little loss of capability. Energy requirements appear less than current desalting technologies. Field testing has begun in Northern California, and will later be moved to Southern California.

Application of Water Treatment Technologies

Water Recycling. Recycled water uses include groundwater recharge, agricultural and landscape irrigation, wildlife habitat enhancement, industrial use, and recreational impoundments. Groundwater recharge and agricultural and landscape irrigation constitute the greatest uses of recycled water in the State. Table 5-2 lists some water recycling plants having a capacity of at least 10 mgd.

Indirect potable reuse of recycled water has been practiced for years through groundwater recharge programs. In Los Angeles County, the Montebello Forebay Groundwater Recharge Project began recharging the Central Basin aquifer with recycled water in 1962. Currently up to 60 taf/yr of recycled water percolates into the groundwater basin, from which it is later extracted for distribution in potable water systems. Water Factory 21 in Orange County and the West Basin Water Recycling Facility have been producing advanced treated recycled water for seawater intrusion barrier injection, with the majority of the injected water entering the groundwater and becoming part of the water supply.

As advanced treatment technologies become more cost-effective, and as public acceptance increases, augmentation of surface water supplies may become another application for recycled water. The San Diego water repurification program, discussed in the sidebar, would be the first example of planned, indirect potable reuse where repurified water is discharged directly into a surface reservoir without percolation or injection into groundwater. (Unplanned, indirect potable reuse occurs whenever treated effluent is discharged into a waterway upstream of another user's water supply intake.) Reservoir retention allows for additional monitoring of the repurified water prior to introduction to a potable water supply. Surface water supply augmentation projects are approved by DHS on a case-by-case basis.

TABLE 5-2

Water Recycling Plants with a Capacity of at Least 10 mgd

Name	*Capacity (mgd)[a]*	*Treatment Process*	*Type Of Reuse*	*Annual Supply (taf)*
San Jose Creek Water Reclamation Plant (Los Angeles County Sanitation District)	100	Primary sedimentation, activated sludge, coagulation, filtration and chlorination	Groundwater recharge, agricultural and landscape irrigation, and nursery stock irrigation	43.2
Donald C. Tillman Water Reclamation Plant (City of Los Angeles)	80	Primary sedimentation, activated sludge, coagulation, filtration, chlorination, and dechlorination	Recreational lake, wildlife lake, and Japanese garden	20.0
Fresno-Clovis Metropolitan Area Regional Wastewater Facilities	60	Primary sedimentation, trickling filter, and activated sludge	Agricultural irrigation	13.7
Los Coyotes Water Reclamation Plant (Los Angeles County Sanitation District)	37	Primary sedimentation, activated sludge, coagulation, filtration, and chlorination	Landscape irrigation, industrial reuse (process water, concrete mix, and dust control), and crop irrigation	5.9
West Basin Water Recycling Facility (West Basin Water District)	37	Coagulation, filtration, clarification and reverse osmosis (5 mgd), microfiltration and reverse osmosis (2.5 mgd)	Industrial use, landscape irrigation, and seawater intrusion barrier	8.4
Chino Basin Municipal Water District Regional Plant No. 1	32	Activated sludge, coagulation, filtration, chlorination, and dechlorination	Landscape irrigation and recreational lakes	1.7
City of San Diego North City Water Reclamation Plant	30	Primary sedimentation, activated sludge, coagulation, filtration, and chlorination	Landscape irrigation	3.0
Terminal Island Treatment Plant (City of Los Angeles)	30	Primary sedimentation, activated sludge, filtration, reverse osmosis, and microfiltration	Seawater intrusion barrier and industrial use	0[b]
Salinas Valley Reclamation Plant (Monterey Regional Water Pollution Control Agency)	30	Primary sedimentation, trickling filters, coagulation, filtration, and disinfection	Agricultural irrigation	13.2
Long Beach Water Reclamation Plant	25	Primary sedimentation, activated sludge, coagulation, filtration, and disinfection	Landscape irrigation, nursery irrigation, and repressurization of oil-bearing strata	5.1
City of Modesto Wastewater Quality Control Facility	25	Primary sedimentation, trickling filter, oxidation ponds, and chlorination	Fodder crop irrigation	14.4
Central Contra Costa Sanitary District Water Reclamation Plant	25	Primary sedimentation, activated sludge, UV disinfection, coagulation, filtration, and chlorination	Landscape irrigation, and light industrial	1.2

TABLE 5-2

Water Recycling Plants with a Capacity of at Least 10 mgd (continued)

Name	*Capacity (mgd)*[a]	*Treatment Process*	*Type Of Reuse*	*Annual Supply (taf)*
Los Angeles-Glendale Water Reclamation Plant (City of Los Angeles)	20	Primary sedimentation, activated sludge, coagulation, filtration, chlorination, and dechlorination	Landscape irrigation and industrial reuse	3.3
City of Bakersfield Wastewater Treatment Plant No. 2	19	Primary sedimentation and oxidation ponds	Crop irrigation	16.8
Laguna Treatment Plant (City of Santa Rosa)	18	Primary sedimentation, activated sludge, coagulation, filtration and chlorination	Fodder irrigation	9.3
Fairfield-Suisun Subregional Wastewater Treatment Plant	17	Activated sludge, coagulation, filtration, chlorination, and dechlorination	Sod farming and duck hunting marsh maintenance	2.4
Michelson Water Reclamation Plant (Irvine Ranch Water District)	17	Primary sedimentation, activated sludge, coagulation, filtration, and chlorination	Landscape irrigation, nursery irrigation, and toilet flushing	8.2
Whittier Narrows Water Reclamation Plant (Los Angeles County Sanitation District)	15	Primary sedimentation, activated sludge, coagulation, filtration, and chlorination	Groundwater recharge and nursery stock watering	9.4
San Jose/Santa Clara Water Pollution Control Plant	15	Activated sludge, filtration and chlorination	Landscape irrigation and industrial processes	7.5
Pomona Water Reclamation Plant (Los Angeles County Sanitation District)	13	Primary sedimentation, activated sludge, coagulation, filtration, and chlorination	Agricultural irrigation landscape irrigation, and industrial process	12.5
City of Visalia Water Conservation Plant	12	Primary sedimentation, trickling filter, activated sludge, and chlorination	Non-food crop irrigation	4.9
Valley Sanitary District Wastewater Treatment Facility (Riverside County)	12	Primary sedimentation, trickling filter, activated sludge, and oxidation ponds	Non-food crop irrigation	4.3
City of Bakersfield Wastewater Treatment Plant No. 3	12	Primary sedimentation, trickling filter	Agricultural irrigation	11.6
Desert Water Agency Wastewater Reclamation Facility (Riverside County)	10	Coagulation, filtration, and chlorination	Landscape irrigation	2.7
Water Factory 21 (Orange County Water District)	10	Coagulation, sedimentation, filtration, carbon adsorption (5 mgd), reverse osmosis (5 mgd), and disinfection	Groundwater injection for intrusion barrier	2.6
Lancaster Water Reclamation Plant	10	Primary sedimentation, oxidation ponds, and chlorination	Wildlife refuge and fodder irrigation	9.7

