California Water: Looking to the Future

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FOREWORD

In general, California has abundant water resources, but they do not occur where people live and work, nor does precipitation occur when water is needed. To deal with these basic disparities, water agencies have built the most extensive "plumbing system" in the world. Local, regional, state, and federal agencies have constructed reservoirs and aqueducts throughout the State.

None of the water projects was constructed easily or without controversy. From one perspective, the history of California is the history of arguing about water. More and more, however, the debates are changing from competition among water users to broader discussions of public concerns and preservation of common interests.

Back in 1957, the Department of Water Resources published *The California Water Plan* (Bulletin 3). That report set forth an "ultimate" plan of potential water development, essentially demonstrating that the State's water resources are adequate to meet its "ultimate" needs. Bulletin 3 was followed by the Bulletin 160 series, published four times between 1966 and 1984 to update various elements of California's statewide water planning. These four technical documents examined then-current California water in considerable detail, outlining the Department's expectations of water supplies and water demand in coming decades.

The present report differs significantly in approach from its predecessors. Taking a broad view of water events and issues in California, Bulletin 160-87 examines current water use and supply and considers at length how California can continue to meet the water needs of a continually growing population. The report also discusses several leading water management concerns, such as the quality of water supplies, the status of the Sacramento-San Joaquin Delta, and evolving water policies. Overall, Bulletin 160-87 sets forth a wide range of information and views that we hope will aid water managers, elected officials, and the public.

One final, cautious thought about the nature of planning reports is in order. A comment attributed to baseball's Casey Stengel is applicable to the projections herein: "Making predictions is very difficult, especially about the future."

David N. Kennedy
Director of Water Resources

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OVERVIEW

There is probably no such thing as a "simple" water problem in California. Practically every individual issue involves conflicting facts and viewpoints. Nevertheless, at the risk of oversimplification, the following observations summarize California's water resources picture in 1987.

In roughly three out of four years, California's *natural* water resources, including rights to the Colorado River, are sufficient to meet all its water needs for the foreseeable future. Surface reservoirs and ground water basins provide seasonal regulation from wet months to dry months.

In dry years, Californians must withdraw water stored in reservoirs and ground water basins during normal and wet years, and they must practice more than usual conservation. However, with proper development and management, water rationing should rarely be necessary.

There is every indication that California's population will continue to grow at substantial rates for the next few decades. In 1985, 26.1 million people were living in the State. By 2010, according to projections, this figure will have reached 36.3 million. Even an increase of this magnitude, however, is much lower than long-range forecasts made in the mid-1960s.

Meeting the water needs of a growing population will involve a diverse range of water management approaches. Conventional reservoir development becomes more costly each year, and emphasis is now shifting to water conservation, water salvage, conjunctive use of surface and ground water, water banking, water transfers, water sharing, and waste water reclamation.

The aqueducts and reservoirs of the State Water Project (SWP) and the Central Valley Project (CVP) now form an interconnected system that meets *supplemental* water needs throughout most of the State, reaching more than 75 percent of the State's population. Although local and regional agencies have built some of the State's major aqueducts, future needs for supplemental water beyond the capability of local resources will be met mostly through connections to the SWP–CVP system.

Very few large reservoir sites are still available for development. One of the most promising remaining sites is Los Banos Grandes Reservoir, an offstream storage project on the western side of the San Joaquin Valley near San Luis Reservoir. Another major project now moving into development is the Kern Water Bank, a potentially very large ground water storage facility in Kern County.

In the Sacramento–San Joaquin Delta, many of the present-day problems associated with water transfers can be corrected with step-by-step improvements in existing channels, together with programs to strengthen Delta levees and restore Delta fisheries. Federal regulatory programs

The Klamath River drains much of wet and mountainous northwestern California, where rainfall in some places can average close to 200 inches a year.

administered by the U.S. Army Corps of Engineers, which govern activities in wetlands and navigable waterways, will play a large role in determining which Delta improvements are undertaken.

Several large water projects studied intensively in the 1960s and 1970s have been deferred indefinitely. These include the Enlarged Shasta Reservoir, the Glenn Reservoir, and the Marysville Reservoir. These projects are simply too expensive for agricultural water users under any foreseeable conditions. Nevertheless, the State should reassess these projects from time to time and keep its long-range options open.

Some foothill, mountain, and other rural communities not served by the SWP or CVP have reached the limits of their developed supplies and are seeking to add to their water supply systems. However, few affordable projects are available in these areas, and inability to finance additional facilities can greatly handicap small communities. Because storage in mountain and foothill ground water basins tends to be very limited, serious shortages can develop in one- or two-year dry periods.

California's substantial ground water resources will more and more be used to augment available surface supplies during extended, multiyear droughts. Through exchange agreements, large ground water basins can help meet both drought and short-term needs of most areas served by major aqueduct systems. To maintain long-term viability, arrangements should be made to replace the water in wetter years, thereby reducing or eliminating ground water overdraft.

Approximately 2 million acre-feet of present statewide water use is being met from long-term ground water overdraft. This is a reduction of 600,000 acre-feet from the late 1960s. Some 1.3 million acre-feet of overdraft is in the San Joaquin Valley, and the remainder occurs in various regions of the State. Most of the water associated with overdraft is used for agriculture. Some of this overdraft will eventually be offset by imports of excess water from the Delta. A portion of the overdraft cannot economically be replaced by imported water and will simply continue as one-time water mining until pumping costs become excessive.

Recent changes in agricultural economics have caused a leveling-off in irrigation water use for the first time in more than 50 years. Although the future for agriculture is difficult to assess, it seems unlikely that agricultural irrigation will expand much beyond the recent 9.7-million-acre peak level of use. Earlier projections assumed a future peak of 10.2 to 10.5 million acres. Since irrigated agriculture uses about 80 percent of the State's developed water, a lesser future need than was projected in the past would have a marked impact on the State's overall water picture and would make control of overdraft more manageable.

A number of factors are causing irrigation efficiency to increase throughout the State. These include higher water costs, higher irrigation labor costs, drainage problems, and competition among farmers. Since a great deal of the "extra" water presently used for irrigation is reused downstream, greater efficiency does not automatically make the water supply go farther. The two principal areas in which increased efficiency will have statewide benefits are the Imperial Valley and western San Joaquin Valley.

In the last few years, long-simmering agricultural drainage problems have come to the forefront of water management issues, particularly on the western side of the San Joaquin Valley. Plans to achieve salt balance in the soil by exporting drainage to the Delta have been shelved because of concerns over elements in the drain water that are toxic to fish and wildlife. Extensive investigations are under way to cope with drainage problems. It is clear that an important step in reducing drainage impacts will be improved irrigation efficiency.

Water quality protection programs are in a state of flux, shifting from traditional concerns with prevention of biological pollution to heightened concern about contamination with toxic substances. New monitoring techniques are revealing that some of the State's water resources are contaminated with very small but possibly significant concentrations of both natural and man-made toxic substances. The ability to measure small concentrations has outstripped our understanding of the significance of these concentrations. Recent passage of Proposition 65 will, it is hoped, provide an impetus for the research necessary to resolve these issues. Federal, State and local agencies are continuing programs to clean up existing sites and reduce such contamination in the future.

As population and water use increase, more pressure is placed on fish and wildlife resources and scenic values. More water is now being allocated for fish and wildlife than was considered necessary in earlier years. Proposals for such increased requirements must be evaluated on a case–by–case basis to determine their impacts and overall reasonableness. A number of new water allocations have been successfully negotiated between water interests and those representing fish and wildlife interests.

California's water policies are evolving year by year as new statutes, court decisions, and agreements become effective. Potentially, one of the most far–reaching policies will involve implementation of the Public Trust Doctrine, which provides that water rights decisions made years ago can be revised by regulatory bodies and the courts, in light of new conditions.

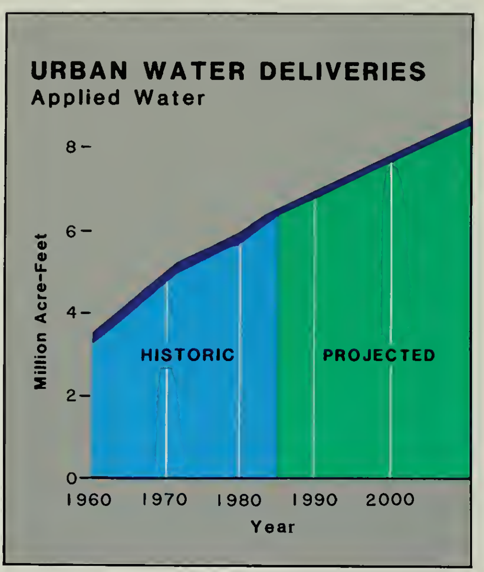
WATER USE IN CALIFORNIA

California's developed water supply -- currently about 32 million acre-feet per year -- is used to irrigate crops, meet household needs, maintain landscapes, support wildlife, satisfy manufacturers' cooling and processing needs, and control salt-water intrusion. In addition, this supply supports instream uses such as generating electricity, maintaining streamflows for fisheries, feeding lakes and streams for recreation, and supporting navigable waterways for shipping. Of the total amount of water used by the agricultural and urban sectors, 83 percent goes to agriculture and 17 percent to urban use.

Although substantial, the amount of water needed to satisfy each of these uses is significantly offset by widespread reuse involving stream rediversions and ground water pumping. In 1980, for example, total agricultural and urban applied water use in the Sacramento River basin was about 10.2 million acre-feet. Yet, because the basin draws part of its supply from surface water returned to streams by other users, and part from ground water supplies percolated from irrigated fields, the basic water supply required that year was only 7.4 million acre-feet, with 0.7 million acre-feet of the applied water flowing into the Delta. Furthermore, water used in the basin that flowed back to the Sacramento River and into the Delta helped maintain flows that supported fish and pushed back salt water entering from the Pacific Ocean through San Francisco Bay.

Urban Water Use

As population increases, so does urban water use. Although California's communities have instituted effective water conservation programs -- and are expected to continue refining and expanding them -- the magnitude of the State's projected urban growth will continue to increase the need for additional water supplies. California's population is projected to increase about 39 percent by 2010; its urban applied water demand is expected to rise by 32 percent in that same span of time.



The State's Population -- 1980, 1985, and 2010

As the nation's most populous state, California added 2.4 million people between 1980 and 1985, a 10-percent increase. This gain represented 22 percent of all U.S. growth in that period. Natural

California continues to grow. Our 1985 population of 26.1 million is projected to reach 36.3 million by 2010, a 39-percent increase in 25 years.

increase (births minus deaths) accounted for 1,143,000 more people, while net migration (in–migration minus out–migration) accounted for 1,264,000 more. Average increase per year over the five years was 481,000, or 2 percent.

Two–thirds of this growth has taken place in ten counties, largely those along southern coastal California. The South Coast region grew by the greatest number of people, 1.25 million, while the Colorado River region experienced the greatest rate of growth, 19 percent.

California's biggest one–year increase since World War II occurred between July 1985 and July 1986, when 623,000 people were added to the State's population. Natural increase accounted for 267,000, the most in the State's 137–year history. Net migration accounted for another 356,000 people, the largest one–year migratory growth since the mid–1950s.

Between 1985 and 2010, California's population is projected to increase by 10.2 million people. That will bring the State's total to 36.3 million (2 million more than was projected just four years ago in Bulletin 160–83). The South Coast region, with a projected increase of 5 million people, is expected to gain the most, followed by the Central Valley (Sacramento and San Joaquin valleys combined) with a total increase of 2.8 million. The big jump in Central Valley population is expected to result from (1) continuing expansion, dispersion, and diversification of industry; (2) increasing appeal of affordable Central Valley housing; and (3) growing public acceptance of long commutes to the San Francisco Bay area over Altamont Pass and other routes from San Joaquin and Stanislaus counties.

California's Population--1980, 1985, and 2010

in millions

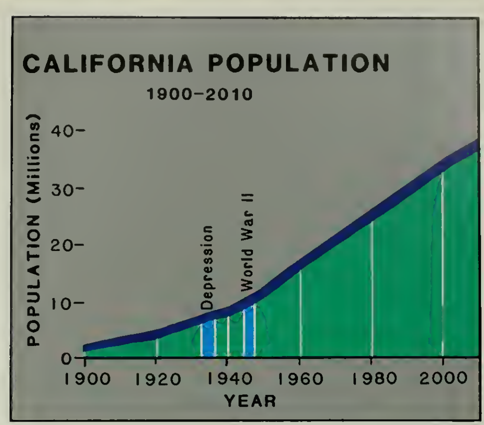
Region	1980	1985	2010	Increase 1980–1985		Increase 1985–2010	
San Francisco Bay and Central Coast	5.8	6.3	7.9	0.5	8%	1.6	26%
South Coast	12.9	14.1	19.1	1.2	10%	5.0	35%
Sacramento River	1.7	1.9	3.0	0.2	13%	1.1	57%
San Joaquin River and Tulare Lake	2.2	2.5	4.2	0.3	15%	1.7	67%
Colorado River	0.3	0.4	0.7	0.1	19%	0.3	91%
Remaining Regions	0.8	0.9	1.4	0.1	13%	0.5	57%
California	23.7	26.1	36.3	2.4	10%	10.2	39%

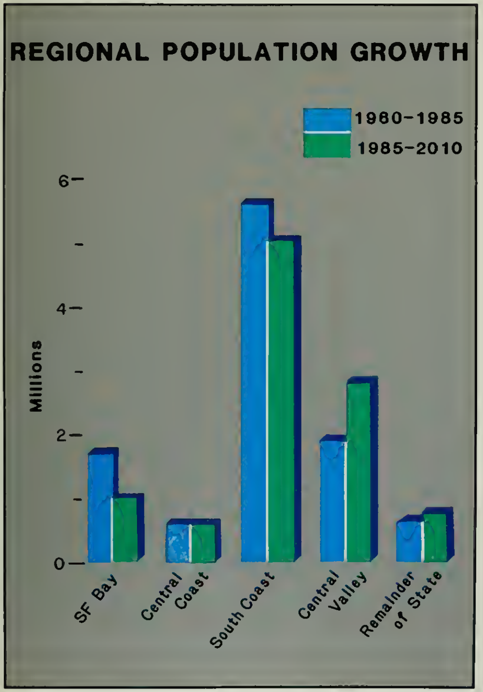
Source: California Department of Finance.

The Colorado River region, which stands out sharply from other regions with a 91-percent increase by 2010 (0.3 million people), is growing around Palm Springs and in the Coachella Valley, as retirees continue to convert second homes to permanent residences or move into new developments.

Population Highlights

Growth has been slower in the San Francisco Bay and Central Coast regions than elsewhere in the State. In San Mateo and Santa Clara counties, a softening in the market for the region's high technology products and a shortage of moderately priced housing have slowed the growth rate, and the decline in the lumber industry has slowed growth in Siskiyou, Humboldt, and Mendocino counties. In San Francisco County, 15 straight years of population decline was turned around in 1980 by a sizable increase, which has continued.



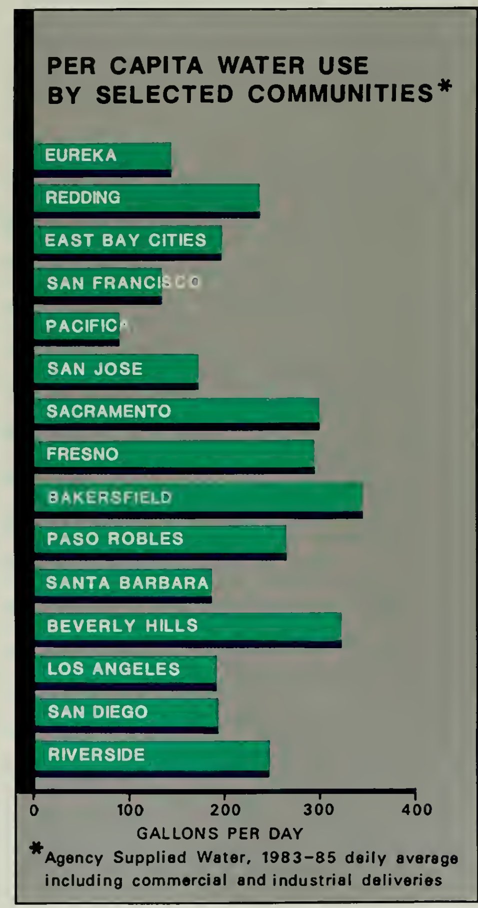


In the South Coast region, Los Angeles County has undergone accelerated growth from increased migration from Asia and Latin America, plus natural increase, which accounts for 60 percent of the gains. Growth in neighboring Orange County is attributable to expansion in the aerospace/electronics and service industries; however, high housing costs, diminishing availability of land, and congestion are contributing to a slowdown in population increase. The major growth areas are in San Bernardino and Riverside counties, which are situated within the commute zone for the metropolitan Los Angeles area. Kern County's turnaround from a declining 1960s population to growth in the 1980s has been achieved by the incentives of relatively low living costs and the area's proximity to the Los Angeles metropolitan market area.

Other Factors Affecting Urban Water Use

Several significant trends are developing in relation to urban per capita water use in California. Construction of more multiunit housing, the general reduction in residential lot sizes, the increasing number of residences built since enactment of legislation requiring low water-use fixtures, and the multitude of local agency water conservation programs in effect are all tending to reduce per capita water consumption. Other conservation trends include increased plantings of low water-using landscapes and more efficient watering. In addition, regulatory controls on waste water discharge are promoting increased recycling of industrial process water.

At the same time, however, offsetting factors are also at work. Most significantly, much of the new water use in the State's coastal regions (where 80 percent of California's population lives) is occurring in the warmer inland coastal areas where developable land is more abundant. In general, per capita water use is substantially higher in these inland areas than it is near the ocean. For example, the coastal city of Pacifica, located 8 miles south of San Francisco, is covered much of the time by a cooling fog layer and has a per capita water use average of 80 gallons a day. A few miles



City dwellers are becoming more water-conscious, and public agencies are helping by encouraging the use of drought-resistant landscaping and requiring low water-use plumbing fixtures.

away in San Bruno, on the eastern side of some rolling coastal hills, the climate is generally warmer and per capita water use is 120 gallons a day.

Across the bay from San Bruno, just beyond another range of hills, the weather is warmer still, and residents of Concord, Pleasant Hill, and Walnut Creek use an average of 155 gallons of water a day. Thus, even with effective water conservation measures, regional average per capita water use often rises because of the warm climate where most of the new large-scale development is taking place.

Agricultural Water Use

The amount of water used by agriculture is determined by the extent of irrigated acreage, the relative proportions of types of crops grown (the crop mix), and irrigation efficiency. Each of these factors has contributed significantly to the continually changing level of water use.

Historical Irrigated Agriculture

Just before World War II, irrigated acreage in California totaled about 5 million acres. Rapid growth occurred immediately after the war. By the late 1950s and on through the 1960s, the rate of increase slackened. Then, during the 1970s, the rate picked up again. There has been a leveling off, and even a slight decline, since 1980. The 1980s have experienced large fluctuations, with the 1985 acreage down slightly from the 1980 level.

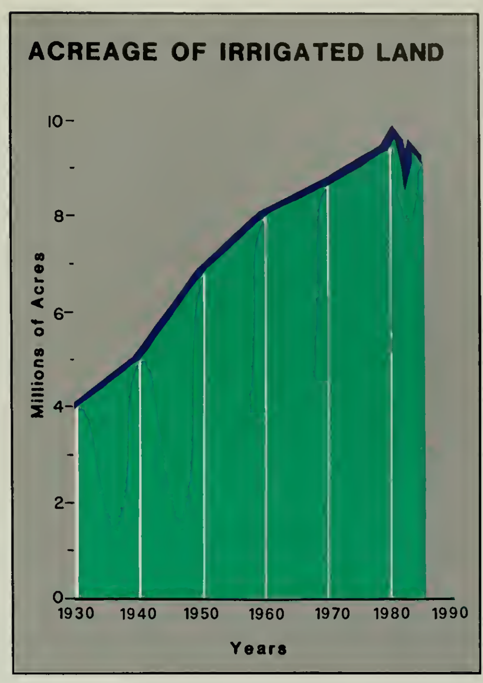
The figure, "Acreage of Irrigated Land," presents data for 1930, 1940, 1950, 1960, 1967, and 1972, and for each year from 1980 through 1985. Although a straight line connects data points before 1980, irrigated acreage fluctuated from year to year during this time, but not as drastically as during the 1980–1985 period, described below. Over the 50–year period from 1930 to 1980, the *average* increase in irrigated lands amounted to more than 100,000 acres a year.

These were the changes that occurred after 1980:

1981 -- 9.7 million acres under irrigation (highest total in California history).

1982 -- Total irrigated acreage dips 200,000 acres to 1980 level.

1983 -- Total irrigated acreage drops 900,000 acres, due to the impacts of farmland flooding and the federal Payment–In–Kind (PIK) program, under which farmers were compensated for not planting certain field crops.

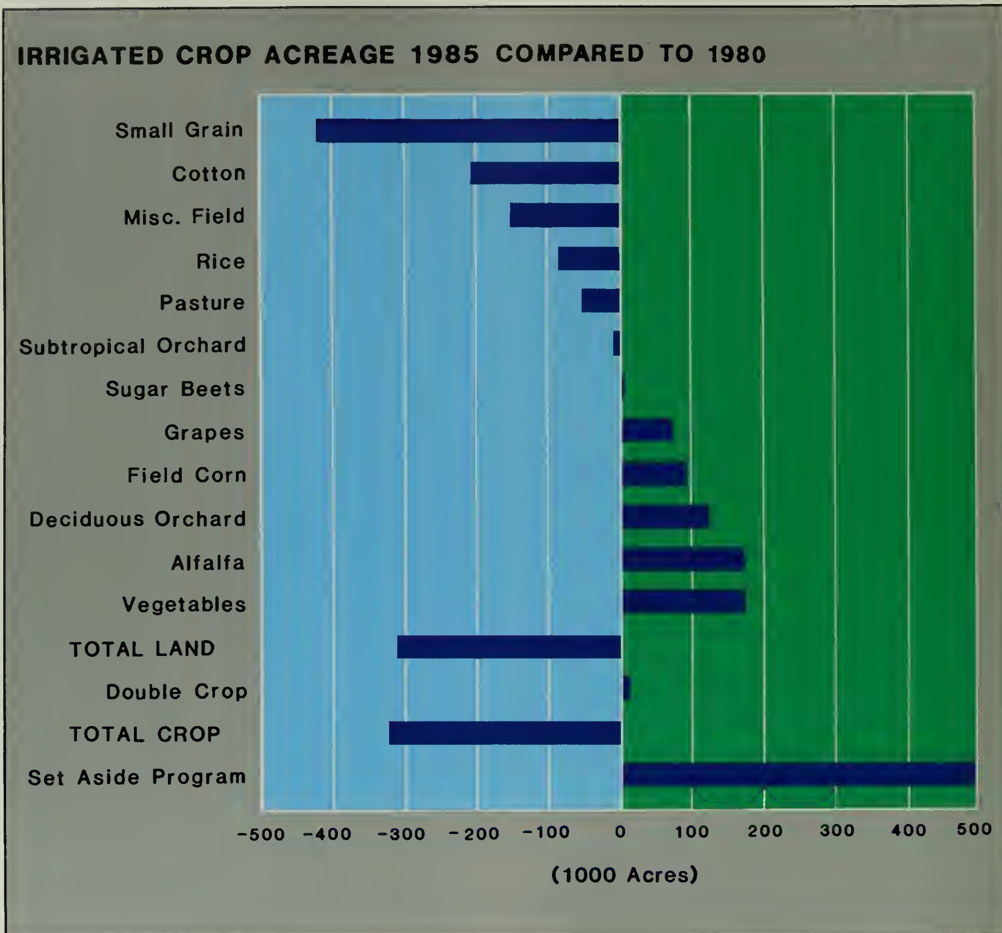


1984 -- Total irrigated acreage rises 800,000 acres; despite continuance of the PIK program, field crop acreage increased, as well as fruit, nut, and vegetable plantings.

1985 -- Acreage drops 200,000 acres to a total of 9.2 million acres. (The 1985 Farm Bill's set–aside program signed up 500,000 acres, but some of the land had already been out of production under previous programs, and fruit, nut, and vegetable acreage continued to increase.)

The mix of crops planted in California changes yearly. Large changes in acreages of annual crops such as dry beans, canning tomatoes, and rice can occur in response to fluctuating market conditions, adverse weather or flooded land at planting time, or federal crop control programs. Acreages of perennial crops also change frequently, though usually at a slower rate than those of annual crops. Even with perennials, however, in recent years large–scale changes have occurred over relatively short periods -- for example, the dramatic increase in wine grape plantings and the sharp reduction in peach tree acreage.

The Central Valley produces crops of the widest diversity and highest value of any comparable region in the world.



Future Agricultural Water Use

To make projections of future water use, the Department of Water Resources' planners usually project future statewide acreage figures for specific crops. Crop acreage projections are traditionally based on estimates for future markets for California-produced food and fiber -- markets influenced by such factors as State and national population figures, food consumption patterns, foreign trade, crop yields, federal farm policies, and California's ability to compete with other producers, both nationally and abroad. Although in the past it has been difficult to predict precisely how influential each of these factors would be, the experts have generally agreed on the direction of trends, and the resulting crop acreage projections have been accepted as reasonable. Today, however, economic uncertainties are more pronounced than in the past, and views differ widely over the magnitude and direction of the major forces that will shape crop markets in the coming decades.

In view of these uncertainties, our present estimate of future agricultural water use is based not on specific future crop acreages, but rather on the assumption that net water use by agriculture will continue at about the same level it reached in 1980 when 27 million acre-feet was used statewide. Some regional adjustments have been made, however, to reflect urban encroachment onto irrigated land in the South Coast region, and reductions in the use of developed water supplies are expected to occur because of increased agricultural water conservation. In many cases, new urban development will use about the same amount of water as the crops it replaces.

In all probability, the actual level of agricultural water use in California will be different in 2010 than it was in 1980. According to some estimates, the level might be higher. On the other hand, reaction to recent economic conditions leads other forecasters to predict decreased agricultural water use in 2010 in some regions of the State. Of particular concern to farmers are the extremely high costs of developing new surface water supplies. At any rate, it does not appear that the basic water management issues addressed in this report -- especially ground water overdrafting in the San Joaquin Valley -- would differ significantly within the range of reasonable estimates of agricultural water use.

Bulletin 160-83, the prior report in this series, shows a projection of 10.2 million irrigated acres in 2010, requiring 28.7 million acre-feet of water -- a projection that still stands within the range of possible outcomes. While the 1.7-million-acre-foot difference between the current projection for 2010 and the one shown in Bulletin 160-83 could alter the need to develop additional water supplies in California, it should be observed that nearly 75 percent of the increase in agricultural net water use forecast in Bulletin 160-83 was expected to be obtained by increasing ground water overdraft, mostly in the San Joaquin Valley. The difference between the two projections does not eliminate the need for new urban water supply initiatives.

Irrigated Land in San Joaquin Valley

The San Joaquin Valley is the largest single block of irrigated land in California. A total of about six million acres of irrigable land overlie usable ground water. In addition, there are about 300,000 acres of urban land.

About 4.7 million acres (80 percent of the irrigable land) are developed for irrigation. Most of the remaining acres either (1) have soil salinity problems that would require substantial amounts of chemical additions, extensive leaching, and, in most cases, installation of subsurface drain systems to make them productive, or (2) have hardpan soils with very low fertility that would require massive subsoil ripping efforts, as well as large applications of fertilizer.

Changing economic conditions have increased the costs of treatments necessary to bring these marginal lands to the point of economic crop production. Because of the high costs, it seems likely that very little development of additional irrigated land will take place in the near future. Also, with the projected population increase of about 70 percent by 2010, the resulting urban development would take significant amounts of currently irrigated land out of production, likely offsetting whatever new irrigated land development does occur.

Other Major Water Uses

Wildlife Refuges. The ten national wildlife refuges and four State wildlife management areas in the Central Valley, which provide a third of the State's wetland habitat for waterfowl, have been sustained for years by surplus surface water, ground water, and irrigation runoff from fields. As the State's demand for fresh water has increased, the quantity and quality of water available for these wildlife areas have been greatly diminished during years of below-normal rainfall. Thus, wildlife refuges need additional water supplies of suitable quality.

Recently, the U.S. Bureau of Reclamation, along with the Department of Water Resources, the U.S. Fish and Wildlife Service, the California Department of Fish and Game, and the California Waterfowl Association, began examining alternative sources of water for these refuges, as well as for waterfowl areas served by the Grasslands Water District. These areas are estimated to need a water supply of more than 500,000 acre-feet annually. At present, average annual water deliveries total about 380,000 acre-feet.

ACREAGES OF CALIFORNIA CROPS

Over 1,000,000	Alfalfa	Cotton	Irrigated pasture
500,000–1,000,000	Grapes	Wheat	
200,000–500,000	Almonds Barley	Corn, field Rice	Tomatoes, processing
100,000–200,000	English walnuts Lettuce	Oranges Sorghum	Sugar beets
50,000–100,000	Avocados Blackeye beans Broccoli	Cantaloupe Lemons Peaches	Potatoes Prunes Safflower
10,000–50,000	Apples Apricots Artichokes Asparagus Bell peppers Carrots Cauliflower Celery Cherries Corn, sweet Figs	Garlic Grapefruit Green beans Honeydew melons Kidney beans Lima beans, baby Lima beans, large Nectarines Oats Olives Onions	Pears Peas Pink beans Pistachios Plums Rice, wild Spinach Strawberries Sunflower Tomatoes, fresh market Watermelon
5,000–10,000	Cabbage Cucumbers	Garbanzo beans Jojoba Squash	Sweet potatoes Tangerines

Fewer Than 5,000 Acres

Aloe
Amaranth
Anise
Bananas
Basil
Bitter melons
Blackberries
Black walnuts
Blueberries
Bok choy
Boysenberries
Broad beans
Brussels sprouts
Cabbage, Chinese
Canary melons
Caraway
Cardoon
Carob
Casaba melons
Castor beans
Casuariana
Cattails
Celeriac
Chayotes
Cherimoyas
Chestnuts
Chicory
Chives
Choy sum
Cilantro
Citron melons
Clover
Collard greens
Corn, crazy
Crabapples
Crenshaw melons
Currants
Daikon
Dasheen
Dates
Dill
Eggplant
Endive
Escarole
Eucalyptus
Euphorbia
Fava beans
Feijoas
Fennel
Filberts
Flax
Fodder beet
Gherkin
Ginger
Grendelia
Guavas
Hops
Horseradish
Jerusalem artichokes
Kale
Kenaf
Kiwifruit
Kumquats
Lavender
Leeks
Lima beans, green
Limequats
Limes
Loganberries
Loquats
Lupine
Macadamia nuts
Mandarin oranges
Mangoes
Marjoram
Mint
Mushrooms
Mustard
Mustard (for seed)
Okra
Olallieberries
Paprika
Parsley
Parsnips
Passion fruit
Pe-tsai
Peanuts
Peas, Chinese
Peas, southern
Pecans
Peppers, chili
Persian melons
Persimmons
Pimientos
Pinto beans
Plumcots
Pomegranates
Popcorn
Prickly pears
Pumpkins
Quince
Radicchio
Radishes
Rapeseed
Rapine
Raspberries
Rhubarb
Rye
Sage
Salsify
Santa Claus melons
Savory
Sesame
Shallots
Small red beans
Small white beans
Snap beans
Soybeans
Sudan grass hay
Sweet sorghum
Swiss chard
Tangelos
Taro root
Tarragon
Thyme
Tomatillos
Tomatoes, cherry
Turnips
Vetch
Watercress

Natomas Central Mutual Water District operates this irrigation system on the Sacramento River just north of Sacramento. Water pumped from the river (1) is piped to an irrigation ditch leading to 4,000 acres of cropland. Excess water drained from fields returns by the North Drainage Canal to a sump (2). In summer, all this water is pumped (3) back to the ditch, supplemented and diluted with more water from the river, and reused. In winter, precipitation runoff from fields is collected and discharged to the river (4). This system, in use for at least 50 years, illustrates reuse systems widely employed in the Central Valley.

Outflow from the Sacramento-San Joaquin Delta. One of the major uses of Central Valley water supplies is to provide the fresh-water outflow needed to meet the Delta water quality standards set forth in State Water Resources Control Board's Decision 1485, the purposes of which are discussed in Chapter 7. On the average, 5 million acre-feet of water must flow out of the Delta each year to meet the current standards. This amount of water is not included under Net Water Use *(table on page 16)*. On an average annual basis, 13 million acre-feet of fresh water flows into San Francisco Bay. The actual amount varies from less than 4 million acre-feet in extremely dry years to more than 60 million acre-feet in the wettest years. Release of stored spring runoff from upstream reservoirs is necessary to meet the Delta outflow requirements in summer months of most years.

Hydroelectric Power Generation. In view of current economic conditions and electrical energy needs, there are few if any prospects for additional, major, single-purpose hydroelectric projects in California. In the early 1980s, however, a large number of applications were filed for permission to develop small hydropower generation facilities. The filings were prompted by passage of a federal law requiring electric utilities to purchase power from small energy producers at rates equal to the cost of the most expensive power the utilities produce or obtain from other sources.

Then, shortly afterward, oil prices dropped and interest in developing these small-hydro facilities waned. Because hydro plants do not consume water, they do not impinge on the total quantity of water available for other uses. Yet, their operation does affect the flows of rivers and streams, so proposals for new facilities receive close scrutiny in many quarters to determine potential impacts on downstream water users.

Other Energy Production: Powerplant Cooling and Oil Recovery. Statewide, the amount of fresh water used for powerplant cooling and oil recovery processes is estimated to be considerably less than 100,000 acre-feet per year. Although either of these two industrial activities may have significant water supply requirements at certain locations, neither is expected to be a major factor in future regional water management plans.

North Coast Wild and Scenic Rivers. Several North Coast rivers have been designated as wild and scenic to protect their natural free-flowing state. On the average, 17.8 million acre-feet of water from parts of the Klamath, Trinity, Eel, Smith, Van Duzen, Salmon, and Scott rivers are in this category. Flows of these designated rivers are not included under Net Water Use *(in the following table)*.

Other Natural Uses. The largest single use of water in California, amounting to some 60 percent of the total supply from precipitation, is for native vegetation and evaporation. About 114 million acre-feet a year is consumed by these uses.

With a linear-move irrigation system, a long line of low-pressure sprinklers is slowly and continuously moved the length of the field. Although they are expensive, these new systems offer good opportunities for relatively precise application of water to field and truck crops.

The Role of Improved Efficiency of Use in Reducing the Need for More Water

Irrigation efficiency is calculated as the percentage of applied water that evaporates from soil and plant surfaces and is transpired by a crop. In response to various economic constraints, California farmers are improving the effectiveness of water application each year by preparing fields more carefully, operating existing irrigation systems with increasing efficiency, improving irrigation scheduling, and adopting new methods of watering, such as drip irrigation, for some applications.

Efforts by the Department of Water Resources and other agencies to promote irrigation efficiency are described in Chapter 9. Irrigation efficiency is expected to increase in the future for the same reasons it has done so in the past: higher costs of crop production and continuing improvements in the design and operation of irrigation systems. In addition, growing concern over drainage needs and the use of agricultural chemicals will increase the attention given to improving irrigation efficiency.

Considering that much excess applied agricultural and urban water is reused, the extent to which water conservation can delay or reduce the need for additional water supplies depends primarily on how much it can reduce the volume of water currently flowing into the ocean and other salt sinks. If the amount of water lost to evapotranspiration were reduced, water supply needs would also decline, but evapotranspiration by plants cannot be reduced, as a rule, without lowering crop yields. Moreover, efforts to reduce evaporation from open water conveyance systems by converting ditches to pipelines and eliminating natural riparian vegetation (thus further reducing evapotranspiration) are often not feasible because of high costs or are not acceptable because these actions would destroy valuable wildlife habitat. These were the conclusions of a recent multiagency, multidisciplinary two-year study of irrigated agriculture. The Central Valley Water Use Study was sponsored by the University of California's Experiment Station and the Department of Water Resources. The findings were published in *Irrigation Water Use in the Central Valley of California* (1987).

Water is applied to crops in various ways, some old and some new. Improving irrigation techniques is a continuing process. For special applications, sprinkling systems are most efficient, and for others, drip irrigation works best.

Furrow irrigation is the most widely used system in California. Its efficiency depends on how it is designed and managed, as well as the type of soil in which it is operated.

Based on these results and other studies, the greatest savings in agricultural water in California would be achieved by improving irrigation efficiency on lands overlying shallow saline ground water in the San Joaquin Valley and by reducing the excess irrigation water that flows from the Imperial Valley to the Salton Sea. The possible use of water salvaged in the Imperial Valley is currently the subject of negotiations between the Imperial Irrigation District and The Metropolitan Water District of Southern California. Use of the salvaged water by MWD could result in reduced need for State Water Project supplies. For the San Joaquin Valley, it was assumed the savings would be put to use in the valley, in effect reducing ground water overdraft.

In the urban sector, the greatest amounts of water would be saved in the coastal metropolitan areas, wherever excess applied water flows into the ocean (including sewage outfall sites). Some lesser savings will likely occur in areas where conservation programs influence property owners to change landscaping vegetation to low water-use plant varieties.

Regional Use of California's Developed Water Supplies, 1980, 1985, and 2010

In 1,000s of acre-feet

APPLIED WATER

	Agricultural			Urban			Other			Totals		
Regions	1980	1985	2010	1980	1985	2010	1980	1985	2010	1980	1985	2010
San Francisco Bay and Central Coast	1,310	1,320	1,260	1,210	1,360	1,600	110	100	110	2,630	2,780	2,980
South Coast	990	900	650	2,780	3,120	4,020	30	20	30	3,800	4,040	4,700
Sacramento River	9,600	7,800	9,000	560	630	840	250	270	270	10,410	8,700	10,110
San Joaquin River and Tulare Lake	18,890	17,600	17,680	830	920	1,400	170	170	190	19,890	18,690	19,270
Colorado River	3,580	3,660	3,280	210	250	410	20	20	20	3,810	- 3,930	3,710
Remaining Regions	1,750	1,630	1,620	270	310	440	280	380	400	2,300	2,320	2,460
STATE TOTALS	36,120	32,910	33,490	5,860	6,590	8,710	860	960	1,020	42,840	40,460	43,220

APPLIED WATER is the quantity of water delivered to the intake to a city's water system or a farm headgate; water diverted from a stream or pumped from underground sources, as in self-developed supplies; and water supplied to a wetland for wildlife. Because of the large amount of reuse that occurs, this term overstates the supply of water needed for a large region.

NET WATER USE

	Agricultural			Urban			Other			Totals		
Regions	1980	1985	2010	1980	1985	2010	1980	1985	2010	1980	1985	2010
San Francisco Bay and Central Coast	1,020	1,010	980	1,160	1,310	1,530	130	130	130	2,310	2,450	2,640
South Coast	790	750	570	2,510	2,820	3,590	210	190	200	3,510	3,760	4,360
Sacramento River	6,900	6,710	6,880	460	500	680	270	270	270	7,630	7,480	7,830
San Joaquin River and Tulare Lake	13,880	13,650	13,860	490	530	760	340	370	390	14,710	14,550	15,010
Colorado River	3,400	3,480	3,120	140	170	270	560	380	300	4,110	4,030	3,690
Remaining Regions	1,350	1,350	1,340	220	260	360	320	340	390	1,890	1,950	2090
STATE TOTALS	27,340	26,950	26,750	4,980	5,590	7,190	1,830	1,680	1,680	34,150	34,220	35,620

NET WATER USE is computed by adding evapotranspiration (the amount of water taken up by plants, transpired by them, and evaporated from the soil), the losses from a water distribution system that cannot be recovered, and outflow leaving an area. This estimate is essential in determining whether an area needs more water.

Statewide Summary of Water Use

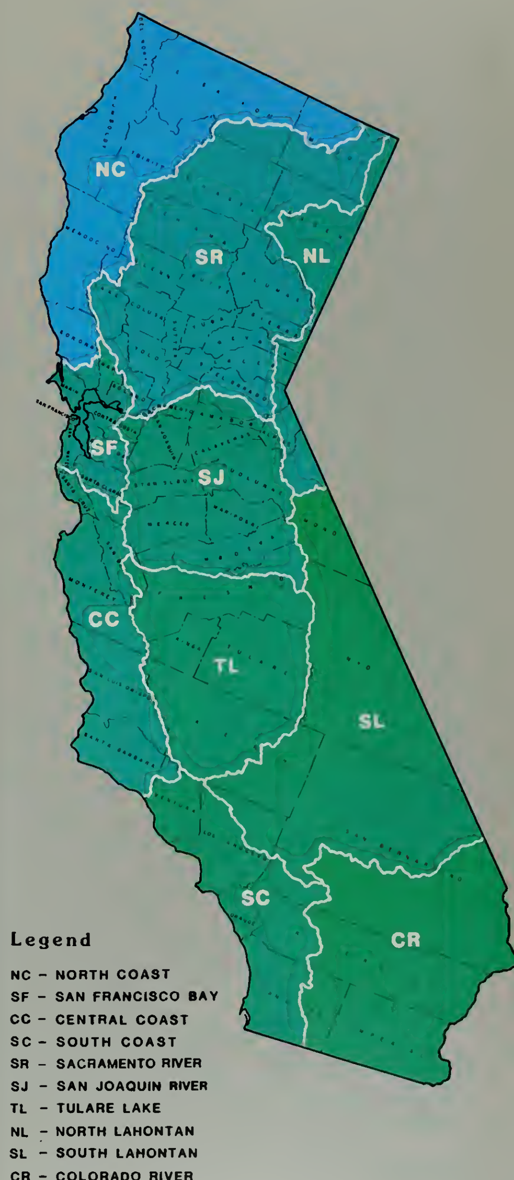
As shown in the tabulations of applied water and net water use in California for 1980, 1985, and 2010 *(opposite page)*, net water use is less than applied water because it takes into account the large amount of reuse that commonly occurs. As discussed previously, the basic assumption regarding agricultural net water use in 2010 is that it will be about the same as the 1980 level, reduced to account for urban encroachment onto irrigated land and the impacts of water conservation. These reductions amount to about 590,000 acre-feet between 1980 and 2010. Although the 1985 level of agricultural applied water use was significantly lower than in 1980, net water use by agriculture did not change nearly as much. This was due primarily to (1) the relatively large reduction in the acreage of field crops in 1985, some of which, such as rice, have significantly lower irrigation efficiencies than do other crops, and (2) the substantial reductions in water applied for rice production needed to reduce the quantity of certain chemicals in drain water flowing into the Sacramento River.

"Urban" net water use generally reflects population increases. As discussed in this chapter, however, water conservation, the location of new urban development, and the changing characteristics of urban communities also influence future water use. The increase in projected urban water use is substantial in all regions, totaling about 1.6 million acre-feet statewide between 1985 and 2010.

"Other" net water uses include water used in public wildlife management areas, at nonurban public parks, and for powerplant cooling and enhanced oil recovery. It also includes consumptive losses from water conveyance systems.

The Colorado River region shows a 340,000-acre-foot decrease in total net water use between 1985 and 2010, which is attributable to agricultural water conservation. All other regions show water use increases, led by the South Coast (600,000 acre-feet) and followed by the San Joaquin River and Tulare Lake (460,000 acre-feet), the Sacramento River (350,000 acre-feet), the San Francisco Bay and Central Coast (190,000 acre-feet), and the remainder of the State (140,000 acre-feet).

MAJOR HYDROLOGIC REGIONS



Comparison of 1983 and 1987 Projections

Projections contained in this edition of Bulletin 160 differ from those presented in Bulletin 160-83 in two essential ways.

- Agricultural net water use projections are now lower because, with the current great uncertainty regarding the future of the agricultural economy, no increase was projected above the level of water use attained in 1980.
- Population growth projections are now greater, reflecting the rapid rise in the number of people in California in the past five years.

The Agricultural Economy: Recent Problems and Prospects for the Future

Since the early 1980s, California has shared a depressed agricultural economy with the rest of the United States. Dramatic changes in the areas of financial management, international competition, and the relation of crop supply to demand have contributed to this economic downturn.

Credit is the lifeblood of agriculture. For years, bankers have loaned money to farmers who have used the money to buy equipment and to plant crops that, once sold, provided funds to repay the loans. Between 1974 and 1981, California farmland values rose at an inflation-adjusted annual rate of about 7 percent, and the outlook for agriculture was generally optimistic. Lenders, sharing this optimism, encouraged farmers to make capital investments, and some farmers went deeply into debt to purchase land, machinery, and other farm-related assets. Between 1975 and 1983, the ratio of U.S. farm debt to net income (income after costs) almost quadrupled.

This rosy picture began changing in 1980 when inflation-adjusted interest rates rose to five percent -- from a low of about one percent in the 1970s -- and farm income began to decline. Consequently, the value of farmland as a source of income and as a speculative investment was dramatically reduced, and the ensuing financial crisis resulted in the putting up for sale of farms that would not otherwise have been offered, pushing farm values even lower. In California these values were hit hardest in the San Joaquin Valley, where from 1983 through 1986 the inflation-adjusted value of field crop land fell 48 percent.

In 1981, foreign exports accounted for about one-fourth of California's gross farm income and 30 percent of its harvested acres. Four years later, exports dipped to one-fifth of the State's gross farm income and the harvested acreage figure dropped to 20 percent, primarily because of the federal government's crop support policy that set relatively high prices for U.S. wheat, rice, corn, and cotton. This policy had two adverse effects on agriculture: it allowed foreign competitors to gain a share of the world agricultural market at California's expense, and it gave some competitors an income cushion that many of them used to implement advanced farming methods and thus increase the volume of crops on the world market. The rise in the dollar's value against other currencies was another reason behind the decline of U.S. farm exports. As a result of the dollar's surge, our farm exports became more expensive than those of other producers. Foreign policies of many countries also influenced agricultural markets through trade barriers, such as quotas and tariffs.

Greater quantities of foreign agricultural products have entered U.S. domestic markets in recent years, encouraged by subsidized, low-cost foreign production, U.S. government-supported domestic pricing, and recent advances in transportation technology. From 1972 to 1982, worldwide farm output rose 25 percent, assisted by a 33-percent agricultural-production increase in some of the less-developed countries such as Thailand, India, Bangladesh, and China. Moreover, for the past several years, political forces have prompted many nations to strive for self-sufficiency in food production. Since storage facilities are often not available, excess crops are exported and frequently sold at prices that are lower than the costs of production, thus adding to the oversupply in the world's agricultural market.

At the same time, large foreign-debt repayment obligations and falling export revenues have made it impossible for some third world nations to buy as much California farm produce as they have in the past. To get by, these countries have exported more of their own farm products -- sometimes selling them at a loss to obtain the hard cash they need to pay the interest on their mounting foreign debts.

In general, the state of oversupply resulting from these debilities has forced crop prices down worldwide. Because these same factors have forced U.S. government-support prices down as well, even subsidized growers in this country have been adversely affected.

California Agriculture's Long-Term Outlook

In speculating about the future prospects of California agriculture, the key question is how well will California farmers be able to compete in the world market. In light of recent changes in market competition for State-grown crops, varying assumptions

As a consequence, this edition of Bulletin 160 projects that, compared to Bulletin 160-83 projections, annual net water use in 2010 for agriculture will be 2.0 million acre-feet less and for urban applications, 0.3 million acre-feet greater. The cumulative effect is a statewide net water projection of 1.7 million acre-feet less than that previously made.

If the revised projections hold true, their major impacts will be (1) less ground water overdraft than stated in earlier estimates and (2) greater future water needs in coastal urban areas.

can be made regarding the direction the agricultural market will take and the competition California growers will face. In fact, the range of possibilities is more diverse than at any time since this Bulletin 160 series began in 1966.

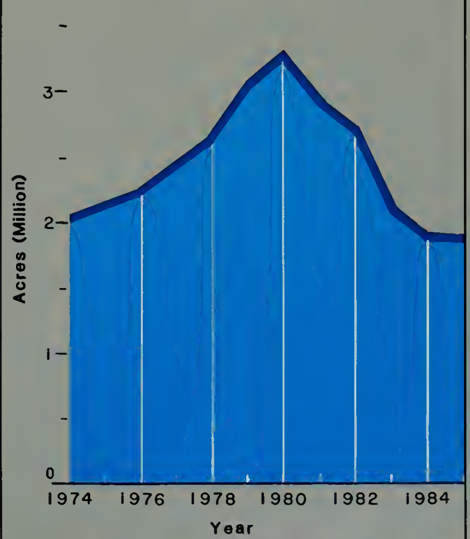
A crucial factor influencing this market competition is the unit cost of California production compared to like costs in other states and countries. To its advantage, California has ready access to technological improvements; it also has large farms and skilled managers who are capable of initiating complex and costly improvements relatively quickly. Moreover, California has climate and soils that are well suited to take maximum advantage of such improvements, and its excellent food processing and transportation industries also contribute to its competitive advantage.

Meeting this challenge will require California farmers to react quickly to take full advantage of all opportunities the market presents. Collecting and accurately analyzing market information will be critical to correct planning, processing, and marketing decisions. Furthermore, vertical integration -- the integrated management of a specific crop from farm production through marketing -- will become more important in the future. Taking these steps would enable California agricultural producers to effectively target products for foreign and domestic markets. Currently, more than three-fourths of California's farm exports go to Pacific Rim nations (Japan, South Korea, Canada, Hong Kong, Indonesia, and Taiwan). Aggressive marketing, combined with growing per capita income in these countries and California's strategic geographic location, may enhance the State's competitive marketing position. As with all international market forecasts, however, this outlook is sensitive to trade barriers, onerous tariffs, and restrictions that (in many cases) are the subjects of current international negotiations.

Future price-cost relationships, the value of the U.S. dollar, changes in farm productivity, government farm-subsidy programs, controls on the use of agricultural chemicals, soil drainage needs, and the availability of affordable water supplies are all factors that, alone or en masse, will significantly influence the extent of production and sales of specific commodities.

On other fronts, progress in removing some trade barriers, coupled with advances in communications, data processing, and transportation, have made international financial and commodity markets almost as accessible to U.S. producers as domestic markets. This wide-reaching development is both good and bad for California agriculture. While marketing opportunities for U.S. producers are greatly expanded, similar opportunities for foreign competitors are also enhanced. Furthermore, increased production potentials elsewhere in the world -- arising from government support of production through selective trade policies and subsidy programs -- suggest that the challenge of competing in the world trade market will increase in the years to come.

ACREAGE USED TO PRODUCE EXPORT CROPS

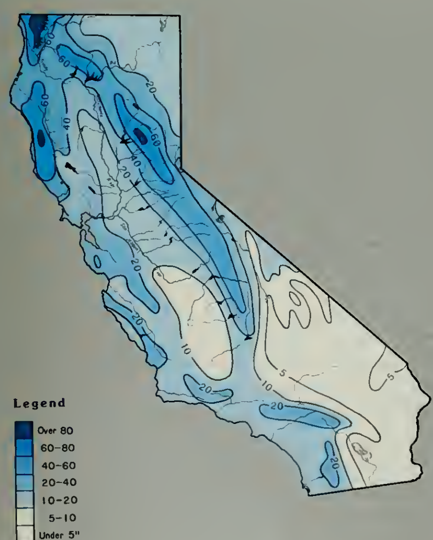


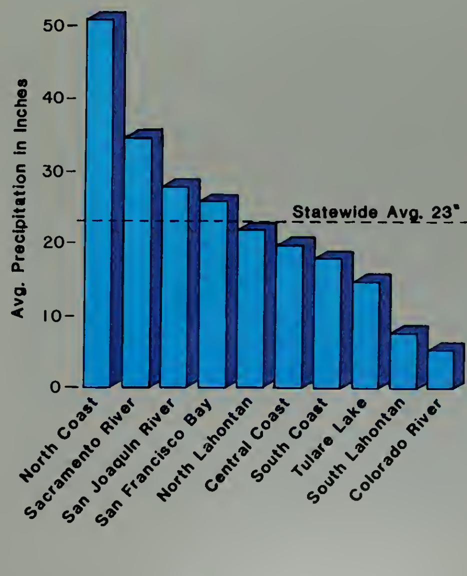
SURFACE WATER SUPPLIES

In the midst of California's many water debates, the question is often asked: "Does California have enough water?" The answer, in simple terms, is *yes*. Unlike its neighbor, Arizona, California has enough natural water resources in most years (including its Colorado River allotment) to meet its foreseeable needs. But this important fact must be qualified by observing that, because of the geographic distribution of the State's water resources, Californians have found it necessary to build vast water storage and conveyance systems. The history of California is intertwined with the development of more than 1,300 reservoirs and thousands of miles of canals and pipelines.

California's surface water supplies are derived from an average annual statewide precipitation of nearly 2 feet, ranging from almost nothing in desert areas to more than 100 inches in mountainous North Coast regions. About 60 percent of this annual precipitation is evaporated and transpired by native trees, brush, and other vegetation. The remainder comprises the approximately 71 million acre-feet of streamflow that drains from the land in an average year. Annual inflow from Oregon streams contributes an additional 1.4 million acre-feet, and water imported from the Colorado River has added another 4.8 million acre-feet a year to California's supply in recent years.

AVERAGE ANNUAL PRECIPITATION

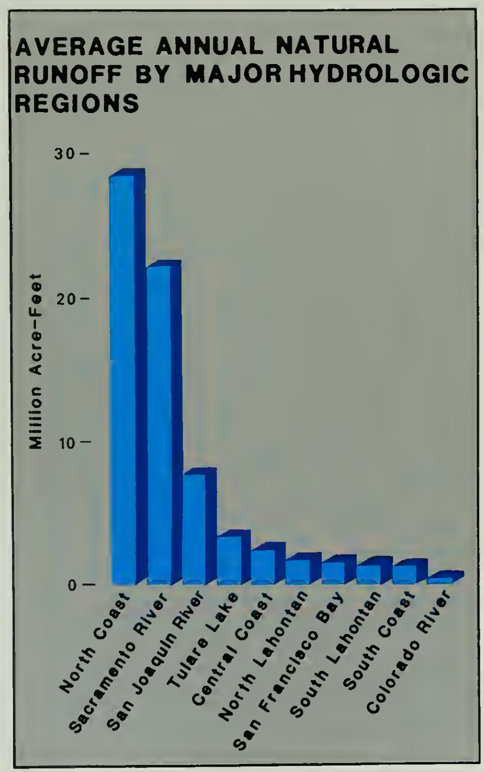




The Warm Springs project in Sonoma County is the only new reservoir built in California in the 1980s with a gross capacity of more than 50,000 acre-feet.

Almost 29 million acre-feet, or 40 percent, of the average statewide runoff occurs in the North Coast region. Rivers there are several mountain ranges and hundreds of miles away from middle and southern areas of the State where the need for additional water supplies is greatest. Consequently, other more accessible California rivers have been tapped for water supplies, while the flows of North Coast rivers contribute only one water diversion to the rest of the State. In fact, many rivers in that region are now protected by State and federal laws that forbid major export water developments.

Although water supplies in the Sacramento River region have already been extensively developed, this stream system still offers the only sizable opportunities for additional surface water development in California. Some potential water development projects are discussed in Chapter 5.



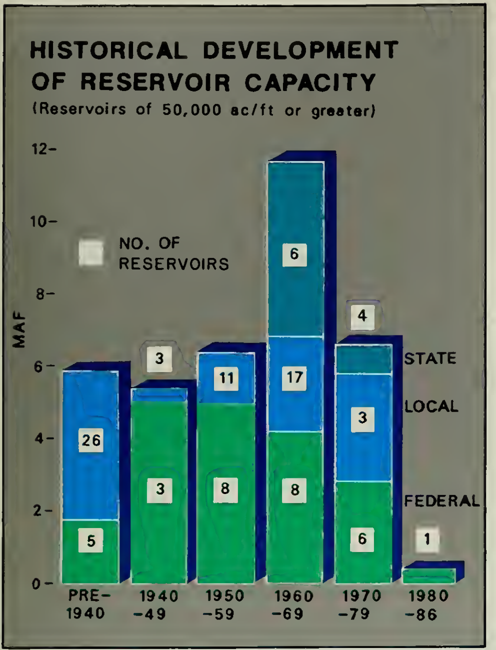
Although average runoff figures are instructive to water planners and of interest to the public, the scale of much of California's water development system has been dictated by the extremes of droughts and floods. Throughout the State's history, the range of recorded water flows has varied dramatically. For example, California's 71-million-acre-foot average annual runoff derives in part from an all-time annual low of just 15 million acre-feet (1977) to an all-time annual high of more than 135 million acre-feet (1983) -- a 120-million-acre-foot range. In February 1986, in just 10 consecutive days, nearly 8 million acre-feet of water flowed past the city of Sacramento in the Sacramento River and the Yolo Bypass. This was more than half the total amount of water that flowed in all the State's rivers during the entire 1976-77 water year.

California's water records show that extremely dry periods can last several years. The seven-year drought of 1928-1934 established the criteria commonly used to plan the storage capacities of large Northern California reservoirs. In fact, many reservoirs built since 1934 are designed and operated to maintain planned deliveries through a repeat of that dry period.

Recognition of the infrequency of droughts such as that of 1928-1934 has resulted in recent years in consideration of operating water supply projects in a less conservative manner than is now used. This approach, discussed in the section titled "Higher Risk v. Firm Yield Operation," would permit increased water deliveries in average and slightly dry years. However, it can increase the risk of running short of water during a severe drought if no provision is made for other long-term storage.

Storage Reservoirs

In all, the State has jurisdiction over the safety of 1,188 dams and reservoirs with a gross storage capacity of 19.7 million acre-feet. There are also 125 federal dams and reservoirs in and adjacent to California, with a combined storage capacity of 22.9 million acre-feet. Taken together, these 1,313 reservoirs can store nearly 43 million acre-feet of water.



The adjacent figure shows the historical development of reservoir capacity in California for reservoirs with gross storage capacities of 50,000 acre-feet or more. The role of local agencies in water resources development is apparent. Locations of major reservoirs built by local, State, and federal agencies are shown on the fold-out map at the back of this report.

Local and Regional Supplies

Local surface water supply projects (as distinguished from State or federal projects) meet about one-third of California's water needs. In each decade of California's statehood, local agencies have undertaken projects to meet their water needs. Initially, surface water development consisted mainly of direct stream diversions; however, early on, these proved increasingly inadequate to meet the needs of growing urban and agricultural areas. By the turn of the century, California's population was 1.5 million, and its irrigated cropland totaled nearly 2 million acres.

Only 20 years later, in 1920, more than 4 million acres were being irrigated, and increased ground water pumping was required to meet escalating water needs. During this 20-year period, many irrigation districts were being formed with the financial ability to construct storage reservoirs needed to regulate surface runoff. Hydroelectric powerplants were also being built at a rapid pace, further regulating streamflow to the benefit of downstream irrigators. Moreover, urban areas were arranging for additional water supplies, with Los Angeles completing its aqueduct from Owens Valley in 1913.

The 1920s and 1930s saw the development of projects to meet regional needs. The East Bay Municipal Utility District finished its aqueduct from Pardee Reservoir on the Mokelumne River in 1929; the city of San Francisco built the Hetch Hetchy Project; and The Metropolitan Water District of Southern California built the Colorado River Aqueduct during this period.

Following a slow period of building activity by local water agencies, construction flourished in the 1960s and 1970s in response to the State's increasing need for power and water. Several large projects were built by local water agencies, some assisted financially by contracts with electric utilities for the purchase of hydropower. In addition, utility companies made substantial additions to their hydropower-generating systems.

The result of more than a century of development by local water agencies is the capability of providing 10 million acre-feet of surface water each year for urban and agricultural users.

Droughts between 1918 and 1925 drew attention to the fact that local surface and ground water supplies could not keep meeting growing water needs in the San Joaquin Valley and Southern California. Since the water development and delivery projects needed to meet these needs were too costly and complex for local agencies to undertake, the State produced plans in 1931 for the Central Valley Project, later built by the U.S. Bureau of Reclamation, and initially proposed elements of the State Water Project, later built by the Department of Water Resources.

State Water Project Supplies

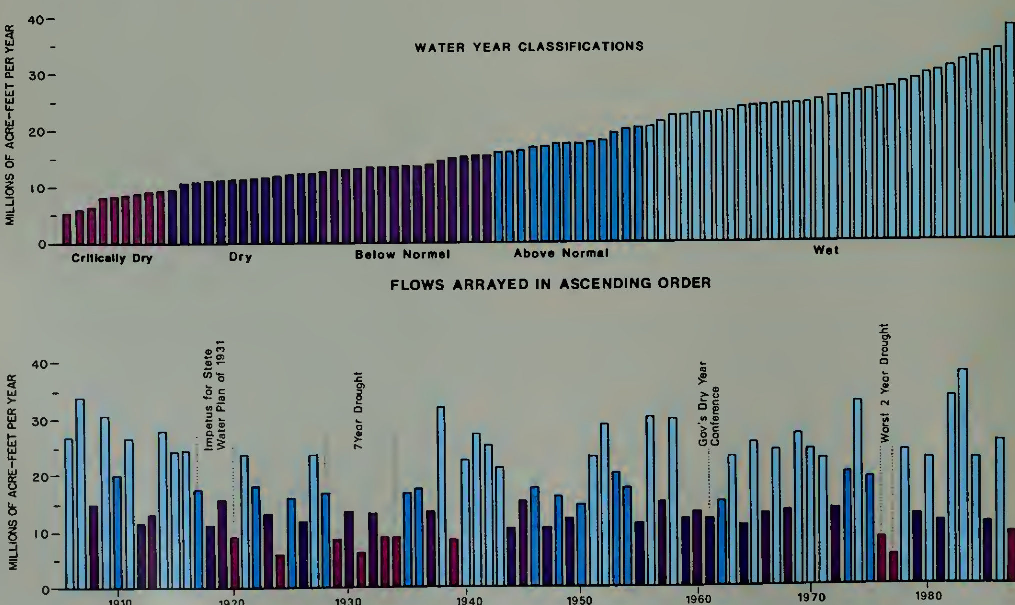
Dependable water supplies from State Water Project facilities are now about 2.3 million acre-feet per year. About half this water comes from Lake Oroville on the Feather River; the rest is developed from surplus flows in the Sacramento-San Joaquin Delta, some of which are re-regulated in San Luis Reservoir.

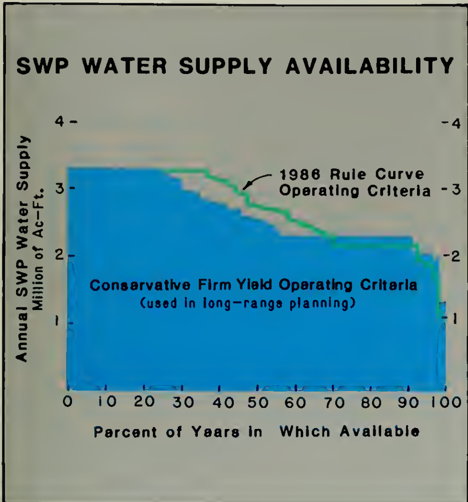
The amount of surplus Delta water supplies is affected by the volume of outflow required to meet water quality standards in the Delta established by the State Water Resources Control Board. Existing standards are specified in Decision 1485, adopted in 1978. In accordance with the Board's continuing jurisdiction, standards will be revised in 1990, following hearings conducted during the next three years. Estimates of necessary Delta outflow have varied widely since planning for the SWP began. Early estimates were much lower than they are today, and dependable supply estimates for the initial SWP facilities were at one time much higher than the present 2.3 million acre-feet. The changes are due both to increased outflow required for fisheries protection and to the fact that operational experience has demonstrated that simply keeping salinity levels at a given objective requires more fresh water than was expected.

Outflow requirements stated in Decision 1485 vary, according to annual hydrologic conditions, and are based on annual flow measurements compiled in the Sacramento River - Four Rivers Index. The graphs below show natural runoff totals for the streams included in the index: the Sacramento River above Bend Bridge near Red Bluff; the Feather River at Oroville Reservoir; the Yuba River at Smartville; and the American River at Folsom Reservoir. The upper graph depicts criteria established for Decision 1485. Eleven percent of the 82-year period represented was classified as "critically dry," and 18 percent more was characterized as "dry" -- including two years in the "below-normal" range (1930 and 1932) but classified as dry because they followed critically dry years.