[a] One mgd equals 1,120 af/yr

[b] Expected to operate by 2000 with annual supply of 19 taf

San Diego Water Repurification Program

The City of San Diego, in conjunction with the San Diego County Water Authority, proposes to repurify 16 taf/yr of wastewater for indirect potable purposes. Results of pilot studies conducted by the agencies show that wastewater can be repurified to a level suitable for human consumption. The agencies would construct an 18 mgd wastewater repurification facility using state-of-the-art technology to treat recycled water from the City of San Diego's North City Water Reclamation Plant. The repurified water would be transported over 20 miles to the 90 taf San Vicente Reservoir, where it would be blended with imported raw water supplies and stored for a period of time. The blended water would eventually be conveyed via the existing El Monte Pipeline to the city's Alvarado Filtration Plant for traditional treatment before being delivered to the city's drinking water system.

Repurified water is based on a concept of multiple barriers. Recycled water from the North City Water Reclamation Plant, treated to levels acceptable for landscape irrigation and for other nonpotable purposes, would be treated further at the proposed 18 mgd wastewater repurification facility. The repurification process would include subjecting the recycled water to four more treatment processes — low-pressure microfiltration, reverse osmosis, ion-exchange, and ozonation. These treatment processes, while redundant in their functions, ensure reliability of the overall repurification system and produce an end product that would exceed current health and safety standards.

Pilot studies show that the City of San Diego could turn recycled water into an alternative drinking water source. The city is preparing an environmental document and has begun design of the project. The project is expected to begin operation in late 2002.

The California Potable Reuse Committee was formed in 1993 to study the viability and safety of indirect potable reuse. The committee, commissioned by DHS and the Department, developed six criteria that must be met before indirect potable reuse is allowed for augmentation of surface water supplies. (DHS has other proposed regulations and criteria for indirect potable reuse through groundwater recharge projects.) The criteria are:

(1) Application of the best available technology in advanced wastewater treatment with the treatment plant meeting operating criteria. Best available technology must include a membrane component with the functional equivalency of reverse osmosis.
(2) Maintenance of appropriate reservoir retention times based on reservoir dynamics.
(3) Maintenance of advanced wastewater treatment plant reliability to consistently meet primary microbiological, chemical, and physical drinking water standards.
(4) Compliance with applicable State criteria for groundwater recharge for direct injection of recycled water.
(5) Maintenance of reservoir water quality. In addition to meeting drinking water standards, recycled water used for reservoir augmentation shall be of equal or better quality than that in the storage reservoir on a constituent-by-constituent basis.
(6) Provision for an effective source control program. The source control program is to include pretreatment/pollution prevention measures that prohibit the discharge of any substance which, whether alone or in combination with other wastewater constituents, causes or threatens malfunction or interference with the wastewater treatment process, constitutes a hazard to human health or safety, or affects the water quality of the potable storage reservoir.

Treatment criteria for reuse of municipal wastewater are mandated in Title 22 of the California Code of Regulations. These criteria specify the treatment level for specific reuse applications. Treatment technologies used for water recycling depend on the reuse application. For most nonpotable reuse applications at least secondary treatment is required. To achieve secondary treatment, conventional biological treatment processes such as activated sludge process, trickling filters, or oxidation ponds are used, followed by sedimentation and disinfection with chlorine.

Tertiary treatment, which is often standard for recycled water, is achieved by adding a filtration step after secondary treatment and before final disinfection. Two major types of filtration technology are applied in tertiary treatment plants: conventional and direct filtration. Conventional filtration, as defined in Title 22, includes coagulation, sedimentation, and filtration to condition the water. Conventional filtration technology requires that the filters be backwashed to prevent turbidity breakthroughs. The Title 22 back-

TABLE 5-3

Sample Desalting Plants

Site	*Owner*	*Capacity (mgd)*[a]	*Comments*
Brackish Water Desalting			
Arlington	Santa Ana Watershed Project Authority	6.0	Operational
Tustin	City of Tustin	3.0	Operational
Oceanside	City of Oceanside	2.0	Operational, being expanded
West Basin	West Basin MWD	1.5	Operational
Wastewater Desalting			
Water Factory 21	Orange County WD	5.0	Operational, being expanded
West Basin	West Basin MWD	5.0	Operational, being expanded to 7.5 mgd
San Diego	City of San Diego	1.0	Operational
Seawater Desalting			
Santa Barbara	City of Santa Barbara	6.7	Standby as drought reserve
Morro Bay	City of Morro Bay	0.6	Standby as needed
Marina	Marina Coast Water District	0.3	Operational
Santa Catalina Island	Southern California Edison	0.1	Operational

[a] One mgd equals 1,120 af/yr

wash requirements result in an equipment-intensive process. Direct filtration provides a cost-effective and convenient tertiary technology when secondary effluent quality is high. The technology will likely be incorporated in areas where effluent from residential areas provides the process water. Newer water recycling facilities use direct filtration as part of the tertiary treatment process. Direct filtration bypasses the sedimentation step. Continuously backwashed direct filtration technology is available, minimizing equipment needs.

Achieving the maximum use of tertiary treated water for landscape irrigation and other outdoor applications depends on the ability to store the treated water supply when it is not needed. Landscape irrigation demands, for example, have a wide seasonal variation in the State's inland areas. (Landscape irrigation demands also vary diurnally, with most sites demanding recycled water at night when supplies are at their lowest levels.) Groundwater recharge is often a cost-effective solution to meeting seasonal demand patterns, allowing the storage of relatively large quantities of recycled water without the capital cost investment associated with above-ground reservoirs.