SACRAMENTO RIVER BASIN FLOWS
(FOUR-RIVER INDEX FOR D-1485)

SACRAMENTO NEAR RED BLUFF, FEATHER, YUBA, AND AMERICAN RIVERS





Close examination of the 82-year sequence *(lower graph)* reveals no definite wet- or dry-period cycles. (Studies have, however, shown some correlation of dry periods to the 22-year sun-spot cycle.) The last 12 years have been remarkably varied, including the driest and fourth driest years, and the wettest and third wettest years since 1906. No year in the 12-year period has been close to the long-term average. With 1987 a critically dry year, it would be highly desirable to know whether 1988 will also be dry. However, past attempts at forecasting indicate low reliability could be expected in predicting what type of year 1988 will be.

Higher Risk v. Firm Yield Operation

The measure of the SWP's delivery capability was founded on the concept of "firm yield" operation. Defined as "minimum project yield" in SWP water contracts, firm yield is the dependable annual water supply that can be made available without exceeding specified allowable reductions in deliveries to agriculture during extended dry periods. Recently, DWR has worked with the major contractors to increase the SWP's average annual deliveries. This is done by relaxing its minimum reservoir carry-over storage requirements to permit increased deliveries in all but the driest years.

The availability of SWP water supply is illustrated by the "rule curve" procedures shown below, with total annual demand set at 3.27 million acre-feet. The solid line in the figure represents the amount of water available under the criteria set for the 1986 curve. (Each year's curve is distinct.) In nearly half the years, the 1986 rule curve would have increased SWP annual delivery capability -- often by as much as 350,000 acre-feet. In a fifth of the years, deliveries would have been approximately 120,000 acre-feet less than under the more conservative criteria. In 1986, operation under the rule curve would have reduced deliveries in extremely dry years by as much as 250,000 acre-feet because reservoir storage would have been drawn down to increase deliveries in the preceding years. Nevertheless, average dry period deliveries during a repeat of the 1928-1934 drought would have been about the same with either of these criteria.

Federal Central Valley Project Supplies

With its present facilities, the Central Valley Project's net water supply capability beyond 2010 is projected to be about 9.45 million acre-feet a year, assuming full use of water by present and projected water contractors. The CVP's northern portion -- consisting of development on the Sacramento, American, and Trinity Rivers -- will, when fully developed, contribute 7.7 million acre-feet of this supply for use in the Delta service area. New Melones, Friant, Hidden, Buchanan, Sly Park, and Sugar Pine reservoirs will contribute the remaining 1.75 million acre-feet. The estimate for the northern CVP system is based on coordinated operation with the SWP to maintain Delta water quality standards in accordance with the Coordinated Operation Agreement.

The magnitude of the CVP's projected total water supply capability depends on reuse of initial deliveries. For example, after Northern California growers use CVP water to irrigate their crops, excess water is returned to the Sacramento River and counted again as project yield available for rediversion or for meeting Delta outflow requirements. Thus, if expansion of CVP water use in the Delta's upstream service areas were not to occur as projected, or if improved irrigation efficiency reduced the volume of return flows, the CVP's water delivery potential could be less than anticipated.

Elsewhere in the CVP system, 800,000 acre-feet of dependable Friant Reservoir supplies are delivered to California growers each year, along with 667,000 acre-feet of nonfirm supplies. The nonfirm supplies are used conjunctively with ground water in the Friant-Kern Canal and the Madera Canal service areas. New Melones Reservoir's dependable water supply potential of 210,000 acre-feet per year is committed to service areas in San Joaquin, Stanislaus, Tuolumne, and Calaveras counties.

Colorado River Supplies

California's basic apportionment of Colorado River supplies is 4,400,000 acre-feet per year, plus not more than half of any excess or surplus water. Because of recent wet hydrologic conditions on the Colorado and because Arizona is not yet taking its full apportionment, California has been able to use an average of about 4,800,000 acre-feet in recent

SERVICE AREAS USING COLORADO RIVER WATER

* User by exchange of its SWP water

years. After the Central Arizona Project is in full operation in the early 1990s, Arizona is expected to fully use its basic apportionment of 2,800,000 acre-feet. Barring an extended drought, California will continue to be able to divert more than its basic apportionment for the next few years. After that, even though the upper Colorado River basin states are not expected to use their full apportionments until as late as 2020, the availability of surplus flows will become less likely. This is because past apportionments of the river's supply considerably exceed the present estimated long-term average runoff. However, a series of wet years could create a surplus that would provide water management opportunities.

Interdependence of Supplies

California communities and farmlands have grown by augmenting inadequate local water supplies with extensive aqueduct systems to import water from areas of abundance. As the map in the back of this report shows, the South Coast region has three distinct sources of imported water, the San Francisco Bay area has four sources, and the San Joaquin Valley has two. Over the years, steps have been gradually taken to interconnect these systems in various ways, and a number of sharing and exchange arrangements have been worked out, making it possible to alleviate a temporary shortage in one area by transferring surplus supplies. For example, during the 1976-1977 drought, through agreements and exchanges, Marin County was supplied with water by virtue of increasing Southern California's use of supplies from the Colorado River, more than 500 miles away.

In situations where a loss of supply occurs, the impact may be felt in a distant region of the State. In the near future, the reduction of California's allotment of Colorado River water (due to the startup of the Central Arizona Project) will place additional demands on the SWP, which derives most of its supplies from the Delta and the Feather River. Likewise, any reductions in Mono Basin diversions on the eastern side of the Sierra Nevada would create an additional need to supplement this supply from sources in the Central Valley.

Highlights of Surface Water Development in California

1850	California admitted to the Union. Population: 100,000.
1887	First irrigation district act passed (Wright Act); provides taxation and bonding powers.
1900	California's population reaches 1.5 million; total irrigated land nears 2 million acres.
1905	Pacific Gas and Electric Company incorporates; begins water and power partnership in Northern California.
1913	Los Angeles Aqueduct from Owens Valley is completed.
1920	California's population rises to 3.4 million; total irrigated land surpasses 4 million acres.
1921	Recent drought and extensive ground water depletion prompts the Legislature to authorize studies that led to "Report to Legislature of 1931 on State Water Plan" (1930).
1923	East Bay Municipal Utility District is formed.
1928	State constitutional amendment is adopted forbidding waste or unreasonable use of water.
1928	The Metropolitan Water District of Southern California is formed to bring Colorado River water to the South Coast.
1929	Mokelumne River Aqueduct begins deliveries to East Bay cities.
1930	California's population reaches 5.5 million.
1934	Hetch Hetchy Aqueduct begins water deliveries to San Francisco.
1938	All-American Canal is completed to serve Imperial Valley.
1944	Shasta Dam is completed.
1947	San Diego's first water import pipeline links with Colorado River Aqueduct.
1960s	Decade of extensive multiple-purpose dam and reservoir construction by local water agencies, largely financed by the sale of hydro power to electric utilities.
1968	Oroville Dam is completed.
1980	California's population reaches 23.8 million; irrigated land totals 9.5 million acres.
1987	The North Bay Aqueduct and the San Felipe Project are completed.

APPORTIONMENT OF CALIFORNIA'S COLORADO RIVER WATER SUPPLY

Agency and Description of Service Area	Beneficial Consumptive Use in acre-feet per year	
Priority Number	Per California Seven-Party Agreement	After Start of Central Arizona Project
1 Palo Verde Irrigation District 2 Yuma Project, California portion 3 Imperial Irrigation District Coachella Valley Water District Palo Verde Irrigation District (mesa lands)	3,850.000	3,850,000
4 Metropolitan Water District	550.000	550,000
5 Metropolitan Water District	662.000	0
6 Imperial Irrigation District Coachella Valley Water District Palo Verde irrigation District (mesa lands)	300,000	0
TOTALS	5,362,000	4,400,000

** Includes Indian water rights and miscellaneous present perfected rights totalling 58,000 acre-feet that reduce Metropolitan's entitlement to 492,000 acre-feet.*

*** Plus not more than one-half of any excess or surplus water in the lower Colorado River.*

Tree Rings Tell Tales of Wet and Dry Years

Trees have spaces between their growth rings that reveal much about the past -- particularly about how wet or dry the seasons were long before people began recording such facts. Water planners are interested in what trees have to tell us about historical weather cycles and rainfall patterns because the more they know about the past the better they can evaluate ways of meeting water needs in the future.

With correlation techniques, tree rings can be used to reconstruct streamflow. This graph shows the results of recent studies of the Sacramento River near Red Bluff, conducted at the University of Arizona's Tree-Ring Research Laboratory. The studies, which focused on samples taken at 16 sites in Oregon and Northern California, reconstructed more than 420 years of Sacramento River basin runoff. In the graph, the lower line shows mean flows, reconstructed from tree ring data; the upper line shows mean flows measured and recorded since 1872. The two lines correspond well, with the 1928-1934 drought standing out particularly well as the most prominent dry period since 1560. The Tree-Ring Lab studies concluded that:

- Water conditions in the basin over the past 100 years have been wetter than the 420-year average.
- The basin's highest and lowest flows over the past 420 years have occurred since the late 1800s, although there have also been other periods of prolonged high and low flows in the past.
- The timing of low flows in the Sacramento River basin coincides to some extent with the timing of low flows in the Colorado River basin, though not to low-flow patterns in basins in the eastern United States.
- Tree growth does not appear to react as noticeably to shorter droughts, such as the record two-year drought of 1976-1977.

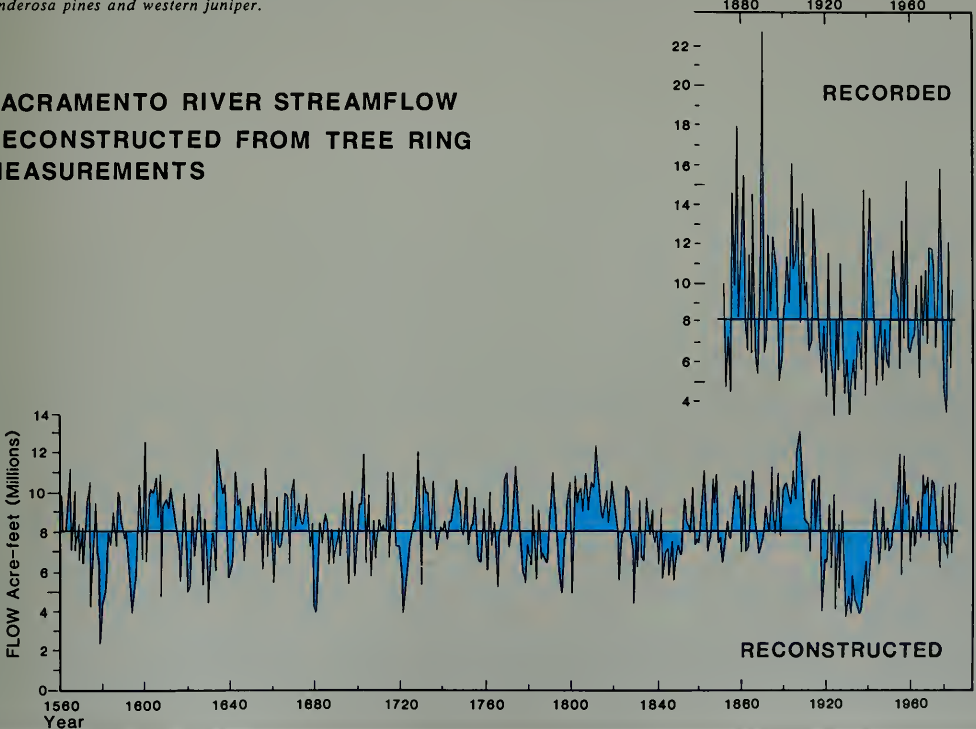
A more recent study of tree rings in Santa Barbara and Ventura counties, conducted by scientists at the University of California, Santa Barbara, confirms that wet and dry periods in the Central Coast or Southern California regions often do not coincide with those in Northern California. Results of this same study indicate that the major dry periods for these regions occurred before formal hydrologic record keeping began.

Just how helpful tree-ring data will be in future California water planning efforts is uncertain, but such data do put the State's more recent wet and dry periods in perspective for water resource planning.

Pencil-thin cores taken by a coring tool allow scientists to study tree rings without damaging the tree. Growth rings are most evident in conifers. In the Sacramento River basin studies, core samples were taken from jeffrey, sugar, and ponderosa pines and western juniper.

Interpretation of tree rings can indicate past precipitation and streamflow. The rings illustrate a tree's growth, each marked by a darker band. Wet years generally produce wide rings; dry years, narrow rings.

SACRAMENTO RIVER STREAMFLOW RECONSTRUCTED FROM TREE RING MEASUREMENTS



GROUND WATER

In absolute terms, California's ground water resources are much larger than its surface water reservoirs. Statewide, nearly 400 ground water basins store about 850 million acre-feet of water. By comparison, the State's surface reservoirs hold about 43 million acre-feet of water. However, as outlined below, much of the ground water is not available for use.

On the average, 16.6 million acre-feet of ground water is pumped yearly, meeting about 39 percent of California's applied water requirements for municipal, industrial, and agricultural uses. The State's ground water basins range in size from hundreds of acres to millions of acres. Depending on their location, however, size alone may not reflect their importance.

Much less than half the ground water in storage lies close enough to the earth's surface to be pumped economically. The amount of water pumped from storage each year is usually a small percentage of the total in storage. Since Californians rely heavily on ground water when surface water supplies dwindle, it is fortunate that much of the State's municipal, agricultural, and industrial development has occurred on land overlying large amounts of good-quality ground water. In fact, some major urban areas and many rural communities (especially mountain towns) obtain all their water from wells.

Natural replacement of water pumped from the ground in California is augmented by engineered replenishment systems. Natural recharge comes from rainfall, snowmelt, and stream seepage, which return an average of 5.8 million acre-feet of water annually. Another 7.4 million acre-feet seeps back into ground water basins after being used for agricultural, municipal, and industrial purposes. In addition, 1.1 million acre-feet of imported surface water and 300,000 acre-feet of seepage water from unlined irrigation canals is intentionally recharged to California's underground basins each year. Taken together, this is a substantial amount of recharge, but it does not completely replace the volume of water pumped. Statewide, ground water pumping exceeds recharge by an average of 2.0 million acre-feet a year -- a deficit condition referred to as "overdraft."

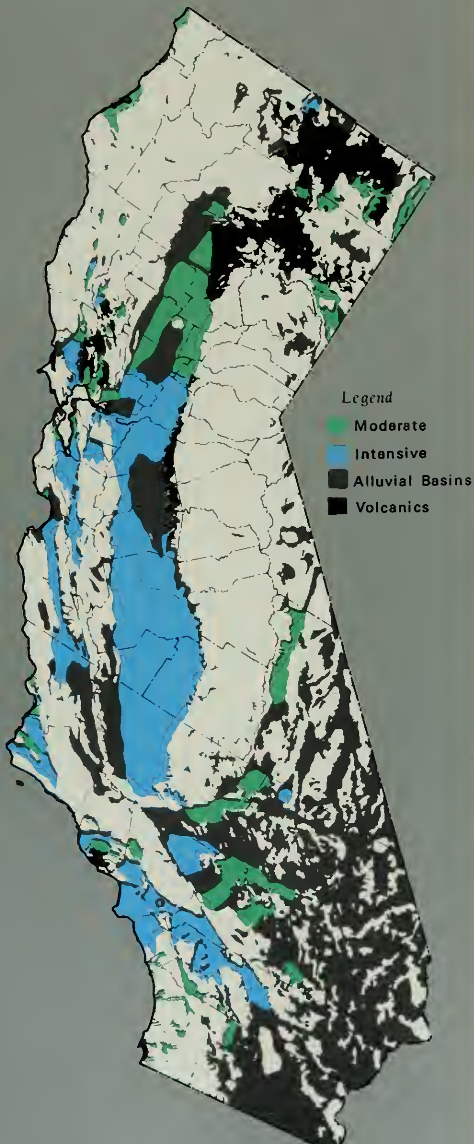
Ground Water Overdraft

Overdraft is usually defined as the average annual rate of ground water depletion in a basin referenced to a specific year of development of the overlying area, such as 1980 or 1990. It is the difference between water pumped by agricultural and urban users and the average long-term recharge. While droughts or wetter-than-normal periods affect ground water by lowering or raising water levels for a short time, the overall trend with overdraft is downward. Overdraft is sometimes also said to occur when basin water supplies are in balance but locally excessive pumping is causing adverse effects, such as degradation of the quality of water produced.

Much early water use in California depended on ground water. The use of ground water grew even greater with the widespread introduction of deep well turbine pumps early in this century. Many basins began experiencing overdraft in the 1920s as expanding water demands led to more pumping.

Thirty-nine percent of the water Californians use comes from the ground.

GROUND WATER BASINS WITH MODERATE OR INTENSIVE DEVELOPMENT



Since overdraft causes declining water levels and therefore increases the use of energy for pumping, the cost of pumping also increases. Other problems can also be associated with overdraft. These include land subsidence, which raises the cost of maintaining roads, bridges, canals, and other facilities; sea-water intrusion, which occurs in coastal basins; and movement of poor-quality water into other parts of a basin or into an adjoining basin. These problems have long been recognized and, while they do not indicate a crisis with our ground water supply, they still represent difficulties.

Recognition of overdraft problems has fostered much water resources planning and development. This is illustrated by a thumbnail sketch of the history of water development in the Santa Clara Valley, located just south of San Francisco Bay.

1930s – Use of ground water encourages the spread of agriculture.

1940s – Overdraft increases pumping costs, and local agencies respond by constructing dams to store winter runoff for later recharge.

1950s – Water levels begin to recover, but continuing widespread development again outruns the dependable water supply and overdraft returns, causing significant localized land subsidence.

1960s – Surface water is imported through the State Water Project.

1970s – Water levels rise, but rapid growth threatens a return to overdraft in the future.

1980s – Surface water is imported through the Central Valley Project.

Similar stories could be told for other areas of the State. In some, overdraft would be eliminated; in others, such as some of the desert basins, overdraft is the only available water supply. In yet others, such as the San Joaquin Valley, considerable progress toward eliminating overdraft would be apparent, but achievement of that goal is not yet in sight. Annual overdraft in the valley has been reduced from a peak of about 1.7 million acre-feet per year in the 1950s and 1960s to about 1.3 million acre-feet per year at present from ground water basins holding 500 million acre-feet of water.

The table shows the amount of overdraft in the State's major regions for a 1985 level of development.

Ground Water Overdraft
1985 Level of Development

In 1,000s of acre-feet

Regions	Overdraft
North Coast	0
San Francisco Bay	30
Central Coast	220
South Coast	120
Sacramento River	110
San Joaquin River and Tulare Lake	1,340
North Lahontan	0
South Lahontan	150
Colorado River	50
TOTAL	2,020

The Significance of Overdraft

Although the table indicates that overdraft is still significant, the immediate consequences are not as dire as one might think. In all regions with overdraft, the amount of overdraft represents a very small annual depletion of ground water in storage. The small overdraft in the San Francisco Bay region does not cause any serious problems. In the Sacramento Valley region, overdraft is concentrated in a few locations that are anomalies in an otherwise water-rich area, and this may be reduced by future improvements in water management.

Overdraft is spread over much of the Central Coast region, with small average rates of decline. The

Shallow ponds in the Santa Ana River, Orange County, are typical artificial recharge facilities for replenishing ground water. Dikes slow the river's flow, forcing it to spread and allowing it to seep underground. Water used for recharge at this site comes from surface runoff, treatment plant discharges, and imported water. The project is operated by the Orange County Water District.

chief problem there is one of potential sea-water intrusion in some of the smaller coastal basins. In the South Coast region, future overdraft may be reduced as more imported water becomes available. The Colorado River and South Lahontan regions include numerous ground water basins with widespread overdraft. In many of these desert basins, effective recharge is near zero, and all pumping results in overdraft. Ground water in these regions can be considered as a nonrenewable resource. However, the locally stored reserves are immense, compared to amounts of ground water overdrafted. In some areas of concentrated overdraft, such as Antelope Valley, overdraft has declined as the cost of pumping water has risen, causing agricultural uses of water to decline.

By far, the greatest incidence of overdraft in California is occurring in the San Joaquin Valley, and even here, important improvements have been made. For example, the Westlands Water District is no longer in overdraft since imported water supplies have been made available, and future projects, although becoming more difficult to implement, will also help control overdraft in other parts of the valley. The main impact of the overdraft has been higher pumping costs that are borne by all ground water users in the area, not solely by those located where overdraft is occurring.

Ground Water Management

Most ground water in California is available to anyone who wishes to pump it. In a few basins, however, problems resulting from unrestrained ground water withdrawals in the past have led to legal action that has caused the establishment of formal ground water management programs. In some other basins, local ordinances and interagency agreements have been used as management measures.

Eight basins in California have had their pumping rights adjudicated by the courts -- six in intensely urbanized sections of Southern California and the others in Kern and Siskiyou counties. In two other highly urbanized basins -- the Orange County coastal plain and the Santa Clara Valley -- ground water management includes pumping fees instituted by special legislative authorization. Recently, the Legislature has authorized formation of ground water management districts in portions of Lassen, Plumas, Mendocino, and Sierra counties. Several other California counties have adopted ground water management measures through passage of local ordinances, although the legality of such measures remains uncertain.

California's Water Conservation and Water Quality Bond Law of 1986

The voters' approval of California's Water Conservation and Water Quality Bond Law of 1986 made $75 million available for low-interest loans for conservation and ground water recharge projects. In response to the passage of this law, local agencies have filed 44 recharge project applications with DWR and requested more than $150 million. The law gives priority to ground water management proposals designed to alleviate overdrafted basins. Thus far, 74 loan requests of about $100 million have been requested from DWR specifically for water conservation projects, many of which will reduce California's ground water demand.

Two Examples of Effective Ground Water Management

The Orange County Water District, formed in 1933 to address serious ground water problems resulting from sea-water intrusion, operates several recharge facilities capable of percolating 250,000 acre-feet of water into underground basins each year. As part of its program, the district has created a hydraulic barrier to repel intruding sea-water by injecting large quantities of reclaimed waste water through wells.

In the San Joaquin Valley, growers in the Lower Tule River Irrigation District use both surface and ground water to meet their irrigation needs. In dry years, these growers irrigate their crops with ground water; in wet years, they rely on water from the Tule River and the Central Valley Project and recharge excess surface water to ground water storage through spreading basins, unlined canals, and the Tule River channel.

Adjudication is a legal process sometimes used to define rights to pump ground water. It has been used in California in the past when uncontrolled pumping threatened to deplete available ground water supplies. It has usually been a lengthy and costly process, involving many engineers and attorneys. Today, California's water management institutions are more flexible and effective than before, and current water supply problems can usually be solved without turning to the courts. Even in the San Joaquin Valley, where overdraft sometimes leads to discussion of adjudication, local water management agencies believe that they are capable of dealing with present and future ground water problems and that management of this resource is most effective without strict pumping controls.

Many of California's local and regional water agencies are actively managing their ground water resources by importing surface water, recharging ground water basins, conserving and reclaiming water, and providing incentives to control ground water pumping. Most of these agencies also measure ground water levels regularly and closely monitor the quality of ground water pumped. Local agencies are continuing to devise creative ways of managing their ground water resources, even where clear legal authority is missing. New sources of funding, such as California's Water Conservation and Water Quality Bond Law of 1986, are increasing the opportunities to construct recharge facilities and implement projects to reduce ground water overdraft.

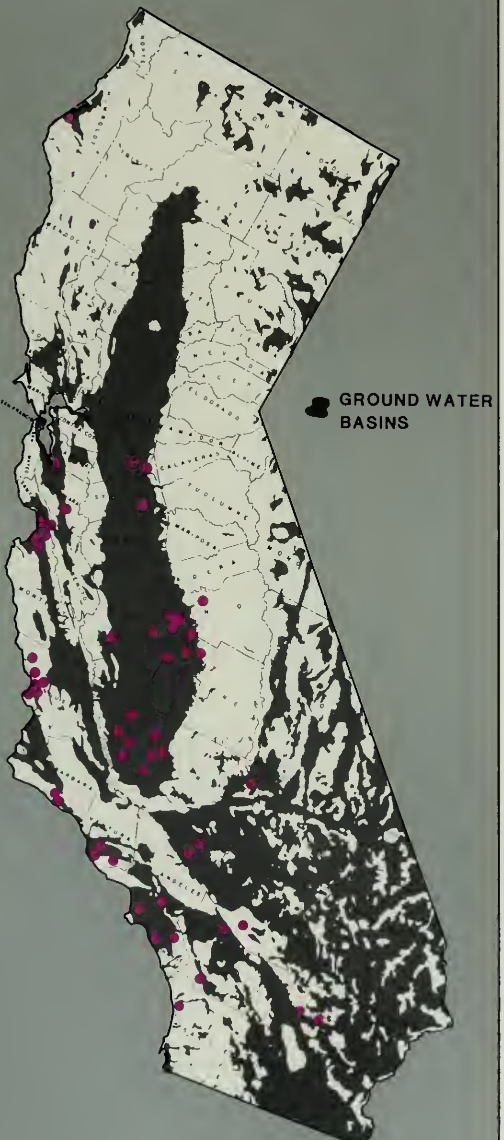
Most active ground water management programs are concentrated in the southern two-thirds of the State, where ground water usage is the most intensive and overdraft conditions have been the most severe. Ground water usage north of Sacramento is significant, but abundant surface water supplies and extensive natural recharge greatly reduce the need for formal management programs.

More than 65 separate water agencies operate ground water recharge projects in California. As early as 1889, floodwater from San Antonio Creek in Southern California was conserved by recharging the alluvial fan at the mouth of San Antonio Canyon. From this modest beginning, intentional re-

BASINS WITH ACTIVE RECHARGE PROGRAMS

GROUND WATER BASINS

PROPOSED RECHARGE PROJECTS UNDER THE WATER CONSERVATION AND WATER QUALITY BOND LAW OF 1986



charge activities have increased substantially. Today, thousands of acres of ponding basins and hundreds of miles of stream channels and unlined canals are used for recharge throughout the State. The amount of water recharged varies greatly from year to year, but, on the average, and in addition to recharge of local water supplies, about 1.1 million acre-feet of imported water is recharged under typical hydrologic conditions. Significant amounts of local runoff that would otherwise be lost are also recharged. Many other agencies provide intermittent surface water supplies to users who would otherwise pump ground water. This is called in-lieu recharge because the ground water that is not pumped accumulates in storage and is saved for use during dry periods. All these activities are referred to collectively as conjunctive use operation -- an efficient and cost-effective way of stretching available surface and ground water supplies.

In furthering the concept of conjunctive use, DWR has sponsored ground water recharge demonstration programs with two local agencies: Mojave Water Agency (MWA) and San Bernardino Valley Municipal Water District (SBVMWD). In the summer of 1978, about 24,000 acre-feet of water was released into the Mojave River channel from Silverwood Lake to recharge downstream ground water basins. MWA later acquired title to the water in lieu of deliveries through the California Aqueduct. A program with SBVMWD provided for recharge of up to 50,000 acre-feet of SWP water in ground water basins within the district's service area. From mid-1978 to January 1983, about 20,000 acre-feet of SWP water was released to recharge basins in the Bunker Hill and adjacent ground water basins in the Santa Ana watershed. Recharge operations were then terminated when several wet years caused a rise in ground water levels in the basins. In the dry year of 1987, the local district recovered the stored water in lieu of taking SWP deliveries.

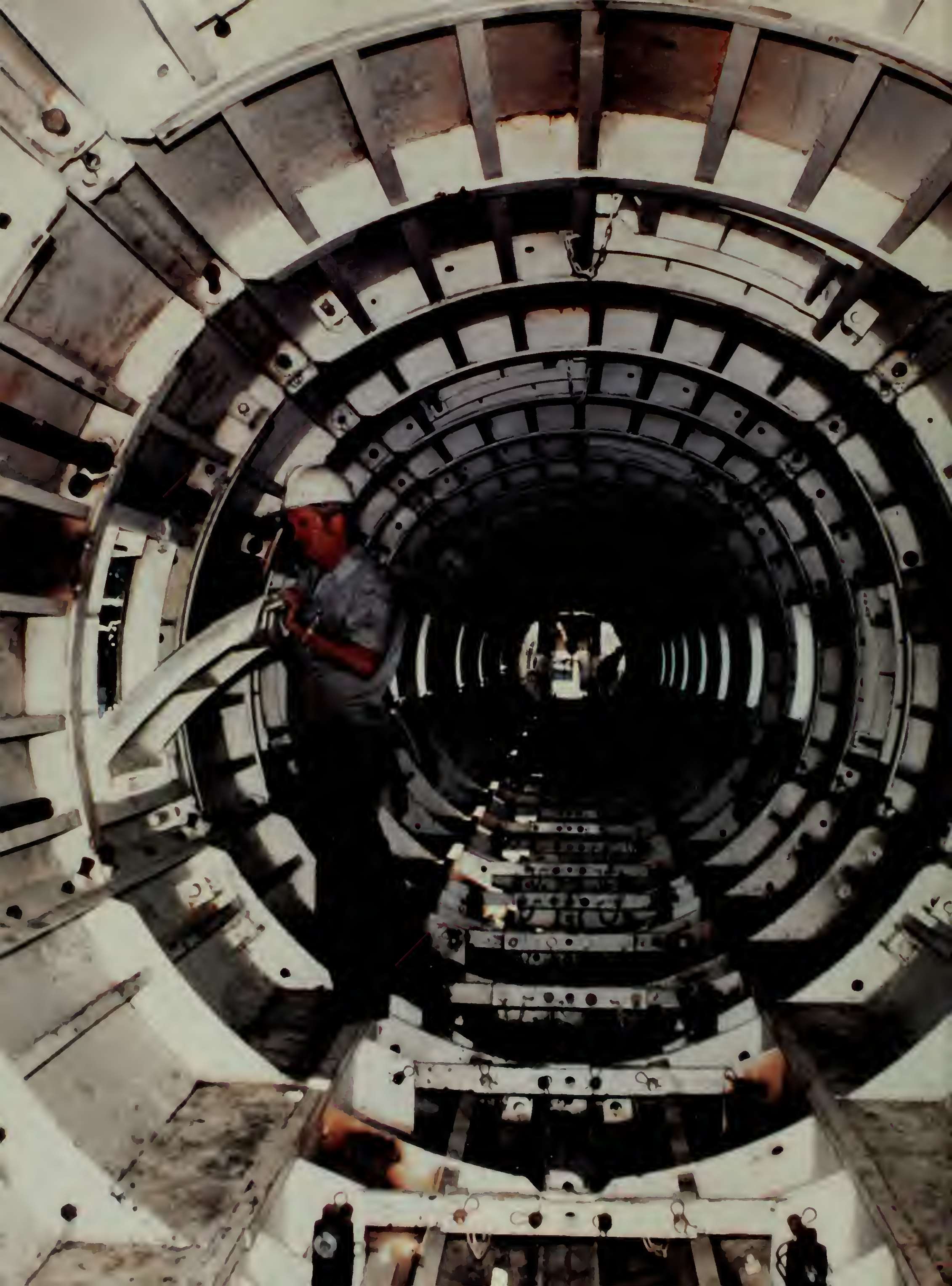
Two San Joaquin County water agencies, Stockton East Water District and Central San Joaquin Water Conservation District, have proposed an exchange of their New Melones contract water with the SWP during drier years for SWP financing of project facilities to divert their contract water to their facilities. The proposal would require conjunctive use by the local districts, which would use more surface water in wetter years and more ground water in drier years. The proposal could add up to about 96,000 acre-feet of water supplies for the SWP in extremely dry years.

Additional conjunctive use operations are now being planned to meet various regional and local water needs. The Metropolitan Water District of Southern California, for example, is completing environmental assessments for a ground water storage (water banking) program in the Chino Basin, is cooperatively operating a similar program in the Coachella Basin, and is negotiating with the Arvin–Edison Water Storage District for the formation of a third such program in Kern County. The Kern County Water Agency, in cooperation with many of its member agencies and the city of Bakersfield, is expanding its ground water banking programs to benefit a wide portion of the southern San Joaquin Valley. The potential for yet another large water banking program exists in the service area of the proposed Mid–Valley Canal in Madera, Fresno, Kings, Tulare, and Kern counties. (The Department of Water Resources' Kern Water Bank is discussed more fully in Chapter 5.)

Impacts of Recent Wet Years on San Joaquin Valley Ground Water Supplies

In recent years, water levels in many areas of the San Joaquin Valley have risen, and many people have concluded that overdraft has been overcome, or at least greatly reduced. For example, from 1970 through the end of the 1976-1977 drought, the amount of water in storage in the Kern County basin declined by about 5.7 million acre-feet. Since that time, ground water storage has increased by about 4.3 million acre-feet.

However, the years since the drought have been unusually wet, with Kern River flows into the valley at 165 percent of average for 94 years of measurement, and most other valley rivers and streams had similarly high runoff figures. Such plentiful local surface water and the increased availability of water from the Central Valley Project and the State Water Project greatly reduced the need to pump ground water. Furthermore, during this period of abundance, local water managers followed good management practices by expanding recharge programs to store large amounts of surplus water in the ground throughout the valley. Unfortunately, when more typical weather conditions return, water levels will dip as ground water pumping is expected to again exceed replenishment.



MEETING FUTURE NEEDS FOR WATER

California will meet its future water needs primarily through a wide variety of management actions designed to supplement, improve, and make better use of existing systems. These will include expanded transportation system capabilities, placing more reliance on ground water basins, and increasing the use of water transfers and water banking in offstream surface and ground water reservoirs. While most of the economical reservoir sites in the State have been developed, some expansion of traditional on–stream storage systems is expected. Some of the specific actions expected to occur are discussed in this chapter.

Statewide Overview

California's estimated total net use of water in 1985 was 34.2 million acre–feet. The table, "Use and Status of Present Supplies" *(following)*, shows the contributions made by various sources of supply in meeting that level of use. Except for the Central Valley Project, developed but unused supplies are relatively small. Assuming a leveling off of agricultural water use, as explained in Chapter 2, the State's yearly net water needs by 2010 are projected to reach 35.6 million acre–feet. While this 1.4–million–acre–foot increase is not great when compared to present use, it represents a substantial part of the remaining potentially developable and uncommitted surface supplies of the State.

Some of the 1.4 million acre–feet can be met from uncontracted–for Central Valley Project supplies. The remainder can be satisfied from a variety of other sources. Not included in the supplemental water needs is correction of the existing long–term ground water overdraft, currently averaging 2.0 million acre–feet per year, statewide. As explained in Chapter 4, some of the ground water overdraft will be offset by surplus Delta supplies from new delivery systems in years of adequate runoff, and the rest will probably be considered to be a one–time depletion.

Two general observations should be made about the projections of future demands and supplies. First, there is considerable variation from year to year in both the demand side and the supply side of the equation. In particular, during dry years when supplies are reduced, demands usually increase.

The second observation is that more and more different types of management options are involved in meeting California's water needs. Depending on the location and situation, they include the following: conjunctive use of ground water and surface water; system interconnections; water marketing, transfers, and sharing; waste water reclamation; desalting; water conservation and salvage; conventional reservoirs; and weather modification. There is probably a fair analogy with the electric utilities in which supplies are being provided from more and more diverse sources.

The table, "Meeting Water Needs to 2010" *(following)*, shows what are presently seen as the sources of supply for meeting water needs in the State to 2010. Changes from existing supplies are shown in the second column. Water savings by the Imperial Irrigation District and lining of the All–American Canal and the remaining unlined portion of the Coachella Canal is assumed to make 250,000 acre–feet available annually to the South Coast region. The CVP has uncontracted–for dependable supplies estimated by the Bureau of Reclamation to be about one million acre–feet.

Interior of a collapsible form being assembled to shape tunnel lining in the Bureau of Reclamation's San Felipe Project, which has begun delivery of water from San Luis Reservoir to Santa Clara and San Benito counties.

Use and Status of Present Supplies

Source of Supply	1985 Net Use		Status
	In million acre-feet	In percent	
Local surface water	9.2	27	Mostly fully used. About 0.1 million acre-feet of unused yield is available in Sacramento Valley.
Ground water safe yield	6.0	17	Modest additional supplies in Northern California are available.
Federal Central Valley Project	7.0	20	CVP has an additional uncontracted-for project supply of about 1 million acre-feet, depending on place of use and other factors. (See Chapter 3.)
Other federal sources	1.3	4	Existing supplies are nearly fully committed.
State Water Project	2.4	7	Dependable supplies of existing facilities of 2.3 million acre-feet are fully committed in dry years. Amount shown includes 0.1 million acre-feet of surplus water deliveries.
Colorado River	5.0	15	Recent use has averaged 4.8 million acre-feet. Firm supply will be reduced to 4.4 million acre-feet after start of Central Arizona Project deliveries. California gets first surpluses in lower Colorado River.
Local agency imports (excluding the Colorado River)	1.0	3	San Luis Obispo County, San Francisco, and East Bay Municipal Water District have unused supplies, but conveyance facilities are needed.
Reclaimed waste water	0.3	1	Some potential exists for increased use of existing waste water supplies, primarily in Southern California and the San Francisco Bay area.
Ground water overdraft	2.0	6	Future amount will be affected by availability of alternative surface supplies and economics of pump lifts.
TOTAL	34.2	100	

Meeting Water Needs to 2010

Source of Supply	Projected 2010 Net Use	Change from 1985	Remarks
	In million acre-feet		
Local surface water	9.2	—	Some relatively small additions are expected.
Ground water safe yield	6.1	0.1	Some additional development is projected in Northern California basins.
Federal Central Valley Project	7.8	0.8	San Felipe Division; New Melones supply contracts; Mid-Valley Canal service area.
Other federal sources	1.3	--	None assumed by 2010.
State Water Project	3.2	0.8	Increase in dependable supplies is 0.9 million acre-feet. Assumes additions to SWP shown on figure.
Colorado River	4.2	-0.8	Assumes no surplus flow available. Assumes 200,000 acre-feet of 450,000 acre-feet of water salvage is reserved for future use in the Imperial Valley.
Local agency imports (excluding the Colorado River)	1.1	0.1	San Francisco Bay region, including some use of American River water by East Bay Municipal Utility District.
Reclaimed waste water	0.5	0.2	Mostly additional projects in South Coast and San Francisco Bay regions.
Ground water overdraft	1.8	-0.2	Decrease due to Mid-Valley Canal supplies is nearly offset by increases in other locations.
Source yet to be determined	0.4	0.4	Needs are primarily in South Coast and Tulare Lake regions.
TOTALS	35.6	1.4	

Major Water Management Actions whose effects appear above in the "Change from 1985" column are listed here and described in subsequent sections of the report.

WATER SUPPLY ADDITIONS:	Delta Pumping Plant Completion Los Banos Grandes Reservoir North Delta Facilities	Kern Water Bank South Delta Facilities North Fork Stanislaus River Project
DELIVERY & USE OF DEVELOPED SUPPLIES:	Coastal Aqueduct-SWP East Branch Enlargement-SWP CVP Wheeling-Purchase-SWP Imperial Irrigation District Salvage Water	San Felipe Division-CVP New Melones Reservoir-CVP Mid-Valley Canal-CVP East Bay MUD American River Contract-CVP
USE OF RECLAIMED WASTE WATER:	Various projects, primarily in the South Coast and San Joaquin Valley regions.	

Waste water reclamation is assumed to add 200,000 acre-feet of replacement supply. For the SWP, supply additions described later could provide about 900,000 acre-feet of dependable supply. With those additions, there would still be a potential shortfall in dependable supplies of 400,000 acre-feet per year in 2010, in addition to the ground water overdraft. If this shortage actually materialized, it would have to be offset by a variety of management actions appropriate to the situation. With the exception of the IID-MWD exchange and the CVP-SWP wheeling/purchase, no specific amount has been assumed for water marketing. However, additional water transfers are expected to play a role in meeting needs, particularly if shortages should develop in South Coast urban areas.

Amounts shown in the table for surface water projects are largely *dependable* supply, which is balanced against the *average* net use. While this is a useful comparison, to some extent it is an instance of mixing apples and oranges. Urban and agricultural development in California relies on having a dependable supply of water available. The inability to maintain dependable water deliveries during a sustained drought would have a severe impact on the State's economy. Consequently, large water supply systems such as the CVP and SWP are designed and operated to provide a reliable level of water delivery capability -- a firm-yield or dependable-supply type of operation that can maintain most deliveries through a recurrence of an extended drought. For Northern California, this is generally all or part of the historical period, 1928-1934. In addition, pre-established allowable delivery shortages in extremely dry years are usually incorporated in the operational plans and water contracts.

Setting a mode of operation in this manner means that, in wetter years, additional water is available for delivery. This is sometimes referred to as surplus or nonfirm water. For a fully developed project, where demands are equal to dependable supply, surplus water could be expected about 70 percent of the years in an extended period of 50 years or so. At the other end of the spectrum, amounts less than dependable supplies might occur in 2 to 5 percent of the years, after allowable deficiencies.

Surplus water deliveries contribute significantly to the overall usable water supplies of the State. Non-firm water is particularly valuable as a replacement for ground water pumping or for recharging ground water basins, thereby helping to correct long-term overdraft conditions. In addition, by developing conjunctive use programs and using surplus surface supplies in conjunction with ground water, dependable supplies can be expanded.

In this report, estimates of net water use for irrigated crops and turf areas are derived from the amount of irrigation water consumed by plants, averaged over many years of record. Actually, in drought years, water consumption by plants can be significantly higher than average because of the need to begin irrigation earlier and, for perennial crops and landscaping, to continue it longer. Total net water use increases accordingly, so the need for water during dry periods is somewhat greater than shown in the table. Increased conservation efforts to reduce losses can help compensate for the longer irrigation period that is necessary during drought periods.

Most of the better dam and reservoir sites in California have already been developed. Local agencies in particular have largely exhausted possibilities available to them. A few viable projects remain that will help solve growing local water supply problems. These are described in Chapter 6.

For local agencies unable to finance new supplies, reducing system losses and increasing water conservation can ease supply shortages. In some cases, loans and grants under the State's Safe Drinking Water program have helped fund improvements to existing systems.

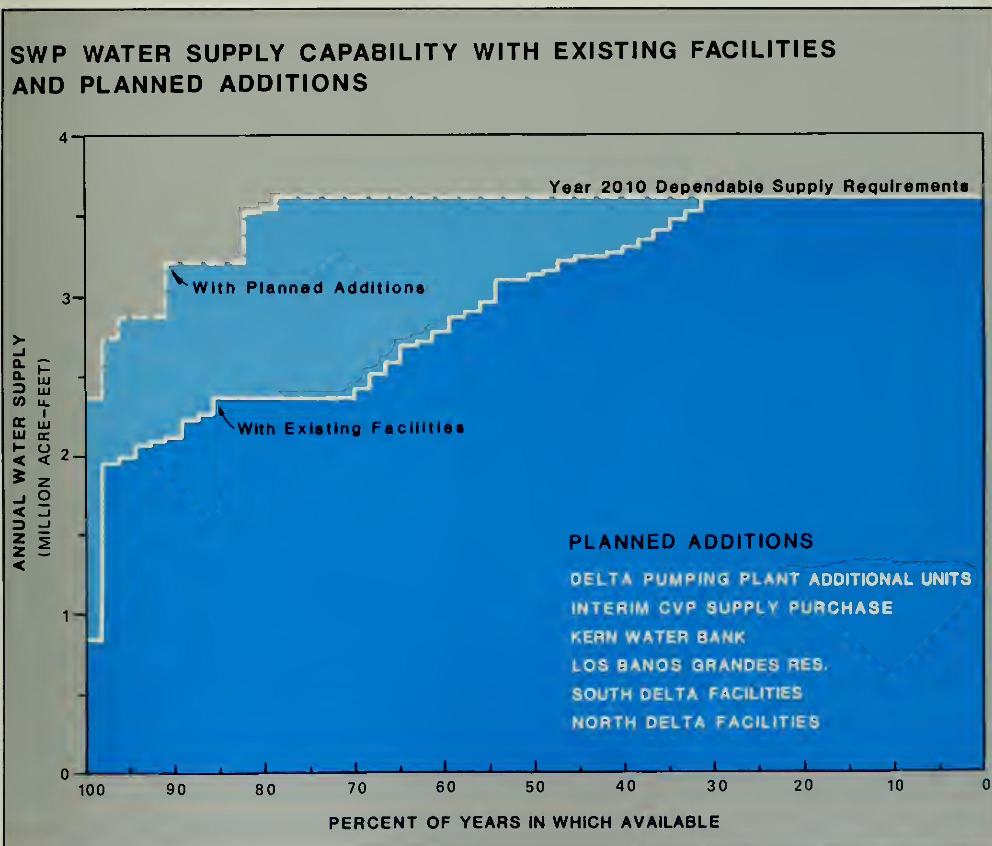
The following sections describe some possibilities at the State and federal levels for adding to presently available water supplies and the additional facilities needed to convey those supplies to areas of need.

Federal and State Water Projects

While the Central Valley Project has uncontracted-for water and does not presently need to add to system supplies, the State Water Project has reached the point where current requests for water by the project's contractors exceed dependable supplies. The U.S. Bureau of Reclamation is in the environmental review process, preparatory to marketing its remaining supplies. For the SWP, the present dependable supply is about 2.3 million acre-feet. Projected requirements in 2010 are about 3.6 million acre-feet, assuming 250,000 acre-feet of water conserved in the Colorado River region becomes available for use in the South Coast region, and waste water reuse increases by 200,000 acre-feet in SWP service areas. Under those assumptions, the *existing* SWP facilities would have a deficit in present dependable supplies in 2010 of some 1.3 million acre-feet.

Various projects, facilities, and programs for augmenting supplies are discussed below and in Chapter 7. Taken together, these actions indicate considerable progress in improving the water supply reliability of the State Water Project. Planned additions to SWP water supplies are listed on the figure below. The lower plotted line represents a dependable water supply capability of 2.3 million acre-feet per year, with permissible deficiencies during a repeat of the 1928–1934 critical dry period. (The dip to about 0.7 million acre-feet reflects extraordinarily dry conditions in 1977.) Excess supplies would be available about 70 percent of the time at this level of dependable deliveries.

With the additions, dependable water supply delivery capability would increase to about 3.2 million



acre-feet per year. Projected 2010 requirements of 3.6 million acre-feet could be provided 90 percent of the time, with permissible deficiencies.

A need for dependable supplies amounting to as much as 0.4 million acre-feet in a given year would remain after the supply additions shown. It should be emphasized that this would not be a chronic shortage, but a shortage could occur in dry years. A temporary shortage of this magnitude may well be manageable with extraordinary conservation efforts (measures taken only during time of drought) and such actions as water marketing, water banking, or extra withdrawals from ground water storage.

SWP Wheeling and Purchasing of CVP Supplies

In 1986, the United States and California reached agreement on the "Coordinated Operation of the Central Valley Project and the State Water Project" (COA). Section 10(h) of the COA provides that DWR and the U.S. Bureau of Reclamation promptly negotiate a contract for the SWP to wheel water for the CVP on the basis of equal priority of SWP long-term contractors and for the Bureau to sell interim CVP water to the State with a priority like that of long-term CVP contractors. There is also a provision in the COA for the Bureau to purchase additional wheeling that uses surplus capacity in the California Aqueduct (SWP) after all SWP contractors' needs are met.

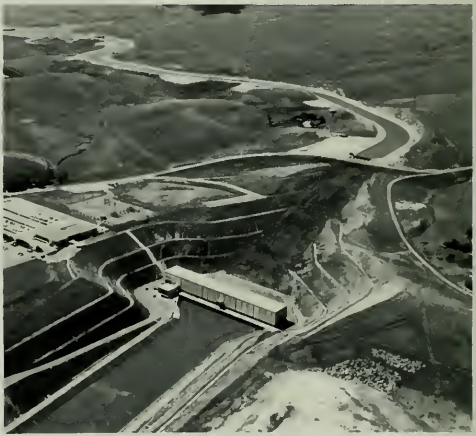
Under this arrangement, it is assumed an interim supply of 250,000 acre-feet per year, less dry-year deficiencies, would be available to the SWP to at least 2010. It is possible that up to 500,000 acre-feet might be available. Negotiations are presently in progress to work out the details of the wheeling and purchase contract.

Even further optimization of the SWP-CVP system would probably result from operation of the CVP water facilities by the State, as has been suggested from time to time. There are many problems yet to be sorted out and even identified before any serious proposal could be evaluated. Nevertheless, during 1987, the federal government indicated a serious interest in pursuing this idea, and preliminary discussions have begun.

The Delta Pumping Plant

The most advanced program to augment the water supply of the State Water Project is the installation of more pumping units at the Harvey O. Banks Delta Pumping Plant. The plant was built to hold 11 units, but only seven were initially installed. The additional units, which will increase pumping capacity from 6,400 to 10,300 cubic feet per second, are scheduled to go into operation in the early 1990s. They will provide standby capacity for the present units and permit more pumping to be performed with cheaper off-peak power. They will also allow a small amount of additional pumping in the winter, increasing dependable supply of the SWP by about 60,000 acre-feet per year. At first, the plant will pump at no more than the average historic pumping rate from March 16 through December 14, in accordance with criteria established by the Corps of Engineers under federal law.

Full operation of the Delta Pumping Plant depends on increasing the channel capacity in the southern Delta. After additional fish mitigation measures are designed and agreed upon, a revised permit will be sought from the U.S. Army Corps of Engineers to allow the SWP to develop more channel capacity and divert more water during the winter, thus increasing its ability to fill offstream storage reservoirs and ground water basins south of the Delta.



State Water Project water leaves the southern Delta through the Delta Pumping Plant and is lifted 244 feet by seven giant pumps into the California Aqueduct. Four more pumps are being added.

Offstream Storage South of the Delta: Los Banos Grandes Project

Nearly all interests agree that plans for future water development should emphasize water diversion from the Delta during winter months to storage facilities south of the Delta. In 1984 the Legislature overwhelmingly approved authorization of the Los Banos Grandes Offstream Storage Reservoir as a future SWP facility.

The proposed Los Banos Grandes Reservoir on Los Banos Creek just south of existing San Luis Reservoir would store excess water pumped south from the Delta through the California Aqueduct during wet months, primarily November through March. Studies thus far suggest that a reservoir with about 1.25 million acre-feet of storage capacity would be the most cost-effective size for the SWP, increasing dependable supply for the SWP by about 214,000 acre-feet. The studies were based upon long-term conditions and assumed the full use of the four additional pumps at the Banks Delta Pumping Plant, as well as an improved Delta water transfer system. Comprehensive feasibility studies now under way are scheduled for completion in 1989.

Site of proposed Los Banos Grandes Reservoir (in blue) is south of the Delta in the foothills of western San Joaquin Valley, just upstream from Los Banos Detention Reservoir. In the foreground, Interstate 5 and the California Aqueduct.

As at San Luis Reservoir, the project would include a pumping-generating system for filling the reservoir from the California Aqueduct and for recovering energy when releases are made. The potential for a joint project with the Central Valley Project is being studied, as is increased energy generation through a pumped-storage operation with several electric utility companies.

Cachuma Reservoir Enlargement

SWP water supply can be augmented by local projects, provided certain guidelines are met. Santa Barbara County, in evaluating its future water needs and alternative sources of supply, decided to serve its northern area through the Coastal Branch of the California Aqueduct. Its southern coastal area would be served by enlarging Cachuma Reservoir on the Santa Ynez River because it appears to be a less expensive alternative than delivering water from the California Aqueduct. Preliminary studies indicate the enlargement would yield a new supply of about 17,000 acre-feet per year.

A feasibility study in cooperation with the Bureau of Reclamation and Santa Barbara County is now under way to determine the feasibility of enlarging Cachuma Reservoir. The reservoir is owned by the Bureau of Reclamation.

Cottonwood Creek Project

Cottonwood Creek, in Shasta and Tehama Counties, is the largest uncontrolled tributary of the Sacramento River and a major contributor to flooding, particularly along the upper river. In 1970, the Corps of Engineers obtained congressional authorization for a two-dam project on Cottonwood Creek for flood protection and for developing additional water supply that would have been sold to the State Water Project. However, the Corps terminated studies of its proposed project in 1985, when revised cost estimates resulted in water costs too high for SWP contractors.

In carrying out its commitment to help the local counties solve their flood problems, in 1985 DWR reinitiated studies of less costly upstream reservoirs identified in earlier investigations. Analysis showed three tributary reservoirs (Hulen, Fiddlers, and Dippingvat) would substantially reduce the 100-year peak floodflow on Cottonwood Creek.

Subsequent analysis of the Dippingvat project showed that a more desirable arrangement was a combination diversion and storage dam at the lower Dippingvat site, with a diversion canal to a storage dam at the Schoenfield site in the adjacent Red Bank Creek basin. This project has the potential for fishery enhancement in Cottonwood Creek and on the Sacramento River at the Red Bluff diversion dam. Feasibility studies of Dippingvat and Schoenfield started in July 1987.

Auburn Dam

In 1967, the Bureau of Reclamation began construction of Auburn Dam on the North Fork American River. At the size then planned, the reservoir would have had a capacity of 2.3 million acre-feet. Work was suspended in 1978, pending completion of additional seismic evaluations and resolution of instream flow issues involving the lower American River.

In February 1984, a State/Federal Auburn Dam Task Force was formed to re-evaluate the project. As the result of revised federal policy, the non-federal share of the cost of federal water projects has increased considerably since the project was authorized. Funding has not been identified to repay these costs. The portion of the project allocated to water supply produces a cost for water that is unattractive to most potential purchasers.

The record flows experienced in the American River system in February 1986 prompted the Bureau of Reclamation and the Department of Water Resources to fund a study by the Corps of Engineers of alternative flood control measures for the lower American River. Results of the Corps' study show total flood control storage requirements on the American River would be 900,000 acre-feet for about the 200-year level of protection. This estimate reflects revised hydrology that incorporates recent rainfall history. The present 400,000 acre-feet of flood control storage in Folsom Reservoir controls only a storm that, on average, could occur once in 63 years, well below the desired level of protection.

The two controlling factors at the Auburn Dam site seem to be the amount of justifiable storage capacity above that needed to protect the Sacramento metropolitan area from flooding, and the amount of financing that can be obtained from the State and the city and county of Sacramento. At the present time, the 2.3-million-acre-foot reservoir is too expensive to finance. A smaller dam providing the required flood control storage, with some additional storage for water supply and power generation, may be an achievable project. A further consideration is that there is substantial opposition from environmental interests to any size dam at the Auburn site that results in a permanent pool of water inundating the channel upstream of the site.

Ground Water Storage

One method to increase the dependable supply of the State Water Project is to store surplus water in ground water basins during years of abundant supply for extraction and use in dry years. Using available ground water storage space has many advantages over construction of a new surface storage facility. Ground water storage results in less evaporation, has a lower capital cost, usually does not require an extensive distribution system, and is generally more environmentally acceptable than surface storage. Also, imported water stored underground would reduce pump lifts for other pumpers in the basin while that water is in storage.

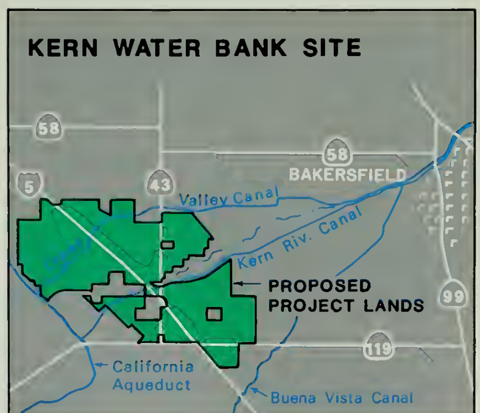
At the height of the record February 1986 storms, Folsom Dam was spilling 130,000 cubic feet per second into the American River, 15,000 cfs more than the design capacity of downstream levees protecting the Sacramento metropolitan area.

One water planner has likened our surface reservoirs to checking accounts and our ground water storage to savings accounts.

To facilitate ground water storage programs for the State Water Project, Senate Bill 187 passed the Legislature and was signed into law by the Governor in 1985. The bill authorizes the inclusion of ground water storage projects south of the Delta into the SWP, subject to (1) a finding of feasibility by the Director of Water Resources and (2) the securing of a contract with the SWP water contractor in whose service area the project is located. SWP system operations studies suggest that significant additional water could be made available through conjunctive use of surface facilities and a ground water storage program.

The Kern Water Bank

The Department of Water Resources proposes to establish a ground water project in Kern County that would permit SWP water to be recharged, stored, and extracted. The project is being developed in cooperation with the local SWP contractor, the Kern County Water Agency. Known as the Kern Water Bank, the project will serve two important functions. First, it will be operated in conjunction with State Water Project facilities and local facilities to increase SWP dependable supplies. Second, its facilities will also be used by local agencies to increase the amount of local water that can be captured and stored.



The Kern Water Bank project is planned in two phases. The first involves acquisition of land along the lower part of the Kern River to build recharge basins and extraction wells. These facilities, which will be used to store and recover SWP water, will complement the existing recharge area operated by the city of Bakersfield. As now planned, operation of the first phase facilities and the city's recharge basin will be coordinated, with SWP water and local water being recharged in either facility when space is available. The project will be operated to avoid adverse impacts on local water supply.

The initial phase of the Kern Water Bank is expected to increase the dependable supply of the State Water Project by about 140,000 acre-feet. Furthermore, the proposed ground water project will make possible the recharge of local water that would otherwise be diverted through the Kern River Intertie into the California Aqueduct or would flood Tulare Lake farmlands. The greater ability to make local exchanges of water, along with elimination of pumping to irrigate property acquired for the project, will reduce regional overdraft.

The second phase of the project will involve recharge of SWP water elsewhere in Kern County by means of in-lieu recharge. This will involve some construction of new surface delivery facilities. In effect, SWP water, when available, will be delivered to ground water users who will reduce their pumpage. The State Water Project will receive ground water storage credits for the reduction of ground water pumping.

Conveyance System Additions

By far the greatest amounts of additional supplies are needed in areas of the State relying on interbasin transfers of water. Enlargement of and additions to aqueducts of the federal CVP and the SWP are looked to for conveying most of the water delivered to meet the increase in needs. In addition, several regional agencies have proposals for adding to their imported supplies. Planned construction or enlargement of some major conveyance facilities is described in the following sections.

The East Branch Enlargement, California Aqueduct

The original capacity allocations in the California Aqueduct provided for The Metropolitan Water District to take delivery of about 72 percent of its maximum annual entitlement via the West Branch (and 28 percent via the East Branch). The reduction of water supply to Southern California from the Colorado River and extensive growth in the eastern part of the MWD service area have resulted in the need for increased capacity to allow a greater share of water deliveries to be made through the East Branch.

Existing capacity of the East Branch is 1,643 cubic feet per second immediately beyond the West Branch, dropping to 1,200 cfs at Devil Canyon Power Plant near San Bernardino, a distance of about 110 miles. As presently planned, enlargement will be carried out in two stages. The first, adding about 750 cfs of capacity, is scheduled to be in operation in 1992. The second, estimated to be needed by 2004, would add another 750 to 933 cfs, depending on the reach involved.

The Coastal Branch, California Aqueduct

Over the past few years, Santa Barbara County, San Luis Obispo County, and DWR have joined in evaluating alternative water supply projects. Among these alternatives are various local water development projects, plus importation of contracted-for SWP water through the authorized Coastal Branch of the California Aqueduct. According to the findings of a 1985 reconnaissance study, the most economical alternatives for meeting future needs in Santa Barbara County were importing SWP water and enlarging Cachuma Reservoir as a local water supply unit of the SWP. For San Luis Obispo County, a 1986 study recommended imported SWP water as the best way to meet projected needs.

Based on these two studies, in 1986 both counties asked DWR to proceed with advance planning studies for the Coastal Aqueduct. These studies should be completed in mid-1989. If the two counties decide to participate in the Coastal Aqueduct, DWR will proceed with final design and construction. The aqueduct is expected to be in operation about 4½ years after final design is initiated. Together, the two agencies have contracted for 70,486 acre-feet of water per year from the State project.

The Nacimiento Pipeline

The Monterey County Flood Control and Water Conservation District completed construction of Nacimiento Reservoir in 1958. In a 1959 agreement, San Luis Obispo County acquired the rights to 17,500 acre-feet of water from the reservoir. About 1,300 acre-feet has been contracted for, to be used in the area around the lake, leaving 16,200 acre-feet available for distribution to other parts of the county.

The East Branch Enlargement, a project to expand the capacity of the California Aqueduct, will bring more water to the eastern part of The Metropolitan Water District's service area.

A pipeline from Nacimiento Reservoir could convey the water farther south within San Luis Obispo County. Assuming the county elects to participate in the Coastal Branch, the Nacimiento supply will not be needed until about 2010.

San Felipe Division of the CVP

The San Felipe Division, with its initial phase completed in the summer of 1987, delivers water from San Luis Reservoir to Santa Clara and San Benito Counties. Facilities may be extended later to serve Monterey and Santa Cruz counties. When fully developed, the project will deliver about 152,000 acre-feet to Santa Clara County and 40,000 acre-feet to San Benito County. About 60 percent of the water delivered to Santa Clara County will be used to recharge the ground water basin. Nearly all the water sent to San Benito County will be used to replace boron-contaminated ground water and to bring agricultural land into production.

American River Aqueduct, East Bay Municipal Utility District

In planning to meet future water needs in its service area, the East Bay Municipal Utility District signed a contract with the Bureau of Reclamation in 1970 for up to 150,000 acre-feet of American River water from the Folsom South Canal. This would supplement EBMUD's Mokelumne River supply. By taking delivery from the Folsom South Canal, EBMUD would minimize treatment costs and provide a continuing supply of high-quality water to customers.

In 1972, the Environmental Defense Fund and others filed a lawsuit that seeks to prevent EBMUD from diverting from the American River. The suit contends that the water should be diverted below the confluence with the Sacramento River so that beneficial uses of the water in the lower American River are not diminished. In late 1984, the court appointed the State Water Resources Control Board as referee, directing it to investigate and prepare a report on the legal, technical, and public trust issues that the suit raised. In mid-1987, the Board began hearing comments on and objections to its staff's recommendation, which sided with EBMUD on the basis of water quality considerations, provided that certain instream flow standards are maintained in the lower American River.

The North Bay Aqueduct of the State Water Project

In 1963, Napa and Solano counties contracted with the SWP for a total of 67,000 acre-feet of water per year on full delivery--25,000 for Napa and 42,000 for Solano. Phase I aqueduct facilities were completed in 1968 to serve Napa County with supplies obtained by interconnection with the Putah South Canal of the federal Solano Project. When Phase II facilities are completed in late 1987, both counties will be able to receive SWP water, and deliveries from the Solano Project will cease. A pumping plant on Barker Slough in the western Delta will lift water into a pipeline extending about 25 miles west, connecting with Phase I facilities near Cordelia. The North Bay Aqueduct will also transport the city of Vallejo's present water supply now being diverted from nearby Cache Slough.

The Mid-Valley Canal Project

Ground water basins in the San Joaquin Valley, primarily along the eastern side within the Central Valley Project's service area, have long been extensively overdrafted. This has occurred because local surface water, imported water, and renewable ground water supplies are inadequate to sustain the irrigated agriculture that has developed on the overlying lands. Overdraft now averages more than one million acre-feet per year.

The need for more conveyance facilities to bring additional water to this area has been recognized for 25 years or more, and various plans have been prepared. In 1984, the Bureau of Reclamation, in cooperation with the Mid-Valley Water Authority and DWR, renewed planning for such facilities. This effort, which involves evaluating and updating earlier plans, is directed toward federal authorization of a project to import an average of about 400,000 acre-feet yearly to offset present ground water overdraft. Mid-Valley interests have agreed that no new land would be brought into production with the project. Construction of the Mid-Valley Canal would also create more opportunity for water banking by both the CVP and the SWP.

Temporary delivery of 150,000 acre-feet of water yearly to the Mid-Valley Canal Water Authority is now under study by the Bureau. This action assumes both direct delivery and exchanges of water with various water districts. It would use capacity available in the California Aqueduct, the Cross Valley Canal, and other existing facilities. No new facilities would be needed.