Desalting. According to the International Desalting Association's inventory of worldwide desalting plants, the United States is second in usage of desalting in the world, with almost 1 maf/yr of installed capacity. (Only Saudi Arabia has more installed capacity.) In 1985, the United States had less than 7 percent of the world's capacity; by 1993, that figure had risen to nearly 15 percent. Common feedwater sources for desalting plants include brackish groundwater, municipal and industrial wastewater, and seawater. Costs of desalting increase with increasing feedwater salinity. Table 5-3 lists some larger desalting plants in California.

Reverse osmosis accounts for 89 percent of the installed capacity of desalting plants in California, including all the significant plants supplying municipal water supplies or recycling municipal wastewater. Reverse osmosis is likely to continue to dominate in California, given recent improvements in membrane performance. Reverse osmosis membranes have changed greatly in the last 20 years. Membranes are available to serve many purposes. This allows water suppliers to select and operate membranes specifically suited to the feedwater quality and the required product water quality. Membranes have developed into two principal classes.

The first class is the traditional reverse osmosis membrane which rejects all salt ions (as well as other dissolved constituents) equally. This process, also called hyperfiltration, is used on water requiring the removal of all classes of dissolved constituents. The second class of membrane processes is represented by MF, UF, and NF. For example, nanofiltration membranes reject larger dissolved ions such as calcium and

**Seawater Desalting–
Marina Coast Water District**

Marina Coast Water District is the primary water supplier for the City of Marina. MCWD relies on the Salinas Valley groundwater basin as its primary water supply source, as do other Salinas Valley urban and agricultural water suppliers. Overdraft of the Salinas Basin has caused seawater from Monterey Bay to migrate into two of the three aquifers underlying the coastal part of Salinas Valley. Seawater intrusion has rendered some groundwater unfit for use. MCWD has had to replace shallower wells with deeper wells to meet demands for potable water. MCWD investigated ways to diversify its water supply sources because of potential groundwater extraction limitations, and chose desalting as its preferred option.

MCWD completed construction of a reverse osmosis seawater desalting plant in 1997. The plant produces approximately 300,000 gpd of potable water (equivalent to 340 af/yr), and uses beach wells for seawater intake and brine disposal. A shallow production well drilled into beach deposits near MCWD's water treatment plant provides intake water for the desalting plant. Using a beach well to supply seawater minimizes the need for extensive pretreatment. Beach sands filter most of the suspended material in the seawater. The reverse osmosis system is a single stage system operated at 40 to 45 percent recovery rates.

The project produces a reject brine flow of about 450,000 gpd. An injection well in a shallow sand aquifer is used to dispose of the brine. Power requirements for the desalting plant are estimated at 5,000 kWh of electricity per acre-foot of water produced, or about 15 kWh for each 1,000 gallons of desalted water. Total capital costs for the desalting plant were about $2.5 million.

sulfate, along with equally large dissolved feedwater constituents. When used in a water softening role, they will remove calcium, magnesium, and sulfate from water, but allow sodium and chloride ions to pass through. Nanofiltration membranes are often used for water softening.

Advances in membrane technology have reduced operating pressures, increased flow rates, and increased salt rejection in typical reverse osmosis applications—thereby reducing treatment costs. As operating pressures have decreased, so have energy costs. Energy requirements have accounted for at least 50 percent or more of the operating costs of a reverse osmosis plant. New membrane materials have allowed more membrane area per module and higher productivity per square foot. Increased productivity of membranes and their longer life expectancy reduces the capital cost of the plant, reducing the cost of water. Increasing salt rejection provides better water quality. In the case of groundwater desalting, the high purity product water can be blended with raw water to meet the desired overall product water quality.

Treatment of Contaminated Groundwater

The selection of technologies for treating groundwater contamination depends on site conditions and the contaminants to be removed. Although there are a variety of options, no one technology is necessarily capable of responding to all conditions found at a groundwater contamination site. In practice, treatment technologies are sometimes used in combination to remediate contamination. For example, groundwater contaminated with nitrates and pesticides requires ion-exchange technology to remove the nitrates and GAC adsorption to remove the pesticides. Table 5-4 provides some examples of contaminated groundwater treatment sites. Treatment unit capacities at the locations shown range from 0.3 mgd to 4.1 mgd.

Some local agencies have integrated groundwater treatment plants into municipal distribution systems. The West Basin Municipal Water District for example, constructed a 1.5 mgd facility that uses reverse osmosis technology to remove elevated levels of dissolved solids from contaminated groundwater. The plant supplies about 1.5 taf annually of recovered groundwater to the district for municipal use and to Dominguez Water Corporation for municipal and industrial uses.

The Glenwood nitrate water reclamation plant, owned by Crescenta Valley County Water District, is a 3.7 mgd ion-exchange treatment plant. Treated groundwater from the plant is sold to Foothill Municipal Water District and MWDSC for municipal and industrial uses. The plant's eventual project yield will be about 1.6 taf annually. The City of Pomona operates a 15 mgd ion-exchange treatment plant, treating nitrate-contaminated groundwater from the Chino Groundwater Basin. At full capacity, the treatment plant supplies about two-thirds of the city's municipal water demand.

Some aquifers in California are contaminated because of past hazardous waste disposal practices. A number of these sites are undergoing remediation. Carbon adsorption, membrane filtration, air stripping, advanced oxidation processes, biological treatment, chemical precipitation, and innovative treatment technologies are examples of technologies used. For example, Aerojet General Corporation's manufacturing facility in Rancho Cordova operates a 6.5 mgd groundwater treatment facility which removes VOCs from the groundwater. The treatment facility has air-stripping towers and GAC adsorption units. Treated groundwater is reinjected into the aquifer through wells, and is also recharged via surface impoundments. Another example is Valley Wood Treating Company in Turlock, which uses pump-and-treat and *in situ* treatment techniques for chromium-contaminated groundwater. The company pumps groundwater and uses chemical precipitation for first stage contaminant removal. Next, a reducing agent is added to the treated water, which is then reinjected into the aquifer. The resulting reaction reduces chromium *in situ* and subsequently fixes residual chromium in the soil.