Interconnections and Water Sharing

The drought of 1976-1977 showed the capability that exists for water sharing and water exchanges through interconnection of existing aqueduct systems. A small but well-known example is the interconnection made to provide water-short Marin County with emergency supplies in 1977. In that instance, surplus water was available in the Colorado River. Together with a wide range of other agencies, The Metropolitan Water District agreed to

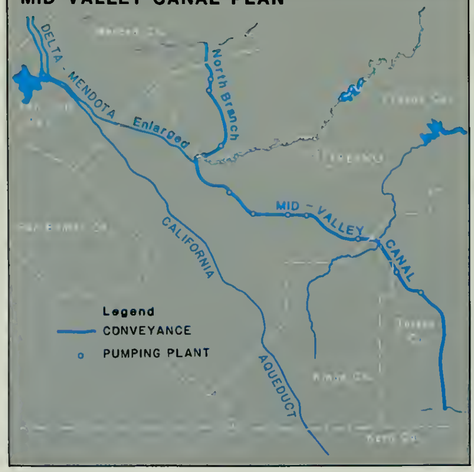
This 63-inch-diameter section of the SWP's North Bay Aqueduct, paralleling Interstate 80 between the Anheuser-Busch brewery and Cordelia Junction, dips slightly to pass under Dan Wilson Creek.

reduce its demand on the SWP and call upon its alternative supply from the Colorado River. (Others included were DWR, the East Bay Municipal Utility District, the Bureau of Reclamation, the State Water Resources Control Board, the Contra Costa County Water District, and the Marin Municipal Water District.) The physical arrangements included the SWP's South Bay Aqueduct, facilities of the cities of San Francisco and Hayward, a new interconnection with East Bay Municipal's facilities, and a new pumping plant built by Marin Municipal in Richmond, discharging into a temporary pipeline laid on the deck of the Richmond-San Rafael Bridge to convey water to Marin Municipal's facilities near San Rafael.

Today in the South Coast region, system interconnections make possible a high degree of water sharing among agencies. The distribution system of The Metropolitan Water District interconnects the SWP's California Aqueduct and MWD's Colorado River Aqueduct. The Los Angeles Aqueduct is also interconnected with MWD's system and the California Aqueduct.

At the State and federal levels, the reservoirs and aqueducts of the CVP and SWP form an interconnected delivery network that can reach more than 75 percent of the State's population.

MID-VALLEY CANAL PLAN



In the agricultural sector, an interim plan for the Mid-Valley Canal service area would enable about 150,000 acre-feet of CVP supplies to be delivered through existing canal systems by means of exchange, transfer, and sharing agreements among the various water agencies in the service area.

A proposal by MWD and the Arvin-Edison Water Storage District, located southeast of Bakersfield, is being investigated by both agencies and potentially affected interests. In this case, MWD would during some years deliver part of its SWP entitlement water to Arvin-Edison, which would use it either for direct spreading or as a surface supply to land that would otherwise have been served by pumped ground water (in-lieu ground water recharge). In exchange, during years when MWD requires additional water, Arvin-Edison would make water available to MWD from its CVP contract entitlement and would meet its needs by using water previously stored underground. MWD would pay for capital additions to Arvin-Edison's water distribution facilities and any additional well capacity or spreading works required to implement the program.

The foregoing examples illustrate that, through creative arrangements, available storage and surplus supplies can be used to help water-short regions of the State overcome their shortages and defer construction involving more costly sources.

Water Transfers

The costs of constructing conventional, large-scale water supply systems have increased greatly over the last two decades, apart from the effect of inflation. Higher costs, along with a steady increase in municipal and industrial water needs, have pressed urban water agencies into looking for supply alternatives. Moreover, some California farmers are experiencing financial difficulties that have forced them to explore other ways of producing income, and some are interested in getting out of water supply contracts entered into in earlier years. Thus, farmers are now giving considerable attention to an option called water marketing, or water transfers, which is the sale or transfer of water or water rights from one user or use to another.

One result of interest in water marketing or water transfers was the enactment in 1982 of the first California legislation aimed specifically at allowing water transfers to take place. Assembly Bill 3491

(Katz) directs the Department of Water Resources and the State Water Resources Control Board to encourage voluntary transfers of water and water rights, and permits water agencies to sell, lease, exchange, or otherwise transfer water that is surplus to the needs of agencies' water users. Transfers are limited to a seven-year period. The act allows agencies to sell, lease, exchange, or otherwise transfer reclaimed or conserved water, and authorizes the Board to issue a conditional, temporary order changing a point of diversion, place of use, or purpose of use from that specified in a permit. (Subsequent legislation related to water transfers and water marketing is listed in Chapter 11.)

As with many "new" ideas, the concept of water transfers has actually been around a long time. When Los Angeles bought out the farmers in Owens Valley early in this century, the purpose was to acquire their water. Other small, often less controversial transfers have taken place throughout the State over many years.

In some situations, water transfers should prove to be a viable alternative to water development projects. They can be a means of using available supplies more efficiently. However, transfers are being approached cautiously. Adverse economic and environmental effects, water rights questions, and third-party impacts must be addressed when effecting a transfer.

Ideally, a market system should improve the lot of both buyer and seller. The buyer should gain by acquiring something needed at a favorable cost; the seller should gain by receiving more in return than would be obtained by retaining the resource. However, there is concern that such transactions may not adequately compensate those not directly involved in the buying and selling process (farm laborers, food processors, and retailers, for instance). Market transfers can realize efficiencies; however, equity questions can arise, including the treatment or nontreatment of instream uses.

Questions are also being raised over whether a market concept would really result in the highest and best use of the resource. It may be more a sign of comparative purchasing power among sectors than an optimum use pattern for the benefit of the whole society. The urban sector, for example, could probably outbid agriculture for a given water supply, but water used to irrigate lawns or wash cars could be regarded as having less economic and social value than water used to produce food.

To date, it appears that a true "market" is unlikely to evolve on a statewide basis in California. However, the fact that water managers and water constituent groups have begun to think in "market" terms has already led to numerous innovative suggestions for water transfers and water sharing. In late 1986, DWR published a catalog listing 30 different proposals that were known of at that time. More ideas are sure to surface as time passes.

DWR will be publishing a guidebook in 1988 to assist those interested in transferring water. The guide will outline the approvals required and offer suggestions on how such approvals can be obtained. DWR is also available to provide technical assistance on specific transfer proposals.

New Technology for Increasing Water Supplies

California's water agencies and research institutions have for many years devoted considerable effort to investigating means of augmenting water supplies by various technological approaches. The following sections describe the present situation regarding the potential for these sources or methods.

Waste Water Reclamation

Important benefits can be gained by reclaiming and reusing water that would otherwise be disposed of. Using water more than once is a conservation measure, and it can also defer or eliminate the need to develop new fresh-water supplies. When a municipal waste water collection system nears flow capacity, enlargement can be postponed by reclaiming the water in a satellite treatment plant near the place of use. Similarly, when an ocean outfall system reaches discharge capacity, reclamation and reuse of a treatment plant's effluent may lower the outflow and defer system expansion.

Reclaimed water in California is used for various purposes -- among them crop and landscape watering, industrial cooling, and ground water re-

A 10-year, multiagency research project in Monterey County confirmed the safety of using reclaimed waste water to irrigate food crops.

charge. Industries sometimes recycle water at a facility to recover heat or materials, to save water, and to eliminate the cost of discharge to a municipal system. Waste water can be treated to drinking-water quality, but the higher cost of such treatment makes this step less feasible when water of equal quality is available from other sources.

More treated municipal waste water is now produced in this State than is being reclaimed; however, water reclamation and reuse are on a gradual upswing. In 1985, about 250,000 acre-feet of reclaimed water from municipal sources was put to direct beneficial use. Urban water managers continue to seek suitable locations to replace drinking-quality water with treated municipal waste water for such applications as landscape and crop irrigation. The greatest potential for wider use exists in the coastal areas of Southern California where hundreds of thousands of acre-feet of treated water are discharged to the ocean every year. Statewide use of reclaimed water could reach 500,000 acre-feet per year by 2010 under favorable conditions.

Some factors stand in the way of the growth of water reclamation projects. The principal difficulty is that opportunities for direct application are often situated far from the point of supply, and the added cost of conveyance facilities and separate distribution systems increases the price of the reclaimed water above that of alternative fresh-water sources. Further, in many such projects, the users are expected to repay the full cost.

Acceptance by the public and the health authorities is another factor. Surveys have shown that water users are often willing to rely on the judgment of their water utility officials, and where uncertainty is present, educational and public relations efforts help consumers to more readily support reuse of treated waste water. Use of reclaimed water to recharge ground water basins may increase significantly, as concerns about public health effects and the cost of additional water treatment are resolved.

Watershed Management

Watershed management can protect developed supplies by reducing sediment accumulation in reservoirs and increasing streamflow by controlling the growth of vegetation. By reducing the density of shrub and tree cover and allowing grasses to grow back naturally, vegetative water use is reduced and runoff increases. Where reservoirs catch and store the increased runoff, water supplies are augmented. Water supplies gained by such means, although small in relation to total runoff, can cost less than supplies developed by building new reservoirs. However, extensive areas would have to be managed to significantly increase statewide water supplies. Vegetation management is now being used principally to improve range, reduce wildfires, and enhance wildlife habitat.

Weather Modification

Research has established that rain and snow from clouds with the right moisture and temperature characteristics can be greatly increased by weather modification. Many investigators believe that average annual precipitation might be increased by about 15 percent. Weather modification has been conducted along the western slopes of the Sierra Nevada and some of the Coast Ranges for several years. However, precipitation will increase only when storm clouds are present to be treated, which means that the technique is more successful in years of near-normal rainfall. Weather modification is most effective when combined with vegetation management to prevent shrubs and trees from taking up the additional precipitation.

A recent DWR study determined that weather modification was a feasible method of augmenting water supplies and hydroelectric energy production for the State Water Project. The area investigated was the Feather River watershed above Lake Oroville. A project is being designed with the objective of increasing snowpack during years when reservoir storage space is available. An operation plan and environmental assessment report will be developed for the project in 1987–1988.

Desalination

The possibility of finding an economical way to desalt ocean water and brackish water has intrigued engineers, politicians, and the public for many years. Much research has been done and, in some parts of the world, desalting is an important source of water. Unfortunately, it is still too expensive for all but a few places and situations in California. Present desalting processes can remove high percentages of organic and inorganic constituents from water, including sea water. Moreover, fresh water obtained from desalting processes can be tailored (by careful selection of process type and design) to meet the water requirements of almost any beneficial use. Worldwide, desalting capacity is about 3 billion gallons per day in 3,500 plants. In the United States, about 750 desalting plants have a combined capacity of 212 million gallons per day. In California, desalting is used to reclaim brackish ground water, desalt sea water, and treat water for industries such as the electronics industry that require process water of high purity.

The principal limitation of desalting is its high cost, which is directly linked to its high energy requirement. In California, this cost factor has greatly restricted the use of desalination. Of the various desalting techniques, the membrane processes (reverse osmosis and electrodialysis) offer the best potential to further reduce costs and thus increase use. Extensive research is being conducted in the private and public sectors to improve the performance of membranes used to remove salt from water. Future improvements in the various distillation methods of desalting are likely to be less significant than those related to membrane desalting.

In California, desalting technology has five viable uses:

(1) Reverse osmosis and electrodialysis membrane desalting of brackish ground water can be used to supply drinking water. This may or may not be related to the brackish nature of the water but may instead be a case in which a particu-lar constituent (natural or otherwise) must be re-moved to meet health or other standards. In the Arlington ground water basin in Southern California, a project is in the planning stage to desalt about 6,000 acre–feet of local ground water a year, and in Orange County, a 1–million–gallon–per–day reverse osmosis demonstration plant is being con-structed. At both sites, the major water quality concern is high nitrate concentrations in the local ground water, a desalting application that is likely to find wider acceptance as new, more efficient membranes are developed.

(2) Reverse osmosis can be used to reclaim domestic waste water before it is recharged into ground water basins. The best example of this in

Banks of reverse osmosis units remove salts from brackish municipal waste water for the Orange County Water District at its Water Factory 21.

California is the Orange County Water District's Water Factory 21, which treats 15 million gallons of waste water a day in an advanced waste water treatment and desalting plant and injects it into the local ground water basin.

(3) As water pollution standards become more stringent, California industries can use desalting to meet discharge requirements. In the San Joaquin Valley, the olive-processing industry, whose discharges are heavily saline, is studying desalting as a method of reducing waste water and supplementing its process water supplies.

(4) Throughout the State, many industries use desalting to develop process water required for manufacturing paper, pharmaceuticals, certain foods, and electronic components.

(5) Finally, sea-water desalting is used at locations such as the Pacific Gas & Electric Company's Diablo Canyon Power Plant, where a sea-water reverse osmosis plant provides in-plant water. In the San Joaquin Valley, many agencies have studied the disposal of brackish agricultural drainage water for decades. DWR has investigated reclamation of agricultural drainage water by reverse osmosis since the early 1970s. Discovery of selenium in this water and the ill effects this constituent has on aquatic wildlife have increased interest in reclaiming drainage water, rather than discharging it to the ocean or estuary. In California, the potential exists to reclaim several hundred thousand acre-feet of drainage water per year through a combination of desalting, salt-harvesting, and power production from salt-gradient solar ponds. Studies on these activities are continuing.

Although the use of desalting to supplement water supplies will continue to be guided by local circumstances, it is likely to increase as the costs of more conventional water supplies rise and the expense of desalting (particularly reverse osmosis and electrodialysis) decreases.

Long-Range Weather Forecasting

Accurate advance weather information -- extending weeks, months, and even seasons ahead -- would be invaluable in planning water operations in all types of years -- wet, dry, and normal. Had it been known, for instance, that 1976 and 1977 were to be extremely dry years or that the drought would end in 1977, water operations would have been planned somewhat differently and the impacts of the drought could have been lessened.

The potential benefits of dependable long-range weather forecasts could probably be calculated in hundreds of millions of dollars, possibly even in billions. The value would be national. For this and other reasons, research programs to investigate and develop such forecasting capability would most appropriately be conducted at the national level. The National Weather Service and the Scripps Institute of Oceanography are engaged in making such forecasts. However, their predictions are not sufficiently reliable for project operation.

Deferred Projects

For environmental, economic, or financial reasons, some reservoir projects once seriously considered for construction have been deferred. Prominent among these are Enlarged Shasta Reservoir, the Marysville Reservoir Project, the Glenn Reservoir Project, and diversions from the Eel River.

Shasta Lake Enlargement

In recent years, the Bureau of Reclamation and the Department of Water Resources have studied the feasibility of enlarging Shasta Dam. One alternative studied was to increase the height of the existing dam by 200 feet, which would enlarge the reservoir's storage capacity from the present 4.5 million acre-feet to 14 million acre-feet and increase the dependable water supply by about 1.4 million acre-feet per year. However, even though the unit cost of water would be relatively low, the capital cost would be substantial, and California's water interests have concluded that other needs should take priority over the additional storage of an enlarged Shasta Lake. These needs include developing more offstream storage south of the Delta, solving San Joaquin Valley drainage problems, and planning for the expansion of the CVP aqueduct system in the San Joaquin Valley (the Mid-Valley Canal). As a result, the Bureau shifted its planning emphasis toward conveying and protecting the quality of existing supplies before developing new supplies. DWR, responding to growing recognition among water contractors of increasing project costs, shifted its planning to smaller, less expensive projects.

Marysville Dam and Reservoir

Marysville Reservoir on the Yuba River, originally authorized as a Corps of Engineers project in the 1960s, was not developed by the Corps, and in 1982 the proposal was reanalyzed as a possible local project of the Yuba County Water Agency in partnership with the Kern County Water Agency.

Later, DWR investigated a multipurpose project to provide power, flood control, and additional conservation yield for the SWP, by using the Corps' plan for the Parks Bar and Dry Creek Dam sites (about 15 miles upstream of the city of Marysville) and updating the construction cost estimates with 1985 values. In 1981, the voters of Yuba County rejected a bond issue for this project. Because of the apparent high unit cost of water from the project and the lack of local support, the proposal is currently inactive.

Glenn Reservoir Project

During the 1960s and 1970s, the State studied various possibilities for developing storage reservoirs on Thomes Creek and Stony Creek on the western side of the Sacramento Valley. Three different reservoir sites were considered for various sizes, combinations, and configurations. These were the Paskenta, Newville, and Glenn reservoirs. Under one routing of Eel River imports, the reservoir(s) would have been used to store water from the North Coast. With the slowdown in agricultural demands, and the prospect of more favorable alternatives, planning for these projects has been deferred indefinitely.

Eel River Exports

The California Wild and Scenic Rivers Act, enacted in 1973, precluded development of many of the North Coast's major streams. The act also provided that the Department of Water Resources, after an initial 12-year period, would report on the need for water supply and flood control projects on the Eel River and its tributaries.

On August 30, 1985, DWR reported by letter to the Legislature: "Based upon the situation today, we see no reason to seek legislation to withdraw the Eel River from the Wild and Scenic River's System. This is a decision to be considered by future generations." The letter also said: ". . . it is our view that we would not look to the Eel River as a practical source of additional water supply within the near future, irrespective of its wild and scenic river status. Possible projects in the Central Valley appear more favorable at this time than development of the Eel. . . . Given California's water situation, it seems neither appropriate nor possible for one generation to fully determine or bind the actions of a future generation. It is certainly possible society may eventually wish to develop the Eel River. However, for today, maintenance of the status quo seems appropriate; that is, leave the Eel in the Wild and Scenic River System, subject to future review."

WATER DEVELOPMENT BY LOCAL AGENCIES

6

As pointed out in the previous chapter, much of the future growth in statewide water demand will be met from the joint facilities of the CVP–SWP system. More than 75 percent of the State's population can be served from the system. Nevertheless, communities not connected to the State and federal facilities are experiencing growth, and they will, in most cases, meet their water needs through some type of local project. And even communities served by the joint system often find it in their interest to develop some portion of their future needs from local sources.

Local sources of fresh water exist in much of California, but, because many potential sites for new dams and reservoirs are environmentally sensitive and difficult to develop, the cost of developing them tends to be prohibitive. Rural communities are particularly hard hit because their ability to repay loans for new water projects is limited. For years, the sale of hydroelectric power generated by dam and reservoir projects often helped offset much of the construction cost. More recently, some water project proponents have also attempted to sell a portion of a project's developed water supply on an interim basis to offset costs even further. Currently, however, the power market is very competitive, and opportunities to sell interim water are scarce.

Despite economic and environmental obstacles, local water agencies are proceeding with plans to develop new sources of water and power. Furthermore, because of the constraints on traditional surface water development in California, some agencies are using other ways to help meet their increasing water needs, including conjunctive use of surface and ground water, waste water reclamation, water conservation, and transferring and exchanging water with other agencies. Some water agencies have obtained financial assistance for local water development projects from grants and low–interest loan programs made available through the Davis–Grunsky program, approved by California voters in 1960, and the State's Safe Drinking Water programs, beginning with another voter–approved measure, Proposition 3 (1976) and continuing with Propositions 28 (1984) and 55 (1986). Local water conservation and ground water recharge projects are provided financial assistance under Proposition 44, authorized by the voters in 1986.

This chapter discusses proposed local water development in various parts of California.

North Coast Region

The North Coast region has California's wettest climate, with annual rainfall averaging from 40 inches to well over 100 inches. The region is also home to more than 1,200 miles of State and federally designated wild and scenic rivers. This abundance of water has historically supported the timber, fishing, and recreation industries, which form the economic base of the region.

Today, the region's most pressing water resource problems are not so much the availability of water as the quality of water supplies. Major storage facilities such as Lake Pillsbury on the Eel River and Ruth Lake on the Mad River contribute to the turbidity of water supplies during dry or critical years when flows into the low reservoirs cut through the deposits of silt. Additionally, sedimentation of these reservoirs appears to be occurring faster than

New Spicer Meadow Reservoir in Calaveras County is being enlarged by the Calaveras County Water District as part of its North Fork Stanislaus River Project.

expected. This trend will eventually reduce available water supplies.

To address the siltation problem, a task force has been formed by the Eel–Russian River Commission. It will determine the source of the sedimentation problem and what can be done to reduce it.

The Smith River coastal plain is expected to develop rapidly in response to construction of a new State prison at Fort Dick. The Departments of Water Resources and Fish and Game are currently studying the water supply and wildlife habitat impacts of the prison.

Other north coastal communities, such as Orick on Redwood Creek, rely on shallow ground water developed on floodplains for local water supplies. These shallow aquifers provide for a natural filtration of the sediment–laden North Coast rivers. In these communities, the quality of water supplies is again the foremost concern because septic leaching and well contamination are becoming more prevalent.

In the Humboldt Bay area, 40 percent of the local water supply is used by pulp mills. During a drought, the mills are forced to curtail their use of water to maintain an adequate domestic water supply. Other communities, such as Willits, are looking to further development of ground water supplies to meet their expanding needs.

Sacramento Valley

The Sacramento Valley receives ample water supplies from Sierra Nevada streamflow and ground water basins underlying the valley. Over the years, local water needs have been met by direct stream diversions, construction of storage reservoirs, and ground water pumping. In the future, however, urban and agricultural growth could require the development of additional water storage projects. Proposed projects under consideration include:

- The Garden Bar reservoir project (on the Bear River above Camp Far West Reservoir), proposed by the South Sutter Water District, which would develop a new firm water supply and generate hydroelectricity. It has been proposed that part of the water and all of the power generated by this project be sold to other agencies.

- The Blue Ridge reservoir project on Cache Creek, proposed by the Yolo County Flood Control and Water Conservation District, which would greatly increase local surface water storage and allow Yolo and Solano counties to meet anticipated water demands beyond 2000. It would also facilitate flood control at Clear Lake and provide major flood control along lower Cache Creek.

San Francisco Bay Area

The North Bay region has traditionally received water from local streamflow, where annual rainfall averaging 20 to 40 inches is normally sufficient to meet regional demands. During the 1976–77 drought, however, the region's water supplies were dangerously depleted, strict water rationing became mandatory, and a temporary pipeline was laid across the Richmond–San Rafael Bridge to import emergency supplies. Since then, to augment its available supplies, the Marin Municipal Water District has constructed Soulajule Dam and enlarged its Kent Lake facility to increase surface water storage. This district is also changing its contract with the Sonoma County Water Agency (SCWA) for Russian River water from an interruptible supply to a firm supply. The North Marin County Water District is negotiating with SCWA to increase its water supply from the Russian River.

In the South Bay region, water demands long ago exceeded local water supplies. Consequently, the city of San Francisco and the East Bay Municipal Utility District (EBMUD) have relied on Sierra Nevada water sources, while Contra Costa Water District (CCWD), under contract with the U.S. Bureau of Reclamation, has taken its water from the Sacramento–San Joaquin Delta. The SWP also supplies water to the eastern and southern portions of the region.

Today, the development of urban areas immediately surrounding San Francisco Bay has stabilized, but suburban areas farther out are growing. EBMUD has contracted with the Bureau of Reclamation to divert water from the American River -- a contract currently being litigated to determine the point of diversion. Alameda County Water District

Soulajule Reservoir, Marin County, was enlarged to 10,700 acre-feet in the late 1970s by the Marin Municipal Water District to help fill growing needs in its service area. "Soulajule," from the coastal Miwok Indians, loosely translates as "filled cradle."

is now analyzing alternative water supply sources because, by 2000, its water requirements are expected to surpass existing reserve supplies. CCWD is actively considering the Los Vaqueros reservoir project to improve water delivery reliability and water quality in its service area. This project could be expanded to help other Bay Area water agencies meet their growing water needs. Finally, current projections by the San Francisco Water Department (SFWD) indicate that additional water, beyond the amount provided by the Hetch Hetchy Aqueduct, will be needed by the late 1990s. Accordingly, SFWD has begun a two-year resource study to analyze water needs and water management alternatives for San Francisco.

Central Sierra Nevada and Foothills Region

The central Sierra Nevada is well known for its Mother Lode region and the great gold rush that began there in 1849. That quest for gold led to some of the earliest development of California's surface water supplies, resulting in construction of widespread ditch and flume systems to divert the water from high Sierra streams needed for hydraulic mining. Some of these systems remain in use today.

Many wooden flumes such as this were built in the Sierra Nevada to carry water for gold mining. Some of these early-day structures are still used for irrigation.

As a result of accelerating population growth, many Sierra Nevada foothill and mountain communities are experiencing water quality problems, deteriorating water systems, and water shortages. As evidenced during the 1976–77 drought, when many local communities were forced to adopt severe water rationing programs, surface water systems in this region lack adequate storage to serve as dependable sources of water. Furthermore, due to the region's geologic formations, characterized by fractured rock, ground water supplies are largely unreliable. Consequently, local water supplies fluctuate widely.

To protect their individual water rights and voice their collective water needs, 11 Sierra Nevada counties have formed the Mountain Counties Water Resources Association. Currently, the association is pursuing legislation to provide financial support for local water supply development. The Department of Water Resources has provided the association information on water development planning and is working with individual counties to estimate future water needs. Several Sierra Nevada water and power development projects (mostly consisting of dams and reservoirs) are now in the planning or construction stage, including these:

- The North Fork Stanislaus River Project, being built by the Calaveras County Water District, is scheduled to be completed by 1990. The project, which is primarily a power generating facility, will initially provide 5,000 acre-feet of "new" water annually, as well as serve as a continuing source of revenue when operations begin. The Northern California Power Agency will purchase the hydroelectric power developed.

- The South Fork American River Project could provide El Dorado Irrigation District with up to 30,000 acre-feet of water a year to augment its current inadequate supplies. Generation of hydroelectric power would help pay for the project. Inability to obtain financing has left the future of this project uncertain.

- The Middle Bar (Mokelumne River) Project, now under consideration by the Amador County Water Agency, would include construction of a 434,000-acre-foot-capacity reservoir and an 80-megawatt powerhouse. The water supply developed would serve western Amador County. This proposal is the focus of considerable environmental controversy.

- The Devil's Nose (Mokelumne River) Project, now being studied by the Amador County Water Department for local water and hydroelectric production. This project, which could yield 35,000 acre-feet of water annually to help Amador County meet future needs, is also encountering environmental difficulties.

Besides these projects, the Cosumnes River Water and Power Authority is considering building as many as six new dams to provide Amador, El Dorado, and San Joaquin counties with more water and electric power. Recent planning called for each county to receive 10,000 acre-feet of nonfirm water in Stage I, and 20,000 acre-feet of firm water in Stage II. This project is experiencing difficulty in obtaining financing.

Also, at the request of the Legislature, the Georgetown Divide Public Utility District in El Dorado County and DWR are analyzing various future water supply alternatives for the Georgetown area.

San Joaquin Valley

For more than a century, San Joaquin Valley water users have depended on runoff from eastside streams and ground water from local wells to meet their water requirements. Water agencies such as the Turlock, Modesto, and South San Joaquin irrigation districts have constructed reservoirs and power plants in the Sierra Nevada foothills, along with extensive canal systems, to enable valley farmers to supplement ground water supplies with surface water. More recently, the CVP and the SWP have added canal systems to import surface water for agricultural areas in the valley.

Even with these extensive surface water supply projects, however, many of the valley's ground water basins have remained in a state of overdraft. Some water agencies have been able to contract with the SWP or CVP to import surface water into overdrafted areas. The Kern County Water Agency is developing new ground water banking programs (discussed in greater detail in Chapter 5).

Also under consideration by valley water officials is a joint proposal by the Kings River Conservation District and the U.S. Army Corps of Engineers to raise the height of Pine Flat Dam on the Kings River. Additional storage capacity resulting from this project would be an alternative to the proposed controversial Rodgers Crossing reservoir sited on an environmentally sensitive stretch of the Kings River. In recently proposed federal legislation to designate a major portion of the Kings River as wild and scenic, the Rodgers Crossing site is included in a Special Management Area to be administered as though it were part of the National Wild and Scenic River System.

Two other reservoir enlargements are being studied by the Corps of Engineers at the request of local water supply agencies. Success Reservoir on the Tule River would be increased in capacity from 85,000 acre-feet to 106,000 acre-feet by redesigning the spillway. Negotiations are under way with Lower Tule River Irrigation District to share the cost of the feasibility study. On the Kaweah River, Lake Kaweah would be expanded in capacity from 150,000 acre-feet to 193,000 acre-feet by increasing the height of Terminus Dam 21 feet. The Corps is also studying a flood detention dam on nearby Dry Creek that would be operated in conjunction with Lake Kaweah to increase flood protection for the city of Visalia. The Kaweah Delta Water Conservation District would share the cost of the proposed feasibility study.

Central Coast Region

Historically, the Central Coast region has relied on local ground water supplies and a few reservoirs to meet its water use requirements. Recently, however, population increases in portions of this region outside the service areas of existing or planned SWP or CVP delivery systems are creating water demands that existing supplies cannot meet. Proposals to augment supplies include the Monterey Peninsula Water Management District's plan to construct a new dam just downstream of San Clemente Dam on the Carmel River to increase surface water supplies for the cities of Carmel, Monterey, Pacific Grove, and Seaside.

In the Salinas Valley, the Monterey County Flood Control and Water Conservation District is studying various means of combating sea-water intrusion into coastal ground water aquifers that is caused by heavy ground water pumping. Under consideration

San Clemente Dam, built in 1921 on the Carmel River, Monterey County, would be inundated by a proposed 29,000-acre-foot reservoir to serve the Monterey Peninsula.

are plans to (1) use Salinas River water instead of local ground water to irrigate crops near Castroville and (2) import ground water from wells located south of Salinas for municipal use at Fort Ord and the community of Marina.

In nearby Pajaro Valley, the Pajaro Valley Water Management Agency is reviewing results of ground water studies that identify local overdraft problems. The agency is also examining its need for supplemental water.

South Coast Region

The South Coast region, with its semiarid climate and intermittent rivers, relied principally on ground water supplies through the late 1800s and early 1900s. As the region's population expanded, however, water demands rapidly outstripped local water supplies. The city of Los Angeles was first to look to the importation of water to meet increasing water needs. In 1913, it began to import water from the eastern side of the Sierra Nevada. Despite this farsightedness, the city and other local water agencies soon needed additional water. This need led to the formation of The Metropolitan Water District of Southern California (MWD), which eventually imported water from the Colorado River to meet the region's growing demands. And, most recently, the SWP has been added to move Northern California water into the region.

Today, continued growth in the South Coast region is creating demands for water exceeding current supplies. Thus, many local water agencies are seeking to supplement their current supplies.

MWD has a number of water supply augmentation projects under evaluation. The loss of 662,000 acre-feet of annual Colorado River entitlement water and delays encountered by the SWP in efforts to augment SWP supplies have prompted MWD to explore various means of obtaining more water. MWD recognizes that not all the projects can be expected to be developed.

Included with projects under study are water conservation and transfer programs in cooperation with:

- Imperial Irrigation District, which could provide MWD with an additional annual water supply of possibly 250,000 acre-feet per year.

- Palo Verde Irrigation District, which could create for MWD a dry-year supply of Colorado River water up to 100,000 acre-feet.

- The U.S. Bureau of Reclamation, which could conserve up to 117,000 acre-feet of water per year by lining the All-American Canal and the remaining 38 unlined miles of the Coachella Canal. Only about 34,000 acre-feet per year is needed for an obligation to Mexico.

Besides these water conservation and transfer programs, MWD is investigating the feasibility of storing in Lake Mead portions of its Colorado River entitlements in years when surplus water is available from the SWP. MWD could also pump, as a one-time use in emergencies or during a water shortage, about 500,000 acre-feet of ground water currently banked in the Coachella, Chino, and San Gabriel basins. Replenishment of such a supply would depend on availability of surplus SWP or Colorado River supplies over several years.

Farther south, the Fallbrook Public Utility District and U.S. Marine Corps representatives at Camp Pendleton have been proposing for many years construction of a dam and reservoir on the Santa Margarita River to provide local residents with increased water supplies. Another local water agency, the San Diego County Water Authority, proposes to build Pamo Dam, on Santa Ysabel Creek, which would store 130,000 acre-feet of emergency water supplies. (Of that amount, 100,000 acre-feet would be specifically set aside for use during a drought or after a major earthquake, either of which could disrupt aqueduct deliveries for several months.) Most of the water stored behind this dam would be pumped from the San Diego Aqueduct. Start of construction of the dam has been delayed until environmental issues have been resolved.

About 25 miles from San Diego, near Escondido, Ramona Water District is building Ramona Dam, which will be able to store 11,000 acre-feet of imported water to augment existing supplies. This water, like the Pamo Dam supplies, would also be valuable in a drought or the aftermath of a large earthquake.

Artist's rendition of proposed Pamo Dam in San Diego County. The reservoir would store emergency supplies pumped from the San Diego Aqueduct.