TABLE 5-4

Examples of Contaminated Groundwater Treatment Sites

Location	*Contaminant*	*Treatment*
Lodi	DBCP	GAC
Lodi	Pathogens	UV
Modesto	DBCP	GAC
Modesto	Nitrates	Electrodialysis
Fresno	DBCP	GAC
Fresno	TCE	Air-stripping
Clovis	DBCP	GAC
Monrovia	TCE	Air-stripping
Monrovia	VOCs	Air-stripping
San Gabriel Valley	VOCs	GAC

Water Supply/Flood Control Technologies

Inflatable Dams

Inflatable rubber, or fabric and rubber, dams and tubes have been used for years as weirs to impound water for water supply and flood control. Inflatable dams were developed and first used in the 1950s in the Los Angeles area. They were typically inflated with water. Since that time, construction materials and control systems have been improved and features have been added, such as fins to reduce vibrations during overflow. Air is now the preferred inflation medium. The manufacturers report that there are about 1,900 of these dams worldwide, with 50 in the United States.

Alameda County Water District's Rubber Dam No. 3 is a representative example of a modern inflatable dam. The 13-foot-high, 375-foot-long dam was

Remediation of Nitrate Contamination–City of McFarland

The City of McFarland in Kern County has a population of about 7,650 people. McFarland Mutual Water Company supplies municipal water. The company depends on groundwater for raw water supply and has four active wells.

Elevated levels of nitrates in MMWC's water were detected in the early 1960s. Many wells sampled showed nitrate levels exceeding the drinking water standard. Studies identified fertilizer application on agricultural lands as a major contributor to nitrates in the groundwater. MMWC abandoned two of its wells due to nitrate contamination and provided treatment for two wells to reduce nitrate levels to meet drinking water standards. Two deeper replacement wells were constructed to extract groundwater unaffected by nitrate or pesticide contamination.

In 1978, the MMWC received an EPA grant to study groundwater treatment alternatives, leading to the 1983 construction of a 1 mgd ion-exchange treatment plant. A second 1 mgd ion-exchange treatment plant for another well was constructed in 1983. The two wells supply about 20 af annually of treated water to McFarland and adjoining rural areas within the MMWC service area.

The plants' designs rely heavily on technology and practices used in the water softening industry. Plant location was dictated by the existing wells and distribution systems. Because there was no centralized distribution system, the plants had to be designed to operate from a single well. Well pumps operate on a demand basis, so the plants had to be able to operate automatically. The system was designed to accept water directly from the well, treat for nitrate removal, and allow treated water to flow directly into the distribution system. The ability of the process to adapt to quick start-up and frequent on-off operation was an important consideration in choosing it over reverse osmosis and biological treatment methods.

Remediation of Volatile Organics Contamination–McClellan Air Force Base

In 1981, McClellan AFB initiated soil and groundwater investigation as part of a Department of Defense program to identify and evaluate suspected contamination at military installations nationwide. Groundwater contaminants identified included VOCs, SVOCs, petroleum hydrocarbons, and trace heavy metals. Subsequent investigations revealed that contaminants had migrated off the base. At least one municipal well was abandoned because of contamination. In 1986 and 1987, 500 homes with private domestic wells to the west of the base were connected to the City of Sacramento's water system.

In 1987, groundwater extraction and on-site treatment began. The treatment involved an air stripper, with incineration and caustic scrubbing of the air stream, followed by carbon adsorption and biological treatment of the effluent. The treatment plant had a capacity of 1.44 mgd and discharged its treated water to Magpie Creek and to a wetland area under permits from the Central Valley RWQCB. Later, the biological treatment unit was removed when the concentration of ketones was low enough to be removed by the air stripper and carbon adsorption units.

In 1996, the air stripper and incinerator were replaced with a UV/ hydrogen peroxide system to remove volatile organics. The GAC is still in use. Operating and maintaining the new system is less expensive than the air-stripping and incinerating process, and the higher treatment efficiency reduces carbon use in the GAC units. Several more years of extraction and treatment of the groundwater will be required before the contaminated aquifer is restored to usable quality.

constructed in 1989 on Alameda Creek in the City of Fremont. The dam impounds a 154 af reservoir for direct groundwater recharge and diverts flows into adjacent spreading grounds in former aggregate pits. The air-inflated dam is bolted to a reinforced concrete slab that was constructed across the stream channel. To clear the leveed channel for flood flows, the dam is deflated by district personnel, or it automatically deflates slowly when overtopped by substantial flows. The dam is reinflated when stream flows subside to safe levels and any water-borne debris has passed the dam. These operations are much easier and safer than alternatives such as installing, tripping, and reinstalling hinged flashboards. A similar inflatable dam has been used in the Russian River at Mirabel since 1976, where water is diverted to percolation ponds.

The San Gabriel, Los Angeles, and Santa Ana River Basins also have similar devices. OCWD installed two large air inflatable rubber dams across the Santa Ana River (Imperial Highway Dam in 1992 and Five Coves

Remediation of Pesticide and Fertilizer Contamination–Occidental Chemical Manufacturing Facility

In the late 1970s, pesticide and fertilizer contamination was discovered in soil and groundwater at the Occidental Chemical Agricultural Products manufacturing facility near Lathrop. The primary contaminants found were dibromochloropropane, ethylene dibromide, and sulfolane. OxyChem removed or capped contaminated soil at the facility in 1981 and 1982. The groundwater remediation program began operation in 1982 and continues today. The original groundwater restoration system was designed to remove DBCP and EDB to 1 ppb. It consisted of five extraction wells, a 500 gpm treatment system, and two wells for deep injection of treated groundwater into an unusable confined aquifer. Sulfolane was not removed from the groundwater, but its injection to the aquifer was considered acceptable since the aquifer was designated unusable for domestic or agricultural purposes. SWRCB Resolution No. 88-63 in 1988, a 1989 revision of MCLs for DBCP and EDB, and a 1989 DHS maximum allowable level for sulfolane in municipal water resulted in more stringent treatment requirements. OxyChem made operational changes in the treatment system and added a biological treatment system in 1992 (microbial inoculation of the carbon treatment system) to remove sulfolane from the groundwater to comply with the new treatment standards of 0.2 ppb DBCP, 0.02 ppb EDB, and 57 ppb sulfolane. Two extraction wells were added, increasing treatment capacity to 600 gpm.

The groundwater restoration system was designed to treat the contaminated groundwater and to control the hydraulic gradient in order to prevent off-site migration of the contaminants. Several dozen monitoring wells were built to monitor the effectiveness of the system. Monitoring reports have shown reductions of contaminant concentrations and control of contaminant plume. However, it is anticipated that groundwater remediation will continue for many years.

Dam in 1993) to divert flows into groundwater recharge basins. The dams are deflated when flows exceed 1,000 cfs.

Other uses of inflatable dams have evolved. In 1988, PG&E replaced flashboards on its Pit No. 3 dam on the Pit River with 6-foot-high inflatable dams. USBR recently replaced two 18-foot-high by 100-foot-long drum gates on the crest of Friant Dam with Obermeyer gates. The gates are steel panels connected to the dam crest by hinges along their upstream edge, and are raised and lowered by air-inflated bladders. During the flood of January 1997, an inflatable rubberized berm was installed on the water side of the Sutter Bypass levee to provide the additional height needed to protect the levee from overtopping. Rubber berms of this type are used as cofferdams during construction projects in wet environments or as pollution containment devices.

Weather Modification

Since the early 1950s, California water users have practiced cloud seeding to augment precipitation, mostly along the western slopes of the Sierra Nevada and along the Coast Range. In 1996, there were 14 active cloud seeding programs operating in California. The goal of these programs is to increase water supply for hydroelectric power generation and for agricultural and municipal uses. Cloud seeding programs have potential legal and institutional issues associated with them, including claims from third parties who allege damages from flooding.

The principal elements of cloud seeding include selection of cloud masses, seeding materials, and methods to dispense the agents within the clouds. Several classes of seeding agents are available. Seeding agents are introduced into the clouds by either ground-based generators or aerial delivery systems.

Precipitation from clouds is a result of two different processes or mechanisms. The first is coalescence, whereby tiny cloud droplets collide to form larger droplets that eventually fall as rain. The coalescence process works at temperatures above freezing. The second mechanism requires ice particles and occurs at subfreezing temperatures. Many clouds contain supercooled water droplets, sometimes at temperatures far below freezing. Eventually the ice particles fall as snow (which will change to rain if the lower levels of the atmosphere are above freezing). Enhancing either of the two processes of precipitation formation can lead to more efficiency in producing rain or snow from a cloud. Some natural clouds appear to be deficient in ice forming nuclei; those clouds offer an opportunity to assist the rainmaking process.

Cloud Seeding Agents. Certain materials have

This inflatable dam is owned by Alameda County Water District.

been found effective in converting supercooled water droplets into ice crystals. Commonly used seeding agents for this purpose are silver iodide and dry ice. Some other chemicals also work, including some organic compounds. Hygroscopic materials such as salt, urea, and ammonium nitrate have been used in warmer clouds to assist the coalescence process.

Dry ice was frequently used in early cloud seeding programs in the United States in the 1950s and early 1960s. A switch to silver iodide occurred in the mid-1960s, probably because of more convenient storage and dispensing capabilities (dry ice applications are limited to airborne delivery systems). Dry ice has received increased attention in recent years due to its low cost and high effectiveness.

Silver iodide has been the preferred seeding agent in the majority of cloud seeding programs in the United States. Particles of silver iodide are usually produced through a combustion process followed by rapid quenching which forms trillions of effective freezing nuclei per gram of silver iodide consumed. Cloud seeding by silver iodide can be carried out using ground-based or aerial generators.

Liquid propane is a freezing agent much like dry ice. Liquid propane has the advantage of working at higher temperatures, up to a degree or two below freezing, whereas silver iodide is not very effective when temperatures are warmer than -5^0 C. Dispensing is limited to ground-based systems because it is a flammable substance. Liquid propane sprayed into the atmosphere chills the air to temperatures well below 0^0 C. As temperatures approach -40°C, water vapor in the air rapidly condenses into trillions of cloud droplets which immediately freeze and grow into tiny ice crystals. Propane is used operationally in clearing supercooled fog from airports in Alaska and the northern portion of the continental U.S.

Pseudomonas syringae, a bacterium thought to reduce frost damage in plants, has been shown to be an effective nucleating agent. Use of this bacterium as a seeding agent has been limited to producing snow in ski resorts, although there have been some experiments with aerial applications.

Cloud Seeding Delivery Systems. Commonly available aircraft can be modified to carry an assortment of cloud seeding devices. Silver iodide nuclei dispensers include pyrotechnic dispensers and models that burn a solution of silver iodide and acetone. In the burning process, a typical silver iodide-acetone solution is forced through the nozzle into a combustion chamber where it is ignited, and the silver iodide crystals formed through combustion are expelled into the atmosphere. Pyrotechnics are similar to ordinary highway flares. Pyrotechnic flares impregnated with silver iodide can be mounted on aircraft, burned, and dropped into the clouds. Dry ice is frequently dispensed through openings through the floor of aircraft modified for cloud seeding. Types of aircraft used in operational cloud seeding programs range from a single engine aircraft to larger twin engine aircraft.

The most common type of ground generator consists of a solution tank which holds the seeding agent. Other components include a means of pressurizing the solution chamber, dispensing nozzles, and a combustion chamber. Frequently, such systems employ a propane tank with a pressure reduction regulator to pressurize the solution tank, as well as to provide as a combustible material into which the silver iodide-acetone solution is sprayed. Other systems utilize nitrogen to pressurize the solution tank. Pyrotechnics are also used at surface sites. Ground generation systems have been developed which are operated manually or by remote control.

Effectiveness. Although precise evaluations of the amount of water produced are difficult and expensive to determine, estimates range from 2 to 15 percent increase in annual precipitation, depending on the number and type of storms seeded. In 1992, both the American Meteorological Society and the World Meteorological Organization issued policy statements cautiously supportive of the effectiveness of weather modification efforts under the proper circumstances.

Long-Term Weather Forecasting

California's experience with flood and drought cycles demonstrates that significant economic benefits would result from the development and application of successful long-term weather forecasting capabilities. With the ability to predict weather patterns in an accurate and timely manner, water resources managers could plan for and mitigate losses associated with floods and droughts.

During the 1980s, research on ocean and atmospheric interactions in the tropical Pacific Ocean produced new and significant insights into the predictability of the so-called El Niño Southern Oscillation cycle. New weather forecasting capabilities developed through research on ENSO suggest potential applications in addressing water resources management issues.

Climate researchers at Scripps Institution of Oceanography are engaged in several efforts to provide experimental climate forecasts up to twelve months in advance. One of these efforts is focused on the use of climate forecasts to improve California's use of its scarce water resources. Scripps is leading a team of University of California scientists to downscale global climate predictions to describe impacts on local water supplies. See Chapter 3 for a discussion on climate variability.