THE SACRAMENTO-SAN JOAQUIN DELTA

Probably no water problems in California have involved more investigations or generated more controversy than those involving the Delta of the Sacramento and San Joaquin rivers. The maze of islands and channels lying at the confluence of these two large rivers has become the focal point for a wide variety of water-related issues. Many different interests have a vital stake in the Delta: farmers, fish and wildlife, environmentalists, boaters, navigation, railroads, highways, and the people and industries that receive their water from the two large export systems, the Central Valley Project and the State Water Project.

The Sacramento–San Joaquin Delta, an area of 700,000 acres, was once a tule marsh fed by winter floodwaters, snowmelt, and tidal flows entering through San Francisco Bay. During flood season, the Delta became a great inland lake; when the floodwater receded, the network of sloughs and channels reappeared throughout the marsh.

Reclamation of the Delta began in the 1850s. By 1930, virtually all the marsh had vanished, to be replaced by farms growing barley, corn, pears, asparagus, and tomatoes. Many miles of entirely new channels had been dredged, and farmlands, small communities, highways, and utilities were protected -- often tenuously -- by 1,100 miles of levees, many of them built on peat soils.

Export of water directly from the Delta first took place in 1940 with the completion of the Contra Costa Canal, a unit of the Central Valley Project. In 1951, water was being exported at the CVP's Tracy pumping plant, supplying the Delta–Mendota Canal. The State Water Project began pumping from the southwestern Delta in 1967, and pumping from the northwestern Delta into the North Bay Aqueduct will begin late in 1987.

The future need for improved water transfer efficiency across the Delta resulted in the U.S. Bureau of Reclamation constructing the Delta Cross Channel between the Sacramento and Mokelumne rivers in 1951 to protect the quality of its Delta–Mendota exports. When the State Water Project's Delta pumps came on line in the late 1960s, it was recognized that facilities would eventually be required in the Delta to improve water transfer efficiency and to control salinity caused by tidal inflow entering the western Delta. The need and authorization for these facilities was recognized in the Burns–Porter Act, approved by the voters in 1960.

However, specific proposals to accomplish these objectives have generated much controversy, and agreement has not been reached upon the best approach to mitigating deteriorating conditions in the Delta. As a consequence, throughout this time -- since export pumping began -- conditions in the Delta have stagnated or worsened. Fisheries declines are well documented, although the causes are not yet fully understood. Water quality continues to be a major operational problem. And Delta levees continue to fail at an accelerating rate. No one seems satisfied with today's conditions, and a consensus appears to be evolving that some form of channel improvements is needed. At this writing, DWR is moving ahead with environmental impact evaluations for alternative improvements in both the southern and northern Delta.

Looking west across the farms and waterways of the Delta. Sycamore Slough is in the foreground.

SACRAMENTO
YOLO
SOLANO
SAN JOAQUIN
CONTRA COSTA
T.8N.
T.7N.
T.6N.
T.5N.
T.4N.
T.3N.
T.2N.
T.1N.
T.1S.
T.2S.
T.3S.
R.1E.
R.2E.
R.3E.
R.4E.
R.5E.
R.6E.
R.7E.
LINE OF SEGREGATION
First Standard Line North.
WESTERN PACIFIC RAILROAD
Dry Creek
GRAND ISLAND
TYLER ISLAND
STATEN ISLAND
ANDRUS
BRANNAN ISD
TWITCHELL ISD
BOULDIN ISD
SHERMAN ISLAND
SAN JOAQUIN RIVER
ULPINOS
LOS
HILLS
ROBERTS ISLAND
UNION ISLAND
RANCHO DE LOS FRANCESES
RANCHO EL PESCADERO
BASE LINE U.S.S.
Scale Two Miles to one Inch.
MAP
SHOWING THE LANDS
OF THE
TIDE LAND
RECLAMATION COMPANY
DIRECTORS
ROBERT WATT
Land of T.L.R.Co. Designated by Red Color.
COMPILED & DRAWN
BY
J. T. GIBBES
1869.

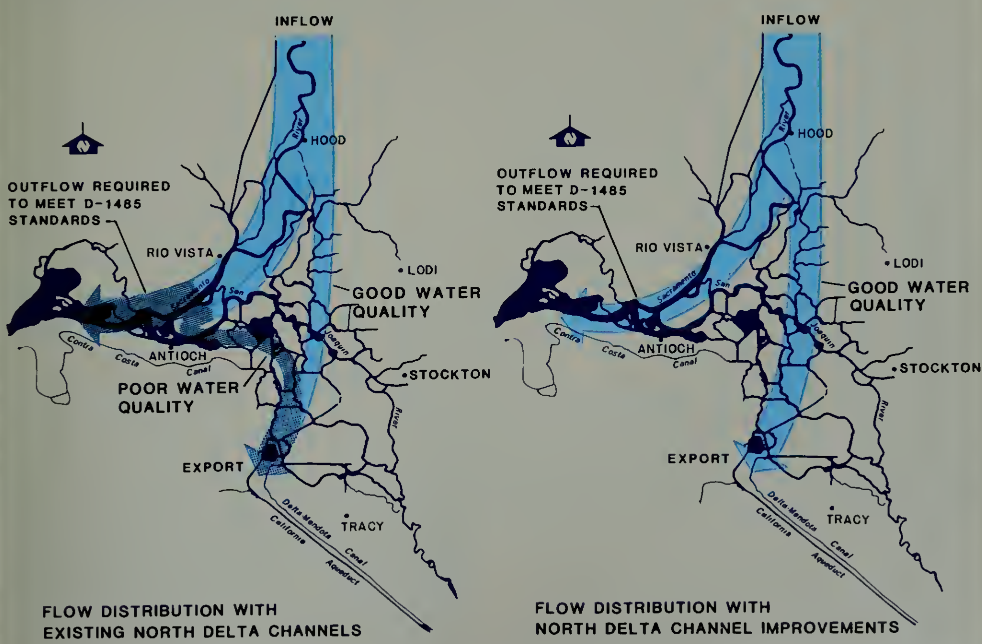
Reverse Flows

The expression "reverse flows" has come to be used to characterize a Delta problem that stems from the lack of capacity in certain channels. Water supplies for export by the CVP and the SWP are obtained from surplus Delta flows, when available, and from upstream reservoir releases, when Delta inflow is low and surplus flows are unavailable. These releases enter the Delta via the Sacramento River and then flow by various routes to the pumps in the southern Delta. Some of these releases are drawn to the SWP and CVP pumps through interior Delta channels, facilitated by the CVP's Delta Cross Channel. Unfortunately, because the channels aren't large enough, insufficient amounts of water pass through the northern Delta channels.

The remaining water flows on down the Sacramento River to its confluence with the San Joaquin River in the western Delta. When fresh-water outflow is low, water in the western Delta becomes brackish because it mixes with saltier ocean water entering as tidal inflow and is drawn upstream into the San Joaquin River and other channels by the pumping plants. Reverse flow disorients migratory striped bass, salmon, and steelhead. Reverse flow further increases the impacts on fish by pulling small fish from the western Delta nursery area into the pumping plants. The massive amount of water driven in and out of the Delta by tidal action dwarfs the actual fresh-water outflow and considerably complicates the reverse-flow issue.

Reverse flow could be moderated or eliminated by increasing the transfer efficiency of the northern

FLOW DISTRIBUTION, WITH AND WITHOUT REVERSE FLOWS



Delta Cross Channel, shown here under construction in the 1950s, diverts Sacramento River water to the Mokelumne River. The water then flows across the Delta to the export pumps near Tracy.

Delta channels. Also, water supply for the SWP would be considerably increased. Currently, during the operational periods that cause reverse flow, more water than is needed for export must be released from project reservoirs to repel intruding sea water and to maintain required water quality in western Delta channels and meet export quality standards. The amount of extra outflow required is substantial. An efficient means of transfer through the northern Delta would make better use of upstream fresh-water storage, and the SWP could gain up to 400,000 acre-feet more per year in dependable supply. Delta fisheries and Delta water quality would also benefit.

Levees and Channels

With each passing year, the fate of the Delta islands becomes more uncertain. Today the centers of some islands are as much as 25 feet below sea level because of a continuing loss of peat soil from oxidation, compaction, wind erosion, and other causes. As a result, the forces for levee failure keep mounting. There is a constant threat of earthquakes in or near the Delta that may detrimentally affect levees or may cause them to fail. Moreover, farm economic difficulties have limited the financial ability of the reclamation districts to adequately maintain and improve levees. Levee failures have become common. Since 1980, there have been 24 such occurrences. Nearly all the islands involved have been reclaimed.

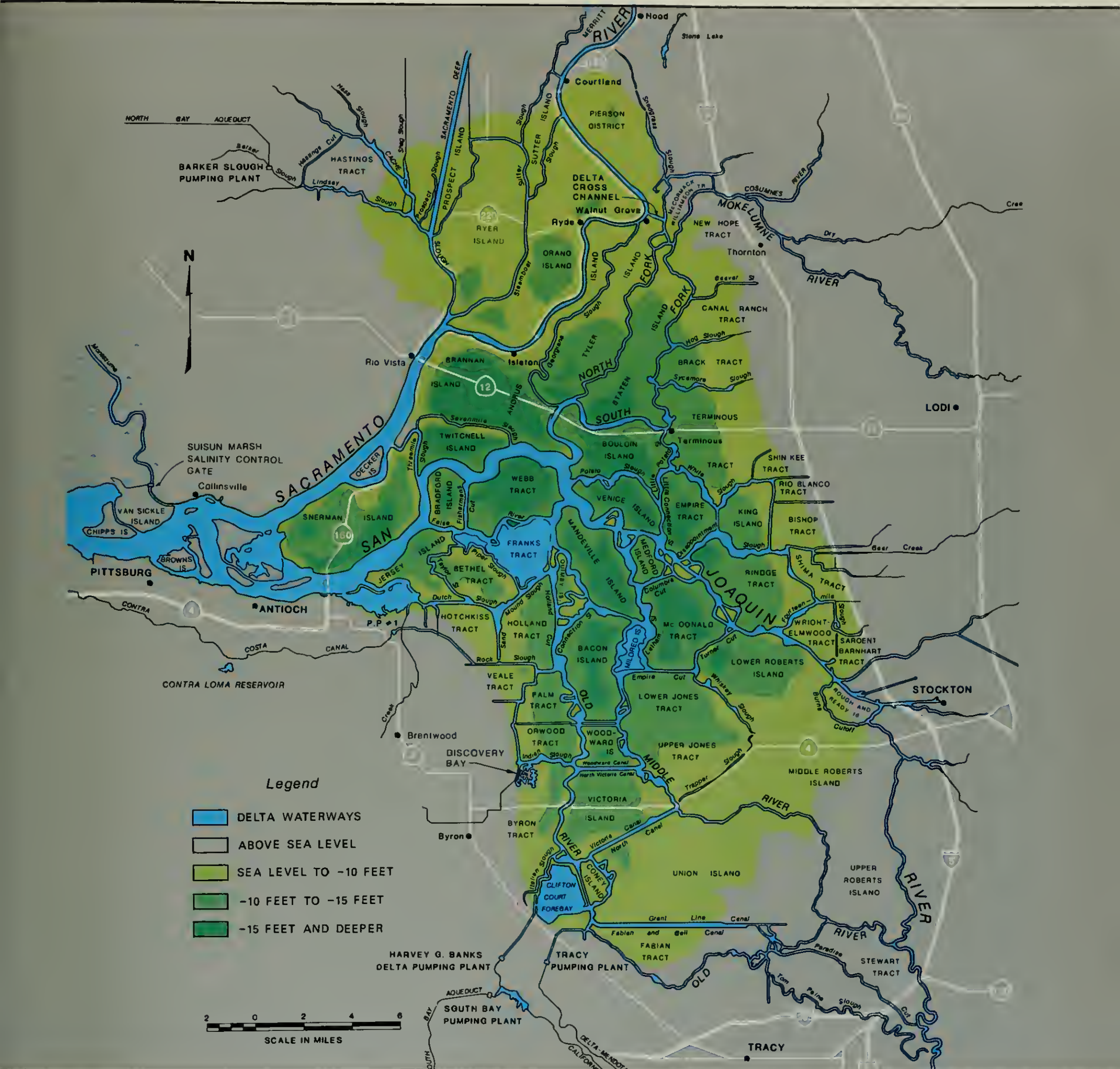
Protection of certain islands from flooding is particularly important because of the threat to life and property, the presence of utilities and highways, and water quality degradation from the potential intrusion of brackish water. As directed by the Legislature, DWR is currently studying the effects of levee failures on highways and water supplies.

Long-term water supply problems could occur when a Delta levee breaks, if an island were allowed to remain flooded and no remedial action were taken. Evaporation from a flooded island exceeds the consumptive use of an equivalent area of irrigated farmland by about one or two feet per year. This increase would require the State and federal water projects to release more upstream water from storage to repel salinity intrusion. Permanent flooding of certain islands in the western Delta (where brackish water and fresh water meet) could increase the upstream movement of ocean salts, requiring the projects to provide more outflow to repel the salts and maintain water quality in the Delta and at the pumps.

From 1980 to 1986, about $100 million was spent on maintenance, repair, and rehabilitation of Delta levees.

LAND SURFACE BELOW SEA LEVEL

SACRAMENTO – SAN JOAQUIN DELTA



The State administration is supporting legislation in the 1987–1988 session that would provide $100 million over a 10-year period to initiate a levee rehabilitation program. Some of the money would be disbursed through subventions and a portion would be spent by DWR on levees of particular significance.

Lack of adequate channel capacity in certain locations also aggravates flood problems. Channel restrictions on the South Fork of the Mokelumne River contributed to the flooding of five northern Delta islands and tracts in 1986. It appears that channel enlargement would provide major flood control benefits and would also significantly alleviate conditions causing reverse flows in the western Delta during the critical late spring and summer months. This is being addressed in the northern Delta planning efforts now getting under way and discussed later in this chapter.

Fisheries and Diversions

The Delta fishery is affected by inflow that is reduced by upstream uses, by diversions that bypass the Delta, and by direct diversions from the Delta itself. Direct diversions include those by industry in the western Delta; 1,800 local agricultural irrigators; the North Bay and Vallejo aqueducts, serving the North Bay area; the Contra Costa Canal, serving the southern San Francisco Bay Area; and the

Delta levees are often battered by high tides, heavy river flows, and wind-driven waves, particularly in winter. This Jersey Island levee withstood heavy weather and high water during December 1983.

southern Delta diversions by the CVP and SWP, which serve the southern Bay Area, the San Joaquin Valley, and Southern California.

This 46-pound striped bass was caught in the Delta south of Decker Island in September 1987.

Fish screens and protection facilities have been constructed for the North Bay and Vallejo aqueducts, the CVP's Tracy Pumping Plant, and the SWP's Harvey O. Banks Delta Pumping Plant. Also, water rights for the CVP and SWP mandate that exports be curtailed during certain months to protect the fishery and that flows be maintained for protecting the Delta environment. Other protection includes screens and special mitigation measures for the Pacific Gas and Electric Company's powerplant diversions in the western Delta. Even with these measures, the need for more protection is evident, because some Delta fisheries continue to decline.

In December 1986, with the aid of environmental groups and State project contractors, DWR signed an agreement with the Department of Fish and Game that will further offset direct losses caused by SWP pumping. The agreement, discussed further in Chapter 11, provides fishery mitigation sufficient to allow DWR to complete the Banks Delta Pumping Plant by installing four additional pumps. That project is discussed in Chapter 5.

Other efforts to understand and improve the fishery resource include the Interagency Ecological Studies Program, which involves participation by the Departments of Water Resources and Fish and Game, the Water Resources Control Board, the U.S. Bureau of Reclamation, the U.S. Fish and Wildlife Service, and the U.S. Geological Survey. Elements of the program are directed to fisheries, water quality, fish facilities, the Suisun Marsh, and San Francisco Bay. About $60 million has been expended on this program alone over the past 25 or more years. To date, State Water Project water users have funded about $30 million of this study and the Bureau of Reclamation has contributed $11 million. Apart from the interagency ecological studies, some $10 million has been allocated for the Fisheries Restoration Program, administered by the Department of Fish and Game, to correct fisheries problems caused by projects other than the SWP and CVP.

Water Quality

Salinity in the Delta is related to the amount of Delta outflow into San Francisco Bay. Decision 1485, adopted by the Water Resources Control Board in 1978, contains water quality standards to protect Delta uses from excessive salinity intrusion. A very important concept is that the rights of the SWP and the CVP to export water from the Delta are subject to maintaining the Delta standards as a base condition.

Export water quality concerns today tend to center on agricultural, urban, and industrial waste discharges, and sources that provide the potential for formation of trihalomethanes (THMs). THMs are chemicals formed in drinking water when chlorine used in water treatment processes reacts with natural substances found in Delta water. These substances include organic acids from the decay of plants and peat soils in the Delta and bromides, which are salts of sea-water origin. THMs are a matter for concern because they are suspected carcinogens. Lessening reverse flows will lower the level of THMs in the export water by reducing the bromides carried by the reverse flows. THMs are discussed further in Chapter 8.

Local Delta Uses

Local Delta water use is protected by a number of measures, such as the Delta Protection Act, the Watershed Protection Law, water rights, and the Coordinated Operation Agreement (see Chapter 11). Additional agreements provide protection in connection with specific local problems.

Project operations sometimes cause problems for Delta farmers by lowering water levels, disrupting circulation patterns, and lowering water quality. At times, diversions also cause erosion of channels and levees when channel capacities are too small for the amount of water passing through them. DWR has negotiated long-term agreements with the North Delta Water Agency and the East Contra Costa Irrigation District to protect agricultural uses. More recently, DWR entered into an agreement with the South Delta Water Agency and the Bureau of Reclamation to construct interim facilities and to develop long-term solutions for the agency's water supply problems.

The Bay-Delta Hearings

Legal obligations to protect Delta water quality and beneficial uses must be recognized in all water resources planning in the Delta. These obligations now exist in the Water Resources Control Board's Decision 1485. The Board began hearings in July of this year to review the relevant Bay and Delta Water Quality Control Plans and water right permit conditions of diverters of Delta water supplies, including the SWP and CVP. New water right decisions resulting from these hearings are scheduled for 1990. In the meantime, DWR is moving ahead with planning to help resolve water problems relating to fisheries, water quality, and flood protection. (The Bay-Delta hearings are discussed further in Chapter 10.)

Delta Planning

Planning for Delta improvements has been under way since the late 1800s. An 1874 report by the Army Engineers suggesting use of surplus Sacramento Valley water to irrigate both the Sacramento and San Joaquin valleys influenced Col. Robert B. Marshall, a topographer with the U.S. Geological Survey and author of a comprehensive state plan for water development issued in 1919. Our present State water system includes many of Marshall's ideas. Reviewing the plan in 1926, the California Water Resources Association commented: ". . . whatever plan the Department of Public Works may recommend, [it] must . . . make some feasible and satisfactory recommendation covering the extremely grave problem of salt water encroachment in the Delta . . . . This is one of the most vital considerations before the people of California today . . ."

Current efforts are focused on Delta levee rehabilitation and water management in the southern and northern parts of the Delta. DWR, the Corps of

DELTA AGRICULTURE

Intensively managed farm operations typify Delta agriculture. Total cash receipts in 1979 showed crop production ($331 million) was about 3 percent of the State total ($12.7 billion). Delta agriculture is a major part of the agricultural economy of Sacramento, San Joaquin, and Contra Costa counties.

Water for irrigation is taken from Delta channels in more than 1,800 separate diversions. During the irrigation season, these diversions require flows of up to 5,000 cubic feet per second.

Records for 1924 through 1977 show significant changes in both acreage planted and relative acreage per crop. The most apparent trends were:

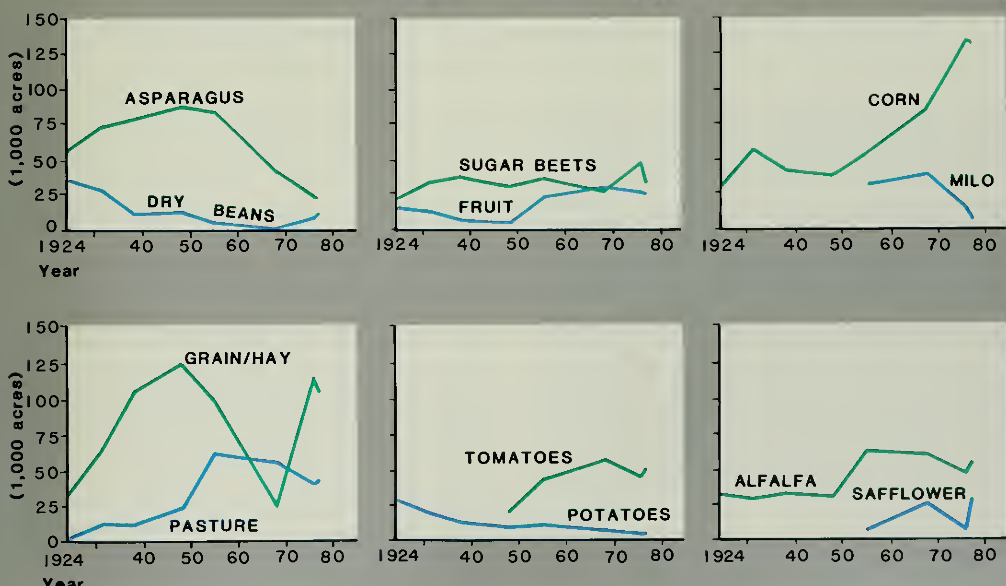
- **Except for tomatoes, acreages of truck crops, asparagus, and potatoes showed a large decrease.**
- **Processing tomatoes became a major Delta crop after 1948.**
- **Fruit crops declined and then increased substantially during the early 1950s..**
- **Grain/hay and field corn have become the dominant crops.**
- **Pasture and alfalfa acreage increased.**

Engineers, and local interests are working to develop a long-range answer to the levee problem. Both the Federal Emergency Management Agency and the State Office of Emergency Services are reluctant to spend more money on disaster relief in the Delta without a comprehensive plan and commitment by the State. In developing a plan, it is appropriate to consider alternative approaches to dealing with the levees. The problem of subsidence is of particular concern in some Delta areas.

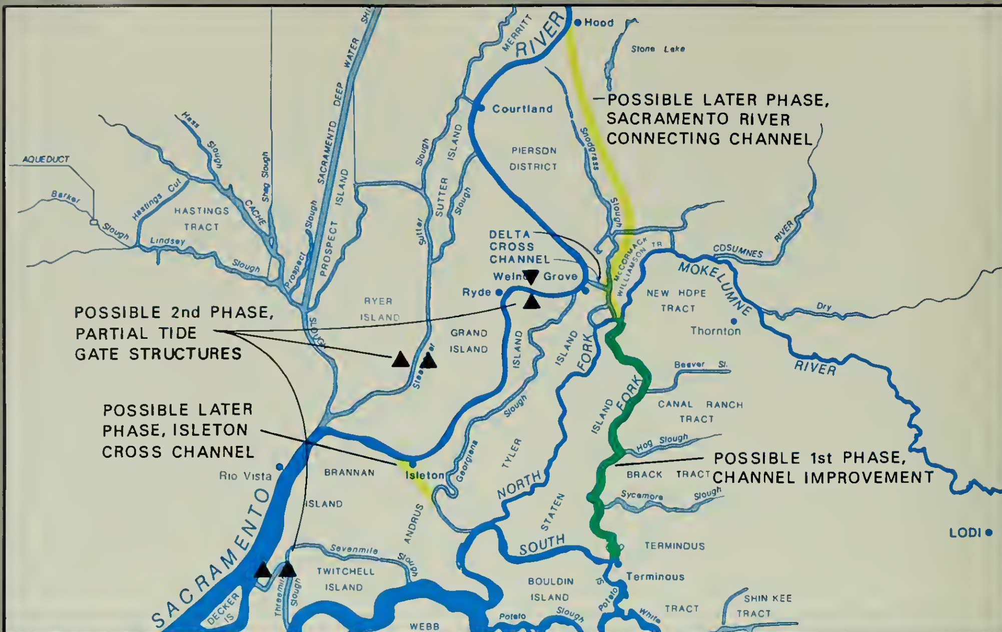
In April 1987, DWR and the Bureau of Reclamation conducted public meetings to discuss southern Delta water management issues. This planning activity is being initiated under the October 1986 South Delta Agreement among the Bureau, DWR, and the South Delta Water Agency that committed all three parties to work together to develop mutually acceptable, long-term solutions to the water supply problems of water users in the southern Delta. Objectives of the agreement are to improve and maintain water levels, circulation patterns, and water quality.

Evaluation of alternatives to meet these objectives will also take into account broader objectives of the Bureau and DWR being pursued in connection with the Delta region concerning fisheries, overall efficiency of SWP and CVP operations, navigation, and flood protection. Some alternatives to be considered in the southern Delta include dredging and channel improvements; channel flow control structures; relocation of the Contra Costa Canal intake; changes to Clifton Court Forebay, including a new intake gate or relocation of the intake and enlargement of the forebay; and interconnection of the CVP with the forebay. Effects on the southern Delta of a Corps of Engineers permit to allow

MAJOR DELTA CROPS



NORTH DELTA ALTERNATIVES



A temporary rock weir, installed by DWR in Middle River in early April 1987 and removed in late September, increased the depth of water at pumps used for irrigation diversions. The south Delta interim facility is planned for use again in 1988.

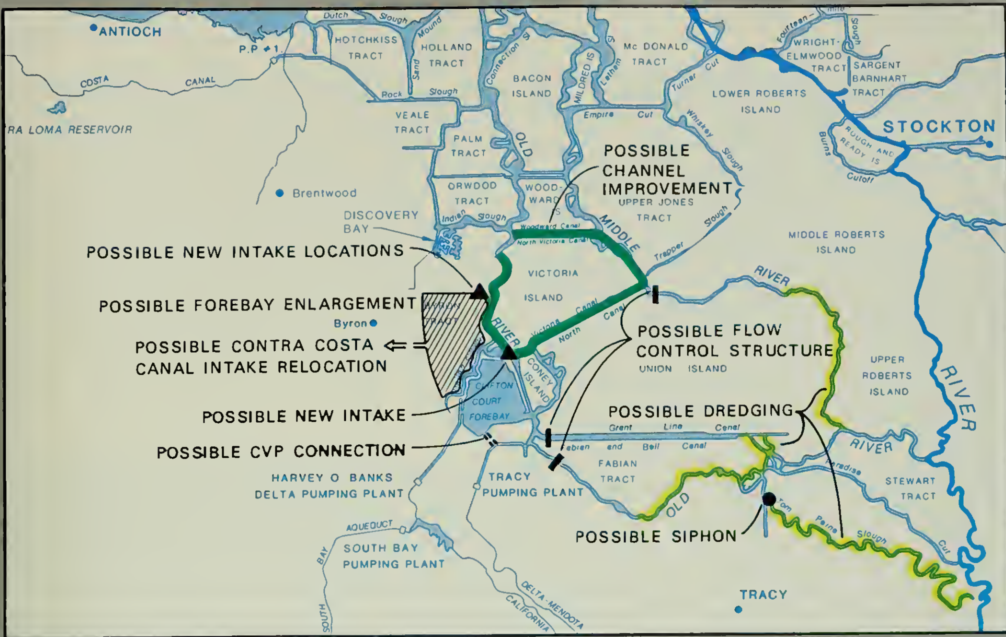
greater flows for south-of-the-Delta water banking and other storage programs will also be examined.

In addition, DWR is looking at a possible conjunctive use program with local interests for use of New Melones water, which would allow the SWP to take the water during dry years, while improving water quality in the southern Delta. Under this program, good quality New Melones water would be released to the San Joaquin River, a tributary to the southern Delta.

Today's planning effort in the northern Delta is proceeding about six months behind southern Delta planning. Public involvement began in August 1987. Northern Delta planning will focus on providing flood protection for islands along the lower Mokelumne River, reducing fisheries impacts, and improving transfer efficiency of federal and State project water across the Delta.

One promising possibility for the northern Delta is a phased program that would start with enlargement of the South Fork of the Mokelumne River. This appears to provide major flood control benefits for

SOUTH DELTA ALTERNATIVES



the area, which includes the five northern Delta islands and tracts that flooded in 1986. It would also significantly reduce reverse flows in the western Delta in late spring and summer, which are critical months for striped bass.

In the western Delta, DWR and the North Delta Water Agency signed a contract in 1981 to protect water supply and water quality in the agency's service area, including Sherman Island. Their agreement provided for a future overland water supply facility for the island. This long-proposed facility and possible alternatives are presently under study.

One alternative is a wildlife management plan for the island. The Department of Fish and Game is evaluating acquisition of waterfowl easements, marsh management requirements, likely costs and revenues, funding sources, and benefits to waterfowl populations. If it were coordinated with other Delta planning, the wildlife management plan could develop a number of significant benefits for wildlife and for flood control. A draft report will be completed in early 1988.

Isolated Channel

Certainly the most controversial water project in California in many years was the proposed Peripheral Canal. This would have been a 43-mile new channel extending from Hood on the Sacramento River to the export pumps near Tracy. After many years of debate, it was effectively rejected at the June 1982 election as part of a water legislation package that had been put on the ballot by referendum. For the foreseeable future, the concept of constructing an entirely new channel to carry the export water appears to be "on the shelf."

Nevertheless, many technical experts believe that at some time it may be necessary to go back to the concept of an isolated channel for water transfer. They argue that the advantages for water quality, fish and wildlife, and export reliability are sufficient to make the idea viable. Given the overwhelming vote against it in Northern California of more than 9 to 1, this seems unlikely, unless conditions or circumstances in the Delta should change significantly. For now, no planning resources are being devoted to this concept.

Federal Regulations

One final observation about Delta planning is that it is becoming more and more apparent the federal government will play a much greater role in determining what is ultimately done than was thought in the past. The facts that the Delta is an estuary, is a navigable waterway, includes wetlands, and has valuable anadromous fisheries make it subject to a number of significant federal laws. These are briefly mentioned here as they relate to the Delta. They are outlined in some detail in Chapter 11. In essence, the Corps of Engineers administers a regulatory program for wetlands and navigable waterways that requires a permit be obtained for any improvement or facilities an agency might undertake in the Delta. Virtually nothing can be done to resolve Delta problems by construction that does not require a permit from the Corps of Engineers. Over the years, activities necessary to obtain a permit have evolved into a very substantive process. Full environmental documentation with a federal environmental impact statement is required for most actions.

The Delta: California's water supply crossroads is also a major recreation area that attracts thousands of people every year.

Although the Corps of Engineers administers the permit process, federal law requires full coordination with the various environmental agencies, such as the Environmental Protection Agency, the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the California Department of Fish and Game. This can become a highly complex process, particularly when there is potential for impacting rare and endangered species. One result of this interaction among agencies governed by different laws is that obtaining a permit requires extensive negotiations. It would be exceedingly difficult to "force" a conclusion by the political process. The only effective approach is to patiently negotiate one step at a time.

A compaction recorder to measure deep soil subsidence in the Delta was installed by DWR in May 1987 on Bacon Island, where peat is now about 12 feet thick. A free-standing 2-inch steel pipe, footed in concrete 440 feet below ground, extends to the surface inside a 6-inch casing. A cable connects the pipe to a drum recorder. As sediments between the surface and the stationary lower end of the pipe settle and compact, the pipe will appear to rise slowly from the casing and the differential movement between pipe and ground surface will be recorded as subsidence. Correlating this movement with surface elevation will provide the amount of subsidence. A nearby installation is measuring shallow subsidence.

SUBSIDENCE IN THE DELTA

Most of the land and levees in the Delta are subsiding, a continuous process in which the surface of the land declines. Subsidence is a matter for concern because it jeopardizes the stability of the levee system and increases the chances of island flooding.

Subsidence is caused by any of several natural occurrences: oxidation of organic soils, wind erosion, the withdrawal of water and natural gas, tectonic movement, or consolidation. Shallow subsidence lowers the surface in the interior of an island. The causes are oxidation and erosion of the organic soils. Deep subsidence lowers the island surface when the porosity of the inorganic sediments below the organic soils is reduced. Reduced porosity can occur naturally or it can be caused by ground water pumping from wells.

The Delta's peat soil has subsided at least 3 feet around the anchor blocks of the East Bay Municipal Utility District's Mokelumne Aqueduct.

The levees are affected by a third type of subsidence that is caused primarily by the consolidation of organic materials making up the foundation of a levee. As a levee settles, the weight of new material added on top to ensure flood safety presses down, causing further consolidation and settling and lowering of the levee.