Environmental Water Use Technologies

Wetlands Management

Wetland plants have been found to remove selenium from water applied to them. University of California, Berkeley, researchers are experimenting in the Tulare Lake Drainage District with wetland plants irrigated with high-selenium drain water in flow-through cells. Careful management of such facilities to remove selenium while avoiding food chain concentrations may result in developing safe operating criteria for wetlands supplied with agricultural drainage water. This may provide another alternative for drainage water management. (Drainage water not used to support wetlands would still have to be disposed of by other means, such as evaporation ponds.)

Real-Time Water Quality Management

One of the actions identified in the 1995 SJRMP plan was establishing a real-time water quality monitoring network for the San Joaquin River, to support water management decisions. The monitoring network collects water quality and quantity data for input to a computer model that forecasts water flow and quality along the lower San Joaquin River.

A goal of the real-time monitoring network is to enable water managers to meet San Joaquin River water quality objectives more often and more efficiently. For example, information provided by the network can support decisions related to reservoir releases at New Melones.

A recently completed demonstration project added instrumentation sites, developed analytical tools to collect and process the data, and disseminated weekly forecasts of daily San Joaquin River flow and salinity at Vernalis. In 1997, CALFED approved Category III funding to implement a two year program to expand the monitoring network. The program is scheduled to begin in fall 1998.

Fish Screen Technologies

State of the Art. Fish screens on water supply diversions protect fish from potential entrainment losses. A properly designed fish screen, with appropriate sweeping velocities past the screen, allows diversions to occur (even when juvenile fish may be present) without causing unacceptable fish losses. Fishery and water interests have been working together for several years to improve existing screens and add them to older diversions that lack screens.

NMFS and DFG have mandates for the installation and operation of fish screens. If a new diversion is installed or significant changes are made to an existing intake, a new fish screen is usually required. DFG has established a prioritized list of diversions that should be screened based on potential fish losses. Protecting the most significant diversions first will help achieve fish protection goals with the available financial resources. Programs to financially assist diverters in the installation of such screens are available through the CVPIA's AFRP, CALFED's ecosystem restoration program, the Natural Resources Conservation Service, and provisions of Proposition 204.

Current fish screen technology reflects criteria established by NMFS and DFG. Physical screens, combined with low approach velocities and proper cleaning systems, can effectively protect fish greater than about 1 inch long. Conventional screens will not protect smaller or larval-sized fish which may be present at some sites for limited durations.

Smaller pumped diversions (slant or vertical pump installations on a river with flows less than 40 cfs) generally use bolt-on screens available from a variety of manufacturers. These screens are similar to those used to reduce debris in sprinkler irrigation systems. Depending on the site and the system, screens may be made of corrosion resistant woven wire, perforated plate, or wedge-wire material (well screen). These materials can be formed into cylindrical shapes or flat plate panels and designed into the intake system.

The number of sites with fish screens (or fish passage improvements) has increased with the availability of public funding assistance (Figure 5-1). For example, the Maxwell Irrigation District now operates a state-of-the-art positive barrier fish screen, one of the first of its kind installed on the Sacramento River. Completed in 1994, the new pumping plant and screen

In February 1998, two large cylindrical fish screens were installed at one of the largest Delta diversions on Sherman Island.

facility diverts approximately 80 cfs at a completed cost of nearly $1.6 million. The screens are intended to protect all fish, but primarily steelhead and winter-run chinook salmon. In 1994, Pelger Mutual Water Company completed construction of its new pumping station and positive barrier fish screen near Knights Landing on the Sacramento River. The facility includes pumps with a discharge capacity of 60 cfs and was completed for a total cost of $350,000.

Larger diversion sites are screened with low approach positive velocity barrier screens. These intake screens may include significant civil works and are often off the main river channels where they must provide fish handling and bypass systems. These facilities require more attention to hydraulic conditions than smaller intake screens.

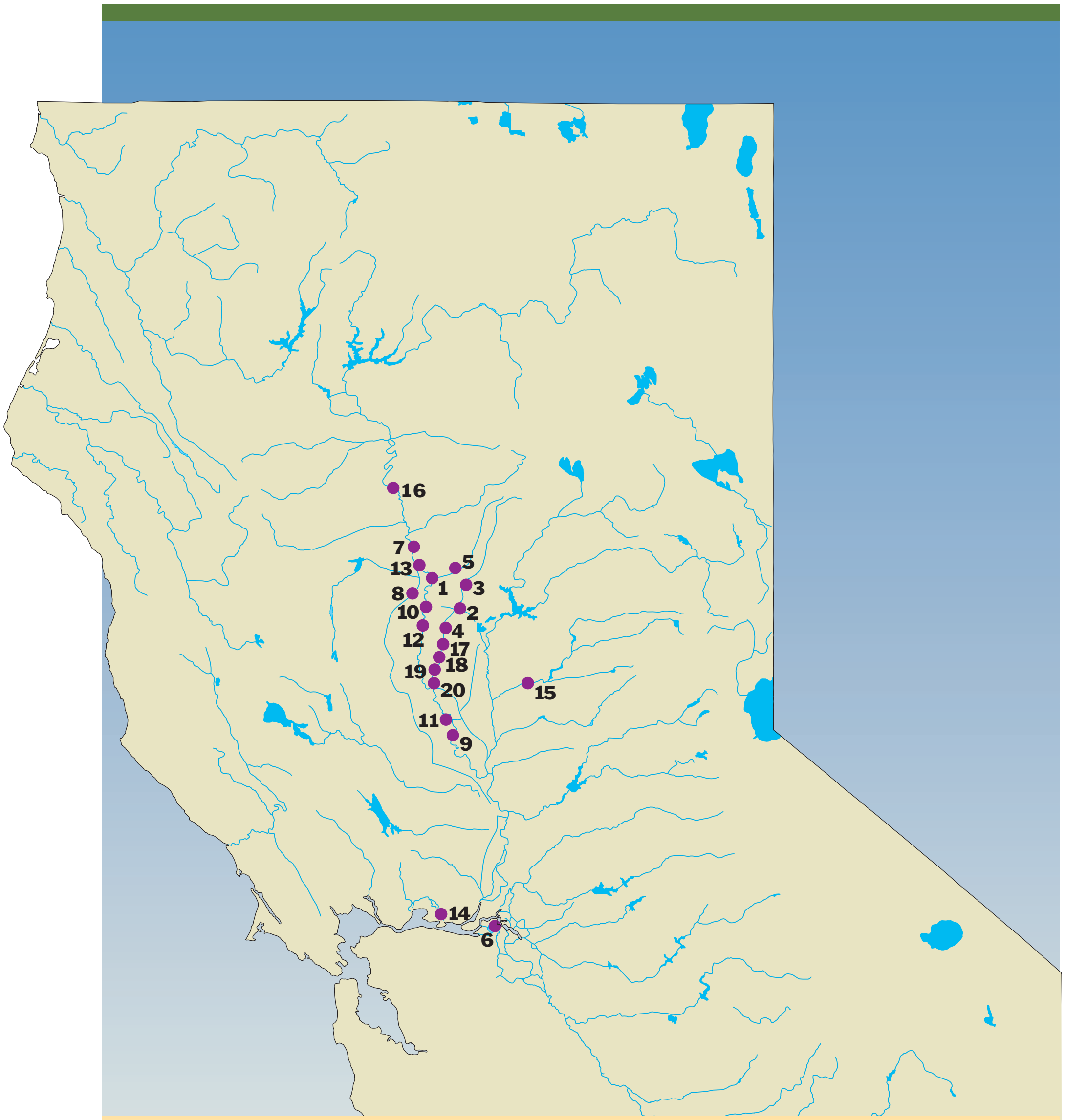
A newly constructed fish passage and screening facility on Butte Creek.

Several recently constructed facilities have been designed to current regulatory criteria for screening, including screens at the M&T Chico Ranch diversion on the Sacramento River, the Parrott-Phelan diversion on Butte Creek, and the Tehama-Colusa Canal. As part of its environmental restoration activities, M&T Chico Ranch relocated its screened pump station from the mouth of Big Chico Creek to the Sacramento River. This $5 million project provides water supply to over 8,000 acres of permanent wetlands and over 1,500 acres of seasonal wetlands, in addition to protecting habitat for migrating spring-run chinook salmon.

Several large facilities are nearing the final phases of design or construction. They include diversions on the Sacramento River at the Glenn-Colusa Irrigation District, Reclamation District 108 near Grimes, Reclamation District 1004 near Princeton, Princeton-Codora-Glenn Irrigation District and Provident Irrigation District consolidated diversion, Browns Valley Irrigation District diversion on the Yuba River, and others. Construction of GCID's Hamilton City Pumping Plant screen began in spring 1998. This $70 million project will minimize fish losses near the pumping plant and will maximize GCID's capability to divert its full irrigation supply. Reclamation District 108 began construction in 1997 on a new $10 million

FIGURE 5-1

Recent Structural Fishery Improvements



1 Sacramento River - M&T Chico Ranch, 1997
2 Butte Creek - Adams Dam, 1998
3 Butte Creek - Durham Mutual Dam, 1998
4 Butte Creek - Gorrill Dam, 1998
5 Butte Creek - Parrott - Phelan, 1996
6 Rock Slough - Contra Costa Canal, 1998
7 Sacramento River - Glenn-Colusa ID, 1998
8 Sacramento River - Maxwell ID, 1994
9 Sacramento River - Pelger MWC, 1994
10 Sacramento River - Princeton - Codora - Glenn ID/Provident ID, 1998
11 Sacramento River - RD 108, 1998
12 Sacramento River - RD 1004, 1998
13 Sacramento River - Wilson Ranch, 1995
14 Suisun Marsh - Five Projects, 1996-1997
15 Yuba River - Browns Valley ID, 1998
16 Tehama - Colusa Canal, 1990
17 Butte Creek - Western Canal WD Dams, 1998
18 Butte Creek - Point Four Diversion Dam, 1993
19 Butte Creek - McGowan Dam, 1998
20 Butte Creek - McPherrin Dam, 1998

fish screen. The project, located at the district's Wilkins Slough diversion, will protect migrating winter-run chinook salmon and other fish. The district anticipates completing the project by the 1999 irrigation season. Reclamation District 1004 began construction of its $8 million fish screen in 1998. The project includes relocation of the Princeton Pumping Plant and conveyance facilities, in addition to a positive barrier fish screen. In 1998, the Princeton-Codora-Glenn and Provident irrigation districts are expected to complete construction of an $11 million fish screen and pump consolidation project. The 600 cfs project eliminates three unscreened diversions.

Current Research. There is significant research and experience in fish screen technology. The technology has responded to a number of factors including ESA requirements in the Northwest and in California for the protection of salmonids, FERC relicensing requirements, and the heightened awareness of fish losses at diversions.

Research can be broken down into two categories: positive barrier technologies and behavioral barrier technologies. Although physical screens are considered state of the art, and are acceptable to the resource agencies, behavioral barriers have been demonstrated to deter fish from being diverted at some sites and may offer enhanced fish protection at even physically screened sites.

This circular flume, called the fish treadmill, simulates the hydraulic conditions that fish may encounter in the Delta. DWR's three year treadmill study began in 1997.

Several significant applied research projects are under way on positive barrier technologies. A research pumping plant has been constructed at the USBR's Red Bluff Diversion Dam to divert Sacramento River water into the Tehama-Colusa Canal. This facility (see photo, Chapter 2) was developed to provide water to the Tehama-Colusa Canal when the diversion dam gates are raised for fish passage. The research pumping plant is testing centrifugal and Archimedes screw pump technologies to evaluate their impacts on fish. The research plant and the biological evaluations of its effectiveness now being carried out are providing valuable data on the potential application of these technologies to other sites.

Since the early 1950s, fish screen design criteria have been developed for juvenile salmon and a few other anadromous species. Little is known about the screening requirements for resident Bay-Delta species (such as smelt) which require protection. Through a cooperative interagency program effort, a large circular screened testing flume has been constructed at University of California at Davis to investigate fish performance and behaviors under various hydraulic conditions. This research will improve understanding of the needs of fish and help design more effective screens.

Screen cleaning and proper operation and maintenance are essential for the reliability of diversion and fish protection. In the last 10 years, cleaning technologies have advanced in response to possible zebra mussel invasions and clogging from aquatic weeds. Combinations of hydraulic and air backwash systems, improved horizontal and vertical brush cleaners, and automated controls have proven effective. Screen materials and coatings have also been developed to prevent biofouling. Some investigations under way include USBR's Tracy Pumping Plant Fish Facility Improvement Program, Contra Costa Water District's new Los Vaqueros and proposed Rock Slough fish screens, and an investigation of air cleaning systems by USBR.