Measuring rates of subsidence and determining its causes requires two types of information: accurate determination of land surface elevation and differentiation of shallow and deep subsidence. Surface elevation can be measured by conventional surveying methods and by use of earth-orbiting satellites. Shallow and deep subsidence are identified by a compaction recorder (see photo at left).

WATER QUALITY

Quality is a crucial measure of a water supply's usefulness. California is a relatively recent culture whose water resources were not severely stressed by potential pollution until the post–World War II population rise. By the time the State was industrializing, there was already a respectful awareness of the problems associated with water pollution. As early as the 1940s, California began to carry out programs to protect its water resources. As a result, many water treatment facilities were built to safeguard people from water quality problems caused by disease organisms. Efforts were also made to keep dissolved minerals, commonly known as "salts," from reaching unacceptable levels.

In recent years, however, we have discovered that our general success in maintaining clean water supplies in California has not been totally effective. Increasing attention is now being focused on constituents other than disease organisms and dissolved salts that affect the usefulness of the State's water supplies. It is apparent that potentially toxic chemicals constitute a widespread threat to our water resources.

A host of manufactured toxics has entered the environment over the past 50 years, but the environmental hazards associated with the use of many of these substances was not generally recognized until recently. As a result, toxic control efforts have sometimes lagged -- in part because analytical methods were not, until recently, sophisticated enough to analyze the chemistry of water samples at levels low enough to detect toxic substances.

As analytical methods have improved, so has our knowledge of California's toxic water pollution problems. Unfortunately, however, the ability to detect toxic chemicals at ultra–low concentrations has not been accompanied by a full understanding of the health implications posed by these pollutants. Increased concern has, though, resulted in valuable research into methods of treating water to remove toxics. For example, research has indicated that granular activated carbon and ozonation can remove a wide variety of organic pollutants from drinking water. Therefore, while the health effects of some toxic substances may not be fully understood, it will probably be possible to treat drinking

Up to 1986, Kesterson Reservoir was the terminus for water collected from some of the underground agricultural drainage systems in the San Joaquin Valley. Collection system and reservoir were closed when drainage water containing selenium was found in concentrations harmful to birds and mammals. A multi-agency State-federal program is now working on the overall valley drainage problem.

Drainage from Walker Mine in Plumas County, June 1986, carries high levels of copper–zinc–iron compounds into Dolly Creek, then to Little Grizzly Creek. Abatement efforts are being pursued.

water for removal of these substances. This whole subject is progressing month by month, and it is likely that effective clean-up technologies will be developed within a very few years.

Water quality concerns affect both surface and ground water supplies in California, and water quality problems involving salinity and other common pollutants have been the subjects of numerous reports issued by DWR and other State agencies. Much less has been written about toxic problems. While only about 5 percent of California's developed water supply is used inside homes, this domestic supply affects us directly because we use it for drinking, bathing, and preparing food. The rest of this chapter emphasizes recent concerns over toxicants in our domestic water supplies.

Surface Water Quality

Overall, the quality of California's surface water is very good. Nevertheless, quality problems (both natural and man-made) do exist in some of the State's surface water supplies. Recently, for example, there has been an increased public awareness of diseases in humans caused by the naturally occurring organism, Giardia. This organism is

Sophisticated laboratory instruments can identify extremely small concentrations of synthetic organic chemicals. The gas chromatograph/mass spectrometer at DWR's water quality laboratory is one of the newer weapons to combat toxic environmental pollution.

To identify and determine concentrations of synthetic organic chemicals, water samples containing organic pollutants are vaporized at high temperature and then separated by passing the hot gasses through long, thin glass tubing. The gas emerging from the far end of the tubing is bombarded by atomic particles, causing organic pollutants to fragment. A detector senses the fragment patterns, which are the "fingerprints" of the pollutants. Next, a computer compares these patterns to patterns of thousands of known chemicals stored in the computer memory. By this means, more than 30,000 individual synthetic chemicals can be identified.

The sensitivity of measurement varies, depending on the specific chemical being analyzed. Concentrations as small as, or even smaller than, one part chemical to one billion parts of water can usually be measured. To put this ratio in perspective, an individual drinking from a water supply containing one part per billion of a chemical would consume only about one drop of the substance during a lifetime.

DWR's experimental salt-gradient solar pond near Los Banos is demonstrating that highly concentrated brines from saline agricultural drainage, collected in outdoor ponds and heated by the sun, can generate electricity. Hot brine is pumped into a heat exchanger, where it heats liquid freon to vapor that drives a turbine, spinning a 10-kilowatt generator. Half-acre pond at left, with a wave-suppression grid, was built in 1985. The generator has operated since May 1987.

sometimes found in mountain streams that are practically free of human-caused pollution and, fortunately, it can be removed from water by conventional treatment.

In some areas of California there are locations where toxic metals derived from mineral deposits are dissolved into surface water supplies. This problem is not always the result of human activity. Usually, though, activities such as mining and road building have exposed mineral deposits to flowing water and caused them to dissolve and cause environmental problems farther downstream.

In terms of volume, the State's most important surface drinking water supplies are the Sacramento–San Joaquin Delta and the Colorado, Sacramento, and San Joaquin rivers.

Sacramento–San Joaquin Delta

The Delta is a water source for agencies that provide drinking water to approximately 15 million Californians, and as such it can probably be considered the State's most valuable surface water supply. Additionally, the Delta supplies water that helps support agricultural lands in the Delta itself and in the Sacramento and San Joaquin valleys. Water quality concerns in the Delta related to

Serpentine, California's state rock, is a commonly occurring natural source of asbestos. Rainwater washing over exposed rocks can raise asbestos concentrations in runoff to high levels. White striations are fine fractures in the rock.

When serpentine breaks up, fragments splinter into minute white asbestos fibers that are invisible to the unaided eye. Water can appear clear and yet be heavily loaded with these fibers, a half-million of which, placed side by side, would equal one inch. Concentrations of asbestos are measured in millions of fibers per liter of water. This sample has been magnified 30,000 times.

drinking water can be traced to a number of potential sources, including:

- Possible salinity intrusion into the western Delta from San Francisco Bay.
- Waste water discharges sometimes contain disease organisms and chemical pollutants.
- Agricultural drainage water may contain pesticide residues and other toxic agents.
- Storm drainage water can contain traces of gasoline, oil, rubber, asbestos, lead, and pesticides.

The quality of Delta water has been extensively monitored by DWR, the Department of Fish and Game, and other State and federal agencies. Until the last few years, however, most of this monitoring focused on ecological concerns and sea-water intrusion problems.

Since 1983, DWR has directed a multiagency monitoring program to test Delta water for constituents harmful to human health. Results to date indicate that Delta water supplies contain very low levels of pesticides and industrial chemicals that are well within safe drinking water guidelines. Selenium levels have also been well within established drinking water criteria.

The primary concern over drinking water taken from the Delta relates to trihalomethanes, or THMs. These chemicals occur in drinking water when chlorine used for disinfection comes into contact with certain natural materials such as decayed vegetation (peat soil, for example) and bromides (salts of sea-water origin). Both of these agents are important to THM formation, and DWR is studying the sources of THM-forming materials in Delta water.

Because THMs are suspected carcinogens, the U.S. Environmental Protection Agency has established a limit on the levels of THMs that may be present in drinking water. This standard is now under review, and it is not clear whether it will be lowered in the next two or three years. Several methods are available to treat water to keep THMs within the present standard, but a lot of research is being done on the issue.

Sacramento River

Pesticide use in the Sacramento River watershed is extensive. For the past few years, in springtime, Sacramento River water taken by the city of Sacramento and treated for drinking has at times had a chemical odor and taste traceable to herbicides used in rice farming.

Although the concentrations of these chemicals in drinking water are not considered harmful to human health, some Sacramento residents have reacted strongly to the odor and taste problems. Accordingly, the Water Resources Control Board, the Regional Water Quality Control Boards, and the Department of Food and Agriculture are establishing a more restrictive control program to regulate the entry of these substances into the Sacramento River. Despite occasional problems caused by toxic pollution, the river supports migratory fish, and its water quality is acceptable for recreational and other uses.

San Joaquin River

During the summer, a large part of the flow in the San Joaquin River is made up of agricultural drainage. This water consists partly of excess irrigation runoff from fields and partly of flow from underground tile drainage systems in the valley. Pesticides in measurable concentrations are not generally present in the subsurface drainage, but they sometimes occur in the excess surface drainage and reach the San Joaquin River.

DWR monitors drainage water for pesticides and other agents that may limit the usability of Delta water for domestic applications. Pesticide monitoring includes inventorying of types and quantities of chemicals in use in the watershed so that most of the pesticides that might be present are specifically tested for.

The table on the preceding page summarizes data collected for eight pesticides during 1985 and 1986. The information gained indicates the extent to which agricultural drainage received by the San Joaquin River influences the quality of water in the Delta. The "San Joaquin River, near Vernalis" column presents the results of sampling at a point at which the river flows into the Delta. Any pesticides that have entered the river from the San Joa-

PESTICIDE MONITORING DATA AT REPRESENTATIVE DELTA SAMPLING STATIONS, 1985 AND 1986

(IN MICROGRAMS PER LITER)

Target Pesticide; Sampling Date	Detection Limits	Lindsey Slough	Sacramento River, Green's Landing	Empire agric. drainage	San Joaquin River, near Vernalis	Banks Pump. Plant	Delta Mendota Canal Intake	Mallard Island	Action Level
2,4-D salt									
7/85	0.1		◆	◆	◆	0.1	◆	◆	--
8/85	0.01		◆	◆	◆	◆	◆	◆	--
12/85	0.01			◆				◆	--
5/86	0.5			1	◆				--
Bentazon									
7/85	0.1		1.6	◆	◆	0.3	◆	◆	--
8/85	0.2		◆	◆	◆	0.5	◆	◆	--
12/85	0.5			◆				◆	--
5/86	1			◆	◆				--
Chloropicrin									
7/85	0.1	◆	◆	◆	◆	◆	◆	◆	50 †
8/85	0.1	◆	◆	◆	◆	◆	◆	◆	50 †
12/85	0.1		◆	◆	◆	◆		◆	50 †
5/86	0.1			◆	◆				50 †
Copper									
7/85	5	7	7		11	11			--
8/85	5	15	◆	6	◆	6	◆	◆	--
12/85	5		5	13	8	◆		8	--
5/86	5			◆	◆				--
Methyl parathion									
7/85	2.5		◆	◆	2.5	◆	◆	◆	30
8/85	1		◆	◆	◆	◆	◆	◆	30
12/85	0.01			◆				◆	30
5/86	0.005			◆	◆				30
Molinate									
7/85	1	1	◆	◆	◆	◆	◆	◆	20
8/85	0.5	◆	◆	◆	◆	◆	◆	◆	20
12/85	0.05			◆				◆	20
5/86	0.05			◆	◆				20
Thiobencarb									
7/85	8	◆	◆	◆	◆	◆	◆	◆	10 †
8/85	1	◆	◆	◆	◆	◆	◆	◆	10 †
12/85	0.05			◆				◆	10 †
5/86	0.05			◆	◆				10 †
Xylene									
7/85	0.2	◆	◆	◆	◆	◆	◆	◆	620
8/85	0.5	◆	◆	◆	◆	◆	◆	◆	620
12/85	0.4			◆	◆				620
5/86	0.2			◆	◆				620

Other target pesticides that were not detected in the samples and for which no action level has been set: Carbofuran, dacthal, D-D mixture, MCPA, metalaxyl, methamidophos, methyl bromide, and paraquat dichloride.

◆ = Not detected.

† = Tentative recommended action level. The action level fo taste and odor threshold is 1.0 micrograms per liter for thiobencarb and 37 micrograms per liter for chloropicrin.

Absence of values or symbols means no analysis was performed for that chemical.

quin Valley are detectable at this location. On the basis of these findings, the San Joaquin River is shown to be only slightly affected by pesticides. Where pesticides were detected, their concentrations were found to be well within established safe drinking water standards.

Besides pesticides in surface water runoff into the San Joaquin River, there is also concern over naturally occurring chemicals that may be present in tile drainage systems in undesirable concentrations. Levels of boron, arsenic, molybdenum, mercury, cadmium, chromium, nickel, zinc, copper, and manganese in the river are being measured and their sources evaluated. It is not clear at this time whether the San Joaquin River contains selenium concentrations that have harmed -- or are likely to harm -- fish and wildlife. The State Water Resources Control Board and the Central Valley Regional Water Quality Control Board are establishing water quality objectives and waste discharge regulations for the San Joaquin River basin to protect the river and the Delta from harmful constituents of agricultural drainage.

Colorado River

Excessive salinity concentrations have long been recognized as one of the major water quality problems of the Colorado River, which provides municipal and industrial water to nearly 14 million people and irrigates 700,000 acres of farmland. The river's heavy salt load is derived from both natural sources and human activities, each contributing about half the total amount. An estimated nine million tons of dissolved salts pass Hoover Dam each year, causing California water users an estimated $100 million in annual damages. Without measures to control it, salinity in the lower reaches of the river will continue to cause major water quality problems.

In 1975, the seven Colorado River Basin states, with the Environmental Protection Agency's approval, adopted water quality standards for river salinity at three stations: 723 milligrams per liter below Hoover Dam, 747 milligrams per liter below Parker Dam, and 879 milligrams per liter at Imperial Dam. Current studies show that, without control measures, salinity could reach 1,000 milligrams per liter at Hoover Dam by 2010.

To adhere to the adopted standards through 2010, about 1.1 million tons of salt per year must be prevented from entering the river. To do this, control activities are being conducted under a federal–state program authorized by Congress. Work began in 1976, and at present 140,000 tons of salt are being removed from the river annually by the U.S. Bureau of Reclamation and the U.S. Department of Agriculture at sites in Colorado and Utah. The long–range salinity control plan calls for completion of 17 additional control measures, limitations on municipal and industrial discharges, increased use of saline water by industry, and improved management of direct and indirect sources of pollution.

Agricultural Drainage: A Long–Standing Problem

Salty drainage water resulting from irrigation in the San Joaquin Valley must eventually be disposed of to prevent harm to the land. Several hundred thousand acres of irrigated agricultural land on the valley's western side are underlain by shallow, semi–impenetrable clay layers that prevent water from moving downward. When irrigation continues and the water is not drained off, the water table rises, which reduces crop yields and can result in land being withdrawn from production. This problem has been compounded significantly in the past five years by the discovery at Kesterson Reservoir that selenium in some drainage water is toxic to waterfowl.

Selenium and other potentially toxic natural substances derive from sedimentary rocks of the Pacific Coast Range. They have been transported over geologic times into the alluvial soils of western San Joaquin Valley. The spread of these substances has been further assisted by subsurface drainage systems, and in recent years the long–standing salinity problem has been reclassified as a toxic threat.

As early as the 1950s, DWR began working with other water agencies to investigate the valley's salinity problems. In 1979, DWR, the State Water Resources Control Board, and the U.S. Bureau of Reclamation published an Interagency Drainage Report that reiterated earlier findings in support of a valley drain extending from the vicinity of Bakersfield to the western San Joaquin–Sacramento River Delta. Today, however, with other toxicants added to the already serious selenium problems, the valley drain is no longer practical -- at least until cost-effective treatment technologies are developed to remove or neutralize the toxicants.

In 1983, DWR and other state and federal agencies began a cooperative investigation to redefine the scope and extent of the valley's drainage problems and to develop a plan for dealing with them. Activities related to this investigation are also being conducted by the State and Regional Water Quality Control Boards and the University of California. The National Academy of Science is providing scientific guidance, and local water and environmental agencies are sponsoring several programs for drainage water treatment and disposal, as well as the reduction of drainage water volumes. Proposition 44, the Water Conservation and Water Quality Bond Law of 1986, authorizes low-interest loans to local agencies to help solve drainage problems.

Investigations to date indicate that any long-range agricultural drainage plan for the valley's western side should include various combinations of the following components:

- Improved on-farm irrigation management measures to reduce drainage volumes.
- Curtailed water deliveries to certain lands containing selenium "hot spots."
- Chemical or biological treatment to remove selenium from drainage water.
- Greater concentration of salts in evaporation ponds designed to be safe for waterfowl and nonthreatening to ground water supplies.
- Formation of regional drainage districts to achieve better coordination.

The San Joaquin Valley Interagency Drainage Investigation is scheduled to release an interim report in fall 1987 and a final report in 1990.

Ground Water Quality

Ground water is particularly susceptible to degradation by dissolved salts, and "salty" ground water is a problem in certain areas of California. Yet, even though it is troublesome, this condition has been well documented in sea-water intrusion areas and largely corrected in the past several decades. Today, the new focus of concern is on chemical pollution of our ground water supplies.

For many years, ground water was assumed to be safe from chemical pollution because contaminant movement was thought to be restricted to the top few inches of the earth's surface. This assumption was perpetuated by inadequate testing and controls, which led to improper use, storage, and disposal of enormous amounts of toxic chemicals. During the late 1970s, scientists realized that certain kinds of organic chemicals -- including solvents such as TCE and pesticides such as DBCP -- are capable of moving through the soil and mixing with ground water.

Two particularly disturbing aspects of ground water pollution are that (1) it can take years for some pollutants to move from the earth's surface into ground water supplies and (2) once in the ground, pollutants can remain at problem concentrations for many decades. For these reasons, numerous governmental programs have been put in motion to identify and correct existing pollution problems, as well as to prevent further ground water contamination. Most of these programs are just a few years old, and in many instances they will have to be continued for many more years to come.

On the bright side, the processes through which ground water supplies become contaminated by toxic chemicals have become much more clearly understood by scientists in recent years, as the methodology for examining ground water contamination problems has improved. Today, it is possible to conduct tests on specific chemicals to predict both their behavior in soil and their capacity to pollute ground water. The California Department of Health Services requires municipal water supply agencies that use ground water to test their water supplies for an extensive range of chemicals known to have the capacity to pollute underground water supplies. Where pollutant concentrations exceed established health safety limits, the water supply agencies work with the Department of Health Services to correct the problem through treatment, abandonment of contaminated wells, or other measures.

Underground chemical storage tanks are a major source of ground water pollution in California, and the Water Resources Control Board and its regional boards are now identifying all underground chemical storage facilities in the State to determine which ones are leaking. Inadequate tanks are being replaced with modern installations equipped with safety systems and leak-monitoring devices. Although this retrofit program is well under way, it will take years to complete because there are so many underground storage facilities in California.

Surface storage of toxic substances can pollute ground water supplies if the storage facilities are leaky. The Water Resources Control Board and the regional boards have a joint program for identifying toxic storage pits within the State, evaluating their adequacy, and implementing corrective actions, when needed.

The California Department of Food and Agriculture requires manufacturers of pesticides used in California to document that they pose no threat to ground water. When manufacturers refuse to provide this documentation or when it fails to show the absence of a ground water threat, DFA can ban the chemical's use in California. DFA also samples ground water supplies that may be polluted. When sampling suggests that certain pesticides threaten the

Willits High School's buses were fueled from this tank for 30 years. The tank was removed in 1985 when it began leaking. Underground tanks holding hazardous materials now must be registered, tested, and monitored under a 1984 State law.

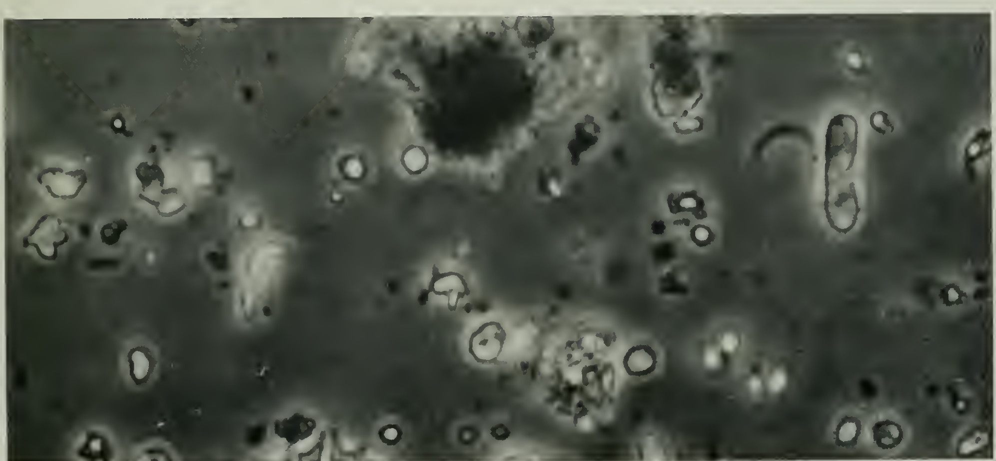
safety of ground water used for domestic purposes, DFA acts to restrict or eliminate their use.

As the State agency responsible for investigating the overall quality of California's water resources, DWR is consolidating the ground water data generated by other agencies and performing supplemental monitoring, as necessary. In addition, DWR maintains a statewide, standardized system for assigning well identification numbers -- a system that is valuable in terms of locating and organizing ground water monitoring data generated by the various agencies. DWR assists other agencies in their ground water monitoring efforts by assigning numbers for wells in their monitoring networks. The statewide database resulting from this cooperative effort will enable DWR to identify significant trends in the overall quality of the State's ground water resources.

In other related efforts, the U.S. Environmental Protection Agency is requiring states to establish detailed ground water protection strategies. The Water Resources Control Board is the lead agency for developing California's strategy.

In response to Assembly Bill 1803 (Chapter 818, Statutes of 1985), the Department of Health Services established a three-year program to determine the presence of organic chemicals in small water systems (5 to 199 connections) in the State that are supplied by ground water. The report summarizing the program's first two years indicates that, of 2,278 wells sampled, 162 showed the presence of organic chemicals and 38 exceeded the action level. The chemical found most often was the soil fumigant DBCP. The next three were solvents. When the program is completed, some 4,500 systems will have been examined, and about half the wells supplying them will have been sampled.

While these programs will improve protection of the State's ground water resources, current knowledge of the extent of chemical pollution in California is now inadequate, as is definitive information on the health aspects of different concentrations of various chemicals. In the next few years, one of the State's biggest challenges will be to evaluate the extent of its chemical pollution problems and carry out appropriate corrective actions. The passage of State Proposition 65 (the Toxics Initiative) in the November 1986 State elections was a strong expression of Californians' wishes to have their water supplies protected from toxic pollutants.



Colonial green algae, magnified 350 times.

WATER CONSERVATION

California's push toward serious consideration of water conservation came during the 1976–1977 drought, when dwindling river, lake, and reservoir supplies caused the water situation throughout much of the State to turn bleak. Since then, much attention has been focused on plans and programs to encourage more efficient use of water.

Water Conservation in Urban Areas

Local urban water suppliers, the Department of Water Resources, and most recently, local governments are actively conducting research, education, and implementation programs to reduce urban water use.

Three hundred urban water suppliers have prepared water management plans under the Urban Water Management Planning Act of 1983. These plans identify many water conservation programs being implemented now and proposed for the future. They include low water–use landscaping and improved irrigation efficiency on large turf areas, water audits and leak detection, industrial water conservation, residential retrofit with low-flow and ultra-low-flow toilets and showerheads, reclamation, capital outlay projects to replace old water mains and similar facilities, public education, and in-school education. DWR has provided technical and financial assistance to urban water agencies and local governments in all these areas since 1980.

Landscape Water Conservation

Roughly half the water used at California residences is used outdoors. Large volumes of water are also used to irrigate parks, commercial landscapes, golf courses, athletic fields, and other sizable expanses of turf. Reducing the water applied to landscaped areas is an important part of water conservation as a whole.

An example of local–State cooperation on water conservation is a publication, *Lawn Watering Guide,* developed for California homeowners by the Los Angeles Department of Water and Power. Aided in part by a grant from DWR, LADWP prepared the *Guide* to show its customers an efficient way to schedule the watering of their lawns. DWR has also issued *How to Produce a Lawn Watering Guide,* which has been distributed widely to water service agencies in California. More than 2 million lawn watering guides are now in the hands of residential water users.

Xeriscape conferences have sprung up all over California, attracting thousands of persons from the landscape industry, the water industry, and local governments who were interested in learning about drought–resistant landscaping. These conferences, now held in all parts of the State, have been instrumental in moving toward a less water–intensive but still attractive urban landscape. ("Xeriscape" means the conservation of water through appropriate landscaping.)

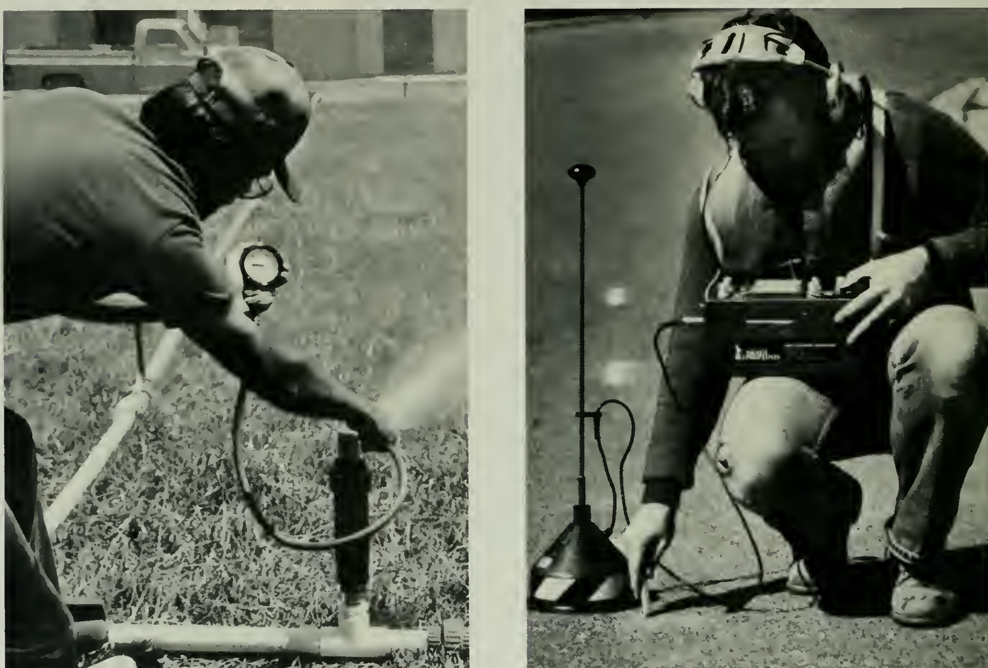
DWR has recently initiated a statewide Landscape Water Audit training course for urban landscape professionals. This instruction is aimed at improving irrigation efficiency on large turf, such as parks, school grounds, golf courses, and cemeteries. Many water districts, the landscape industry, and other public agencies are assisting with this effort and are, in turn, training irrigators in their own locales.

Fifty of these weather stations gather and transmit information that helps farmers decide when to irrigate and how much water to apply.

Many local agencies are becoming involved in landscape water conservation programs. The city of Irvine, for example, along with the Irvine Company and the Irvine Ranch Water District, has embarked on a five-year project to implement a centralized irrigation control and water management system. The city estimates that it will save $133,000 annually and will, by the end of the project, have reduced its total water use in all public landscapes by 28 percent.

Water Audit and Leak Detection

To help save water lost through system leaks, DWR staff trains local agencies in water audit and leak detection procedures and loans them sonic leak detection equipment. The local agency is then able to survey its own system and estimate water losses. Recently 55 local water agencies carried out water audit and leak detection programs. These agencies



Leaky pipes and excessive pressure waste hundreds of thousands of acre-feet of water each year in California. Many water agencies are performing leak-detection programs and auditing their distribution systems to reduce waste. Left, pressure-testing a landscape irrigation system; right, using an electronic device to listen for underground pipe leakage.

In addition, in 1985, the Contra Costa County board of supervisors adopted water conservation guidelines specifying low water-use landscaping at all new multifamily residential, commercial, and industrial developments in unincorporated areas of the county. Ventura County and others have also developed landscape guidelines.

saved more than 16,000 acre-feet of water worth more than $3 million during the two-year program.

As water costs increase, more and more local agencies will be implementing water audit and leak detection programs. Many already have done so, including the city of Los Angeles, which surveys about 500 miles of water pipe and 50,000 meters every year. Several other agencies are also conducting programs, including the East Bay Municipal Utility District in Oakland.

Studies by DWR indicate that leak detection and repair projects are cost-effective water conservation measures, if the cost of water is at least $25 per acre-foot and the initial leakage of the system is at least 3 percent of total deliveries.

Replacing older showerheads with new low-flow devices cuts water use without reducing effectiveness. A 1978 State law restricts the maximum flow rate for showerheads sold in California to 2.75 gallons per minute.

Household Retrofit Program

The household retrofit program, which began in 1977, is one of DWR's oldest water conservation programs. Technical assistance is offered on how to set up programs, and current information is provided on the latest plumbing codes, water fixture laws and regulations, and retrofit program analyses.

In cooperation with local agencies, such as the Santa Clara Valley Water District, the city of San Jose, the Municipal Water District of Orange County, and the Los Angeles Department of Water and Power, DWR has distributed retrofit kits to about four million California households -- more than half the pre-1978 housing. (In 1978, the State required low water-using toilets and showerheads for all new construction. About six million households were built before this requirement took effect.)

Several localities have developed innovative retrofit programs. For instance, the Monterey Peninsula Water Management District gives its customers a large discount on connection fees for new buildings, if ultra-low-flush toilets are installed. These toilets use only 1 to 1½ gallons of water per flush, while water-conserving toilets use 3½ gallons. Since the new connection fees were adopted, more than 75 percent of all new permit applicants have chosen to install the ultra-low-flush fixtures. Applicants can save more than $300 per toilet on permits by installing these toilets.

Water Conservation in Agriculture

California's agricultural sector has for decades been developing and implementing ways to reduce on-farm water use. This conservation effort has been broad-based, involving various public institutions, private industries, and individual farmers. Year by year, on a continuing basis, many different irrigation techniques have been developed to reduce and tailor water use for the varied irrigation conditions encountered throughout the State.

Many of the State's academic institutions have been working a long time to develop more efficient irrigation practices. Schools such as the University of California (chiefly the Davis and Riverside branches); California State Polytechnic University, San Luis Obispo; and others are engaged in intensive agricultural research. Moreover, the California Cooperative Extension Service has played an important role in transferring research experiments from test plots to fields, where new practices can be demonstrated and adapted to specific site conditions.

DWR has had a multifaceted agricultural water conservation program since 1980. It focuses on assisting water districts and growers with irrigation scheduling based on crop water needs, education to improve the efficiency of various irrigation systems, support of research related to improved irrigation management and reductions in evapotranspiration rates of crops, and financial assistance to agricultural water districts to begin or expand their irrigation management programs.

Three federal agencies have also been active in improving on-farm water conservation. The Agricultural Research Service, the Soil Conservation Service, and the Bureau of Reclamation have been responsible for many advances in irrigation efficiency, both in the development of new techniques and the providing of assistance to farmers seeking to improve the design and operation of their irrigation systems.

Lively competition among irrigation-system manufacturers and farm-management companies has also led to improvements in the design and promotion of such systems. Furthermore, lending institutions, whose policies encourage loans for irrigation system improvements, have had a significant impact on the installation of these modern-design systems.

Farm managers themselves are often responsible for the success of the experimentation sponsored by universities, government agencies, and equipment manufacturers because the managers identify specific needs, encourage research, and implement the systems that result from it. Some managers have originated ideas for new system designs and irrigation management techniques.

California Irrigation Management Information System

Since the mid-1970s, DWR has published estimates of weekly crop water use -- information that many farmers have used to schedule irrigations. The estimates are based on measured rates of evaporation from standard U.S. Weather Service evaporation pans installed at selected sites within some of the major irrigated areas of California. Now, in response to the need for real-time evapotranspiration information, daily estimates of crop water use are available through the California Irrigation Management Information System, a large, automated weather station network that records solar radiation, wind speed, rainfall, air temperature, humidity, and soil temperature. These data are transmitted daily by telephone to a central computer that calculates how much water certain plants in a certain area would have used under specified conditions for factors such as soil moisture availability and plant growth. The results are then made available to farmers and other interested parties, who access them through personal computers. The information is also available through irrigation consultants, county farm advisors, Soil Conservation Service field offices, and the media.

Since 1984, DWR has funded five mobile laboratories, which are operated through resource conservation districts. The labs evaluate irrigation systems on site to help growers improve irrigation practices.