Higher velocity fish screens, which reduce exposure to the screen surface, are being studied. These systems are potentially less expensive because of the reduced screen area required. Modular systems are being developed for wider application. Advances in

Behavioral Barrier Demonstration Projects

Several behavioral barrier demonstration projects have been evaluated in the Central Valley.

Georgiana Slough Acoustic Barrier

Juvenile salmon survival has been shown to improve significantly if salmon are allowed to remain in the Sacramento River rather than being drawn into the central Delta via Georgiana Slough. Physical barriers and screens have been considered at this site, but are not feasible because of hydraulic conditions, water quality, recreational uses, and adult fish migration issues. A behavioral system is being studied which would improve fish survival by guiding them away from the hydraulic influence of Georgiana Slough. Twenty-one underwater acoustic speakers were installed at the Sacramento River's junction with the Slough below the town of Walnut Grove. Studies in 1993, 1994, and 1996 showed improved guidance during low flows, but mixed results at higher flow conditions. Results have been encouraging enough to continue investigations at this site under low flow conditions. Adverse effects of acoustic system operation have not been observed.

Reclamation District 108 Acoustic and Electrical Barrier

At this major Sacramento River diversion (700 cfs diversion capacity) near Grimes, acoustic and electrical barriers were tested to see if these technologies could reduce fish losses. Tests were conducted at the site from 1993 until 1996 with mixed results. The acoustic system was suspended from the surface and operated on an on/off cycle to test its effectiveness. The electrical array was mounted to an underwater louver array and was similarly evaluated. Since neither system achieved the required reduction in fish entrainment, RD 108 is constructing a positive barrier fish screen.

Reclamation District 1004 Acoustic Barrier

A similar acoustic barrier was installed at RD 1004's diversion on the Sacramento River near the town of Princeton. From 1994 to 1995, the system was evaluated and found to have marginal benefits. RD 1004 is installing a 360 cfs positive barrier fish screen at its diversion site.

Behavioral Research at Other Sites

The use of low frequency "infrasound" systems and the use of lighting systems (strobe lights) is under investigation at several sites outside of California. Many of these systems are being tested and used with other screening technologies to attempt to improve their effectiveness in difficult hydraulic environments.

automation and control systems are being used to regulate screens' hydraulics and operations and provide better fish protection and diversion reliability.

Technological advances have renewed interest in acoustic and electrical fish guidance systems. In the past, these systems have had limited success affecting fish behavior. Some guidance and protection had been observed, but the systems could not achieve the level of protection desired by State and federal resource agencies. Fish responses to behavioral technologies are variable since they may respond to other environmental stimuli, including hydraulic conditions, temperature, predator avoidance, and lighting conditions. Behavioral barriers are attractive in some cases because physical barriers may not be viable or cost-effective.

Temperature Control Technology

Temperature control technology is used to manage temperature of reservoir releases to improve conditions for downstream fisheries. During summer months, reservoir temperature gradients result in warmer water near the surface of a reservoir, with cooler water remaining near the bottom. Two types of temperature control devices are currently being used in Northern California reservoirs: variable-level outlets that permit temperature selective releases, such as USBR's Shasta Dam TCD; and temperature control curtains, such as those at Whiskeytown and Lewiston Reservoirs.

Temperature Control Devices. Some dams, such as the Department's Oroville Dam, were constructed with temperature-selective reservoir release capability. Retrofits to reservoir outlets can be constructed for those that were not, such as USBR's Shasta Dam. USBR completed the Shasta Dam TCD in May 1997, and is now fixing leakage problems that affect operation of the device. The structural steel shutter device is 250 feet wide by 300 feet high and encloses all five penstock intakes on the dam. The shutters allow for selective withdrawal of water, depending on downstream temperature needs. Prior to installation of the structure, USBR had to bypass Shasta powerplant to provide water of adequate temperature. Installation of the TCD will provide USBR with the flexibility to provide optimal water temperature downstream for the salmon fishery, and allow for hydropower generation.

Temperature Control Curtains. Curtains can control water withdrawal at intake or outlet structures to provide desired temperatures for salmonids and other aquatic species, allowing water to be conserved for other uses. Four temperature control curtains have been installed by USBR, two in Lewiston Reservoir (in 1992), and two in Whiskeytown Reservoir (in 1993). These curtains are constructed of Hypalon, a rubberized nylon fabric. They are supported in the water column by steel tank floats and anchored to stay in place.

At Lewiston Reservoir, an 830-foot-long, 35-foot deep curtain is suspended from flotation tanks and secured by a cable and anchor system. This curtain was designed to block warm surface water from the Clear Creek Tunnel intake. As a result, cold water from the bottom of the reservoir is diverted to Whiskeytown Reservoir. A second curtain was installed around the Lewiston Fish Hatchery intake structure to allow warmer or colder water, depending on the season, to be taken into the hatchery. The curtain, 300 feet long by 45 feet deep, was designed to either skim warmer water or underdraw cooler water, depending on whether the curtain was in a sunken or floating position.

Ideally, cold water diverted from Lewiston should be routed through Whiskeytown's hypolimnion (deep, cold water layer) into the Spring Creek Conduit intake. To accomplish this, two curtains were installed: a tailrace curtain downstream at Carr Powerplant, and an intake curtain surrounding the Spring Creek Conduit intake. The tailrace curtain (600 feet long and 40 feet deep) was installed to force cold water from Carr Powerplant into Whiskeytown's hypolimnion with a limited amount of mixing with the epilimnion (warm surface water). This curtain restrains warm surface water from moving upstream toward Carr Powerplant. With the tailrace curtain in place, mixing is reduced where the density current plunges into the hypolimnion upstream of the tailrace curtain. The second curtain (a 2,400-foot long, 100-foot deep, surface-suspended curtain) surrounds the Spring Creek Conduit intake. This curtain, like the Lewiston curtain, was designed to retain warm surface water while allowing only cold water withdrawal.

The temperature curtains at Lewiston and Whiskeytown Reservoirs reduce the temperature of Trinity River diversions to the Sacramento River by as much as 5^0 F. According to USBR, this decrease is significant, making the temperature curtains a successful tool for conserving reservoir releases.

The smaller temperature control curtains generally cost about $1,000 per foot. The large curtain at Whiskeytown Reservoir cost about $1.8 million. The expected duration of use is about 10 years before replacement may be required. To date, none of the four curtains in place at these two reservoirs has needed major repairs.

A number of studies are ongoing to better refine the curtains' use for temperature control, and to ensure that no adverse impacts result to biological resources in the reservoirs where they are installed.