Laboratories on Wheels

While crop water use estimates help farmers decide when to irrigate and how much water to apply, mobile irrigation management laboratories are available to measure how efficiently an irrigation system is working. These labs are operated by local resource conservation districts, with technical support from the U.S. Soil Conservation Service. Funds are provided by DWR and local contributors. Typically, a team of technicians visits a field or large turf area, evaluates the management of the irrigation systems in use, and recommends water management improvements. Mobile labs currently operate in Fresno, Kings, Tulare, Kern, Ventura, Riverside, Imperial, and San Diego counties.

In southern Riverside County, the Rancho California Water District demonstrates the value of cooperation among farmers, local agencies, and State agencies when the goal is improving irrigation efficiency in areas where water is particularly expensive and scarce. The district has evaluated irrigation systems for almost all growers in its service area, with the growers paying 25 percent of the evaluation cost; the district, 25 percent; and the State, 50 percent.

Agricultural Water Management Planning Assistance

In 1986, the Legislature passed the Agricultural Water Management Planning Act. It requires every agricultural water retailer supplying more than 50,000 acre-feet of water, if not covered by water conservation requirements of State and federal agencies, to report to the Department of Water Resources by December 31, 1989, how its water is managed. If, after preparing the report, the supplier finds that water can be conserved or that the quantity of highly saline or toxic drainage water can be reduced, the supplier must adopt an agricultural water management plan, provided that the Legislature appropriates funds for this purpose.

Other Water Conservation Activities

A short course in irrigation system evaluation, offered twice a year at California Polytechnic State University, San Luis Obispo, is attended by water district and irrigation district staffers, growers, irrigation consultants and managers. DWR and Cal Poly received the Irrigation Association's 1986 National Water and Energy Award for this course.

As a result of recent increased concern over ways of coping with potentially toxic drainage water in parts of the San Joaquin Valley, DWR is working with other agencies and institutions and local farmers to assist in reducing agricultural drainage by improving irrigation management. The objective is to provide farmers with recommendations for improving irrigation scheduling, irrigation efficiencies, and distribution uniformity, and maintaining salt balance.

Other Programs: Urban and Agricultural

The goal of water education programs is to inform children about some basic features of California's water supply system so that they can better comprehend water issues as they grow older. Many water agencies have excellent water education programs for schoolchildren. The East Bay Municipal Utility District, for example, has operated a comprehensive program for over a decade, and The Metropolitan Water District of Southern California, the Los Angeles Department of Water and Power, the Santa Clara Valley Water District, the Soquel Creek Water District, and the Municipal Water District of Orange County also have fine programs of their own.

Water agencies are also working with universities and school districts to credit teachers for attending water education workshops. Some of the agencies using this approach are the city of Riverside, the Western Municipal Water District, the Imperial Irrigation District, the Goleta Water District, the city of Fresno, and the Soquel Creek Water District.

Water conservation public information programs are a vital part of many water agencies' public relations efforts. Some agencies, such as The Metropolitan Water District of Southern California, produce outstanding newsletters and promotional materials on water. Others, such as the city of Fresno, have composed award-winning public service announcements.

For its part, DWR has generated an extensive array of reports, brochures, workbooks, guidebooks, slide-tape shows, public service announcements, and other materials that are available free of charge. The Department also helps water agencies, local governments, and other interested parties develop or expand their own public information programs. As part of the Clean Water Bond Law of 1984 and the Water Conservation and Water

In the Imperial Valley, the Imperial Irrigation District lines irrigation ditches to keep valuable water from seeping below ground. By April 1987, some 900 miles of canal had been completed, with 550 miles to go. This program could be expedited and enlarged under a proposed agreement between IID and The Metropolitan Water District.

Quality Bond Law of 1986, loans of up to $5 million are provided for voluntary, cost-effective capital outlay projects designed to save water. DWR administers this program, and loans are available to any public agency involved in agricultural or urban water management. Examples of projects that might be funded by this program include those to line canals, to construct drainage return-flow systems, and to replace leaky water mains.

Water Conservation: The Future

Efficient use of water supplies in California is an economic and environmental necessity. It will be important for water purveyors and State and local government to analyze the cost effectiveness of water conservation measures and to implement those that are appropriate. Since water conservation involves issues of technology, public awareness and acceptance, and research and education, cooperation between the public and private sectors, the urban and agricultural sectors, and State and local government is needed.

ENVIRONMENTAL ISSUES

Before 1960, planning for future water allocation and use in California seemed to be a fairly straightforward process. With few exceptions, damming rivers to store water for irrigation, urban uses, and hydroelectric power production was not regarded as having a serious detrimental impact on the environment. In the early 1960s, however, relationships between environmental values and water supply became more apparent, and, in the next few years, State and federal legislators enacted many laws to protect environmental quality. This chapter discusses a number of currently significant environmental issues related to water use.

The Public Trust Doctrine

As an outgrowth of the landmark decision in *National Audubon Society v. Superior Court of Alpine County* (1983), much attention is now focused on the public trust doctrine, which provides that the State holds navigable waters and their underlying lands in trust to protect public interests. Previously, the only interests protected were commerce, navigation, fisheries, and the conventional uses of waterways. Recently, however, the courts have expanded the doctrine to protect the public's stake in recreation, fish and wildlife habitat, scenic values, and environmental preservation. Policies on how best to use our resources continue to evolve, and as interpretations and applications of our natural resource laws continue to change, so does environmental planning and decision-making.

In the Audubon case, the California Supreme Court held that (1) the city of Los Angeles' water rights licenses to divert water from Mono Lake's

Populations of trout in Indian Creek, Plumas County, have expanded significantly in recent years. DWR balances releases from its upper Feather River reservoirs, augmenting flows for fish and recreation downstream.

tributary streams are subject to the public trust doctrine; (2) when issuing water rights permits and licenses, the State must consider public trust values; and (3) to protect public trust values, the State must continue to supervise and reconsider existing water rights. The court did not mandate that public trust values take precedence over other beneficial water uses, but rather declared that both our appropriative water rights system and the public trust doctrine embody important precepts and the State must seek a balance between the principles of both systems.

The decision in the Audubon case reflects a change in attitude toward natural resource use and a

Moved by barge-power through the Delta in May 1987, this concrete shell, plus steel radial gates to be added, has now been placed in Montezuma Slough, where the structure will restrict salt-water inflow to Suisun Marsh.

change in policy that will affect water allocation throughout the West. In planning to meet future water needs, public trust values such as recreation or fish and wildlife must be considered equally with other beneficial water uses, and the combination of these values that best serves the public interest must be sought.

Wild and Scenic Rivers

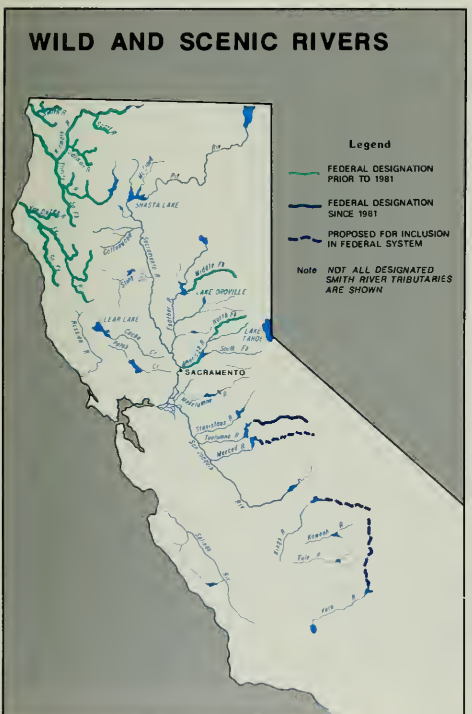
The heightened environmental awareness that flourished in the 1960s and 1970s led to enactment of both State and federal laws that protect free-flowing rivers under a "wild and scenic" designation. Congress enacted the National Wild and Scenic Rivers Act in 1968 and established a system to protect selected rivers from development. The act intended that the damming and diverting of some rivers be complemented by preserving other rivers, or parts of them, in their free-flowing condition to protect water quality and promote conservation in general.

In 1972, the State Legislature passed the California Wild and Scenic Rivers Act, which states that certain rivers have scenic, recreational, fishery, or wildlife values that should be preserved in their natural state for the benefit of the public. The act prohibits dams, reservoirs, or other water impoundment facilities on rivers designated as wild and scenic. Diversions for local domestic uses are permissible. It also bars State agencies ". . . from assisting or cooperating in the planning, financing, or constructing of any project which would have an

Since Trinity Dam was completed in the early 1960s, silt has gradually covered Trinity River spawning gravels, preventing salmon from using them. A river restoration program that includes loosening gravels with heavy equipment has been highly successful, and spawning salmon are now increasing dramatically.

adverse effect on the free-flowing or natural condition of the rivers in the State System."

The national and State systems differ principally on one point: if a river has been designated only under the State's system, the Federal Energy Regulatory Commission may issue a license to build a dam on a protected river under the Federal Power Act. FERC contends that the Federal Power Act preempts State law, including California's Wild and Scenic Rivers Act. FERC, however, is clearly bound by the National Wild and Scenic Rivers Act, and this fact gives one reason why environmentalists seeking to protect rivers from development prefer to seek national designation. At present, Congress is debating whether to include portions of the Kings and Merced rivers and the North Fork of the Kern River in the national system.



Mono Lake

Mono Lake, one of the oldest lakes in North America, lies at the center of the Mono Basin, northeast of Yosemite National Park. It has a number of distinctive natural features that many people believe should be preserved for future generations, which is one reason Congress established the Mono Basin National Forest Scenic Area in 1984. The lake is the terminus for several streams in the Mono Basin, and, except for what evaporates, water flowing into the lake remains there. Although no fish live in the lake (where the water is 2½ times saltier than sea water), it supports huge populations of brine shrimp and brine flies that are the major food supply for thousands of California gulls that breed there. It is also an important stopover for 79 waterbird species, including 30 percent of the world's population of Wilson's phalaropes that rest and feed at Mono Lake during migration.

Water diverted from four Mono Lake tributaries has been flowing to Los Angeles since 1941, when the city began moving Mono Basin water through its 338-mile aqueduct system. This water represents about one-sixth of the city's total water supply, and, en route to Los Angeles, it generates 300 million kilowatthours of hydroelectric power annu-

Smith River, Del Norte County, one of 12 California streams protected as wild and scenic rivers.

ally. In 1974, the State Water Resources Control Board granted licenses for the continued operation of the city's Mono Basin Project.

The Mono Lake Issue

Los Angeles' water diversions from Mono Basin have lowered the lake's water level by more than 40 feet since 1941 and also increased the lake's salinity. If diversions continue at present rates, many people fear the lake's ecosystem will fail. Yet, if the city reduces its diversions, it will have to purchase additional water and energy from other more expensive sources -- principally, the State Water Project. In dry years, such purchases would compete for water available to other areas.

In the summer of 1978, particular concern arose over Mono Lake when the lake's water level dropped enough to expose a land bridge extending from the shoreline to Negit Island, a major nesting and breeding area for most California gulls. That year marked the formation of the Mono Lake Committee, a nonprofit organization dedicated to preserving Mono Lake. Through the efforts of this group, and with help from the National Audubon Society and the Sierra Club, the Mono Lake water-depletion issue has received widespread publicity. These organizations and others have filed several lawsuits against the city of Los Angeles and the State over Mono Basin water rights. Generally, the suits seek to stabilize the lake's water level or to protect fisheries in the lake's tributaries. To date, no court has ruled on the water rights or fisheries issues.

The National Research Council, a division of the National Academy of Sciences, has studied the lake

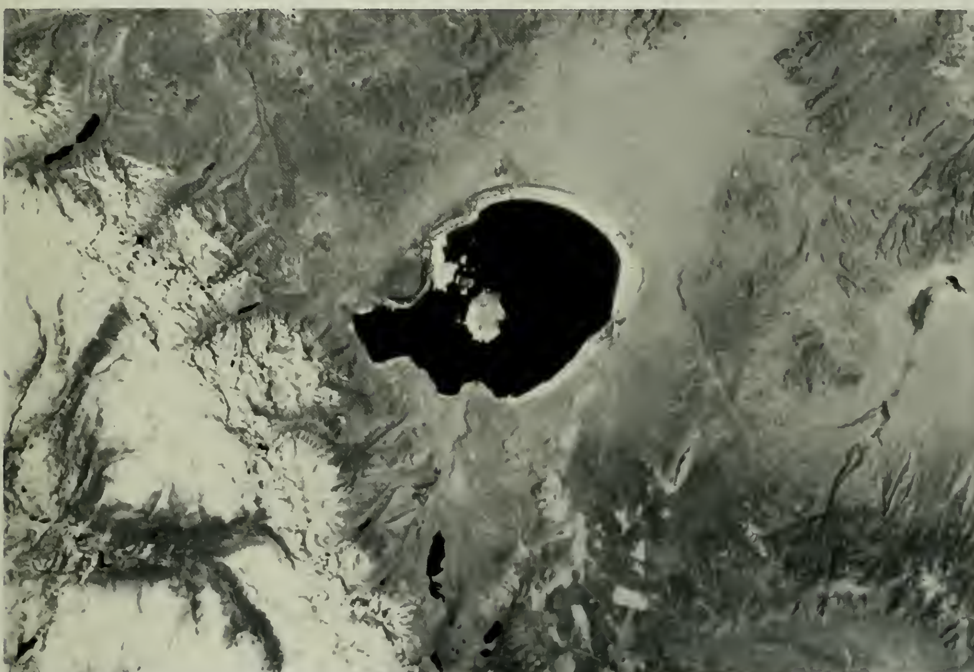
Mono Lake's tufa towers are a major attraction. The towers are formed of solidified salts carried by fresh-water springs that well up from the lake bottom.

to determine whether there actually has been or might be a salinity level that will have unacceptable effects on the lake's ecosystem, and what that level is. Authorized by legislation that established the Mono Basin National Forest Scenic Area, this research sought to identify a critical lake level required to maintain the major wildlife species in the Mono Basin. The council's report, issued in August 1987, concluded that the lake is in good health at present, but a 10- to 20-foot drop from its current level would begin noticeably altering its ecosystem, while a drop of 30 or more feet would make it too salty to support brine shrimp and brine flies and the migratory birds that feed on them.

The Mono Lake situation reflects the full range of important environmental issues and processes now occurring throughout California -- in short, a thorough re-evaluation of society's long-term use of resources in light of changing environmental goals and policies. Resolving the Mono Lake issue in a way that significantly reduces the amount of water diverted to Los Angeles would affect other parts of California's water allocation system, a factor that must be taken into account in the balancing process that the California Supreme Court mandated in the Audubon suit. Specifically, the court required that Los Angeles' water demands be weighed against the public trust values at Mono Lake and that the best compromise be found. Whatever the outcome, it will play a decisive role in planning for future water needs.

The Bay-Delta System

Bordered by salt ponds, marshes, and industrial development, San Francisco Bay is part of a complex Bay-Delta system called the Sacramento-San



A satellite view of Mono Lake, high in the eastern Sierra Nevada. The lake is the focus of continuing controversy because the city of Los Angeles taps streams feeding the lake for part of its water supply and hydroelectric power, lowering the lake's level.

Joaquin estuary. Generally, the system consists of two parts -- San Francisco Bay and Suisun Marsh-Delta -- divided by the saline waters of the Carquinez Strait that separate Vallejo and Benicia.

Water located west of Vallejo is generally oceanic, while Suisun Marsh-Delta water varies from moderately salty to fresh. Water in the Carquinez Strait moves back and forth, depending on fresh-water flow, tides, and wind. Suisun Bay becomes quite salty during most summer and fall months, especially during dry years. (Intrusion of saline water into the Delta is discussed in Chapters 7 and 8.)

When the topic is environmental issues, especially those pertaining to fish and wildlife, San Francisco Bay and the Delta are unified in the eyes of biologists. Many species of special environmental concern spend most of their lives in these areas, and environmental quality in the entire estuary can affect their lives. The estuary and surrounding wetlands serve as a home or migratory pathway for

Waterfowl in great numbers rely on Suisun Marsh as a source of food and a place for rest and shelter.

many fish and wildlife species. In all, more than 40 species of fish have been captured in the Delta and the Suisun Marsh, and more than 120 adult and young anadromous fishes have been identified in San Francisco Bay. The Suisun Marsh encompasses 80,000 acres and is the largest contiguous wetland remaining in California. It provides important habitat for such endangered species as the salt-marsh harvest mouse and the clapper rail (a wading bird), and at times serves as host to millions of migratory waterfowl.

Bay-Delta Issues

Most Bay-Delta environmental issues fall into one of three broad categories: loss of wetlands, waste discharges, and changes in the timing and volume of fresh-water flow.

During the past 100 years or so, the size of many tidal marshes and wetlands in the estuary have gradually decreased as a result of agricultural and urban development. The marshes provide habitat essential to a wide variety of plants and animals, and decomposing marsh vegetation is an important element in the estuary food chain. Furthermore, the marsh acts as a biological filter, with water passing through it often leaving in a purer state than when it entered.

Waste discharge has also been a factor since development around the estuary began to intensify. The Bay and Delta were once viewed as appropriate places to dispose of society's waste products. But in the first decade of this century, waste-related problems involving bacterial contamination led to the closing of local clam and oyster beds to commercial harvesting. In the southern end of San Francisco Bay, where water circulates poorly, discharge of partially treated sewage has caused dissolved oxygen levels to fall below levels necessary for fish.

In the mid-1970s, improved waste treatment changed the focus of the waste discharge issue. Specifically, the focus shifted from concern about dissolved oxygen problems and esthetics to the effects of potentially hazardous substances reaching the estuary from a variety of sources, such as landfills, municipal and industrial effluents, urban runoff, and agricultural waste water. Recently, some important estuarine wildlife -- including waterfowl, clams, starry flounder, and striped bass -- have been found to have elevated concentrations of potential toxins.

Changes in timing of fresh-water flow to the estuary have occurred because of reservoir operation and diversion of fresh water to out-of-basin uses. Some people view these changes as threats to the estuary's ecological system. The areas of particular concern are (1) direct losses of fish and their food in the water diverted, (2) changes in estuarine circulation patterns that can transport young fish to nursery areas, and (3) loss of the essential nutrients that ensure the estuary is capable of supporting the diverse plants and animals that have been present historically.

In 1978, the State Water Resources Control Board adopted Decision 1485, which presented a plan for water quality control. The decision concentrated on salinity problems in the Delta and the effects of the State Water Project and the Central Valley Project on local fish and wildlife.

Essentially, the decision requires the Water Resources Control Board to determine San Francisco Bay's outflow needs so that an effective plan to protect the Bay may be established. To help meet this requirement, representatives of various State and federal agencies have included a Bay element in their Interagency Ecological Studies Program. The goals of the program are to establish the fresh-water flow needs of striped bass, chinook salmon, and other fish, including those in the Bay, and to determine the effects of Delta outflow on estuarine circulation patterns. Agencies represented include the U.S. Bureau of Reclamation, the U.S. Fish and Wildlife Service, the California Department of Fish and Game, the Department of Water Resources, and the Water Resources Control Board.

In 1986, appellate court Justice John T. Racanelli held that the Water Resources Control Board had not fully exercised its authority to protect the Bay-Delta system. He ordered the Board to take a "global perspective" of the region when balancing all the beneficial water uses that affect the system or depend on its good health. By 1990, the Board is to develop water quality control plans that estimate the beneficial uses of Bay-Delta waters and, if necessary, impose water rights' restrictions so that these plans can be implemented.

To review Bay-Delta water quality objectives, modify them for current knowledge, and determine the best way to implement a water quality control plan, the Board began hearings in mid-1987 that are phased over three years. First, the Board, with advice from its regional boards, will consider evidence on the beneficial uses of Bay-Delta waters and the water quality requirements of those uses. Based on this evidence, the Board will prepare a draft water quality control plan and a draft pollutant control policy. It will then receive public comment on these draft plans, and, in the final phase, receive evidence of ways in which various water rights may be conditioned to help meet the water quality control plan.

The Bay-Delta hearings and the requirements of the Racanelli decision are evidence of high regard for natural resources and their beneficial use. The outcome of the Board's three-year effort should help clarify useful principles for planners and decision-makers as they seek the best combination of the water rights system and the public trust doctrine.

The Salton Sea

In 1905, the Colorado River broke through diversion works of a (then) new canal constructed by the California Irrigation Company. For 16 consecutive months, water from the river flowed unimpeded into the Salton Sink, a desert region lying as much as 278 feet below sea level. Before the break could be repaired, the river had created the largest lake in California -- the Salton Sea. Situated 145 miles east of Los Angeles, the sea is more than 30 miles long and 10 miles wide. It, like Mono Lake, is a terminal lake, with water leaving it only by evaporation.

The Salton Sea National Wildlife Refuge, which extends over 33,000 acres and shelters about 350 species of birds, lies at the southern end of the sea. Thousands of migratory ducks, geese, and grebes (diving birds) flock there in winter. Additionally, several endangered, rare, or threatened wildlife species live there or stop over during migration. The sea has also become one of California's popular recreation areas, and its thriving marine sport fishery is one of the most productive in the State. Several commercial marinas, residential recreational communities, and public parks are now located around the sea, and the Salton Sea State Recreation Area lies along 20 miles of its northeastern shoreline.

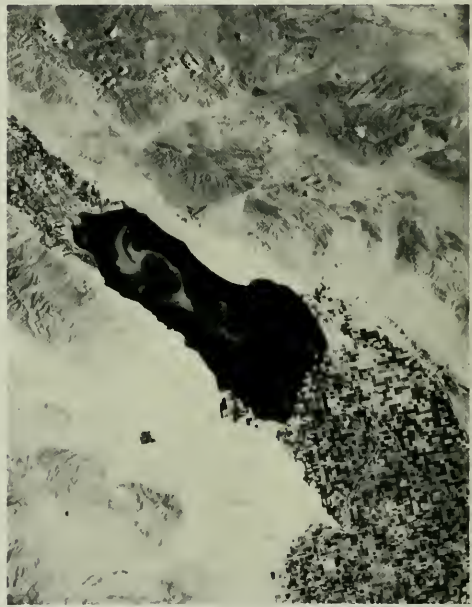
In 1924, President Coolidge declared the Salton Sea an official drainage sump for runoff from agricultural lands, which included all lands lying lower than 244 feet below sea level. For the past 80 years, agricultural runoff has carried an average of 6 million tons of salt into the Salton Sea each year. These salts, combined with the loss of fresh water to evaporation, have greatly increased the sea's salinity. Currently, its total dissolved solids content measures about 40,000 milligrams per liter. (Ocean salinity averages 34,000 milligrams per liter.) Only runoff, rain, and inflow from the New, Alamo, and Whitewater rivers have kept the salinity level from rising even higher.

In 1962, the Colorado River Basin Regional Water Quality Control Board declared in its basin plan that the primary beneficial use of the Salton Sea is to receive agricultural drainage water. In 1968, the California Legislature affirmed that the primary function of the sea is to act as a drainage water sump. Yet, to many people, the Salton Sea is much more than a waste-water discharge site. To some, its value is measured by the record numbers of trophy-sized sport fish that have been caught there. Others see it as a biological haven worth preserving, or as a prime recreational area that provides livelihoods for many people and millions of dollars in State revenue each year.

The Salton Sea Dilemma

For the past several years, the major problems at the Salton Sea have been high water levels caused by increased agricultural runoff, treated urban waste-water flows from the Coachella and Imperial valleys, above-average rainfall from 1976 through 1983, and inadequately treated municipal waste-water flows from Mexico. Because of its increased water volume, the sea has badly damaged some agricultural, recreational, and residential property along its shores.

In June 1984, the Water Resources Control Board adopted Water Rights Decision 1600, which declared that the Imperial Irrigation District was wasting water in violation of California's Constitution. The decision forced Imperial Irrigation to prepare a conservation program and take other steps to prevent water from being misused. Imperial also agreed to follow a nine-year plan designed to conserve irrigation water and lower the Salton Sea's water level by about 8 feet. Not everyone was satisfied with the plan, however, and many wildlife advocates, Salton Sea residents, and business owners told Imperial and State officials they feared the district's plan would rapidly increase the sea's salinity, threatening the fishery and recreation business.



Salton Sea, in the Imperial and Coachella valleys 227 feet below sea level, is the largest lake entirely within California. It is sustained chiefly by irrigation drainage. Satellite view was taken on August 17, 1979.

These and other concerns over fish and wildlife have focused attention on a physical solution to the Salton Sea's rising salinity. One suggestion made in 1974 called for the construction of a dike near the southern end of the sea to impound an area of 30 to 50 square miles in which the salts would concentrate. In 1974, the cost of this project was an estimated $58 million to $141 million. Yet, the subsequent rise of the sea above its estimated 1974 elevations would have overtopped the dike had one been built. Currently, federal, State, and local officials are working together to determine the feasibility and cost of a similar project that would include modifications necessary to maintain current water levels.

The Salton Sea dilemma illustrates how complex water allocation and environmental management have become in California.

The Hetch Hetchy Project

As this report was in final editing, a long-dormant environmental issue of concern to Californians throughout this century was again thrust into the public spotlight. This is the flooding of Hetch Hetchy Valley, part of Yosemite National Park, by the city of San Francisco in the 1920s to develop its principal water supply. The renewed interest in this issue was raised by Secretary of the Interior Donald Hodel, when he suggested that study should be given to dismantling O'Shaughnessy Dam and restoring the long-flooded valley.

Reaction to the Secretary's proposal has ranged from cries of outrage by San Francisco political leaders and water users to smiles on the faces of many water officials. Their amusement arises not from endorsement of the idea but from the irony of the situation since, *in their view*, San Franciscans have smugly criticized other water projects throughout the State over the years, while choosing to ignore their city's environmental transgression.

Most water engineers tend to view the proposal as not practical. This is not only because of the costs of dismantling the dam and developing a new water supply for San Francisco, but also because the city obtains very large revenues from the sale of both water and hydroelectric energy produced by the project. On the other hand, environmentalists seem to be taking the idea seriously and, in all likelihood, it will be with us as an issue for sometime to come. On September 11, the last day of the 1987 legislative session, the Legislature approved Assembly Bill 645, which directs the Department of Water Resources to make an overview-type study of the proposal and report to the Legislature by December 31, 1989.

O'Shaughnessy Dam impounds water in Hetch Hetchy Reservoir.

EVOLVING WATER POLICIES

The development and use of water in California is governed by a complex system of State and federal laws which have evolved over many, many years. Individual components of the legal system include:

- Common law principles.
- Constitutional provisions.
- Statutes approved by the Legislature or the Congress.
- Statutes approved by the Legislature and then approved by the people.
- Judicial decisions in both State and federal courts.
- Contracts.
- Agreements.

This system of law governing water is not fixed but evolves year by year as new issues are raised which require changes and new interpretations. However, as is common throughout the West, most changes are incremental, rather than sweeping, recognizing the cautious and protective view that westerners have about water.

This chapter summarizes the major changes and additions to water legislation, litigation, and agreements that have occurred in the last few years. It also includes a discussion of recent trends in federal regulatory efforts on waterways and wetlands.

Recent Legislation

A number of State laws have been enacted that signal shifts in water policy for the State. The more important areas include water conservation, water transfers, ground water, safe drinking water, and water quality.

Water Conservation

The ethic of conserving water has been woven through law and practice in California for decades. It can be traced back to the 1928 Constitutional Amendment, which was adopted to ensure the reasonable and beneficial use and the prevention of waste and unreasonable use of water. It states:

> It is hereby declared that because of the conditions prevailing in this State the general welfare requires that the water resources of the State be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such waters is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and for the public welfare.

The 1976–77 drought demonstrated, sometimes dramatically, that people can cut back on water use when an emergency requires it. This experience, coupled with the growing cost of major water project development, has led to an array of water conservation programs at the State and local government level.

The two most recent significant pieces of legislation are the Urban Water Management Planning Act of 1983 and the Agricultural Water Management Planning Act of 1986. Both require the larger water suppliers, under certain conditions, to prepare water management plans. These acts are discussed in Chapter 9.

Decorative drought-tolerant plants save both water and money. Landscape irrigation accounts for about half the water used at residences.

Water Transfers

Interest in water transfers (also known as water marketing and water sharing) has grown appreciably since the 1976–1977 drought, during which Californians learned the enormous value of being able to share and exchange water throughout the State's vast, interconnected "plumbing" system.

Between 1980 and 1986, a half dozen laws were enacted that were designed to encourage voluntary transfers, permit water agencies to transfer their surplus water, and require public agencies to allow other public agencies to make use of unused conveyance capacity. DWR has been specifically directed to establish a program to facilitate voluntary transfers, to prepare a water transfer guide, to maintain lists of entities interested in transferring water and facilities available to them, and to recommend changes in law or policy regarding transfers.

Ground Water

California has been making beneficial use of its ground water resources for decades, for both municipal and agricultural purposes. Ground water is generally controlled by the overlying pumpers -- many of whom are local government agencies. Together with periodic major judicial decisions and the growing popularity of and reliance on artificial recharge projects, ground water in California has been managed quite well.

Two recent types of ground water legislation are:

A law enacted in 1985 that authorizes the Department of Water Resources to include feasible ground water projects as features of the State Water Project.

Two laws enacted in 1986 that applied existing provisions dealing with well construction standards and reporting requirements to monitoring

Water Policy Legislation, 1983–1987

Water Transfer

AB 178 (N. Waters), Chap. 1655 of 1984: Extends the law protecting areas of water origin to all future exporters from a number of Northern California watersheds.

AB 2010 (Isenberg), Chap. 1384 of 1986: Authorizes Director, DWR, to negotiate with the Bureau of Reclamation for State to own or operate part or all of federal CVP.

AB 2746 (Katz), Chap. 918 of 1986: Requires a State or local agency owning a water conveyance facility to let another local agency transfer water to a purchaser by unused capacity; transferor must pay fair compensation.

AB 3427 (Kelley), Chap. 364 of 1986: Permits a water transfer agreement to exist more than 7 years, if mutually agreed to by agency and transferee.

AB 3722 (Costa), Chap. 970 of 1986: Requires DWR to set up a program to facilitate the voluntary exchange or transfer of water.

SB 1700 (Torres), Chap. 1241 of 1986: Requires DWR to negotiate with the Bureau of Reclamation for purchase and transfer of water.

Water Conservation

AB 797 (Klehs), Chap. 1009 of 1983: Establishes the Urban Water Management Planning Act to require water conservation and management plans by urban water suppliers.

AB 1732 (Costa), Chap. 377 of 1984: Authorizes sale of general obligation bonds to cover the State's share of waste water projects; for waste water reclamation projects and water conservation loans.

AB 2542 (Peace), Chap. 429 of 1984: Provides that use of Colorado River water reduced by water conservation measures will not cause the loss of water rights.

AB 1029 (Kelley), Chap. 938 of 1985: Authorizes any water supplier or water user to finance water conservation or reclamation and sell the conserved or reclaimed water to another water supplier or water user.

AB 1658 (Isenberg), Chap. 954 of 1986: Requires agricultural water suppliers to determine whether they have significant opportunities to save water. Existence of such opportunity requires that supplier prepare and adopt an Agricultural Water Management Plan.

AB 1982 (Costa), Chap. 6 of 1986: Provides $150 million in low-interest loans to local agencies for water conservation, ground water recharge, and agricultural drainage projects. (Approved by voters in June 1986.)

Water Policy Legislation, 1983–1987 *(continued)*

Offstream Storage

AB 3792 (Isenberg), Chap. 1656 of 1984: Authorizes the Los Banos Grandes Reservoir, south of the Delta, as part of the SWP.

Ground Water and Water Quality

AB 1362 (Sher), Chap. 1046 of 1983: Establishes regulatory provisions to prevent ground water contamination from hazardous substances stored in underground tanks.

AB 1803 (Connolly), Chap. 881 of 1983 and
AB 1803 (Connolly), Chap. 818 of 1985: Requires the Department of Health Services and local health departments to evaluate public water systems for potential contamination.

AB 2013 (Cortese), Chap. 1045 of 1983: Requires persons storing hazardous substances in underground containers to file a hazardous substance statement with SWRCB.

AB 2183 (O'Connell), Chap. 378 of 1984: Authorized an additional $75 million for the Safe Drinking Water Program.

AB 3566 (Katz), Chap. 1543 of 1984: Requires regulation of toxic pits in order to prevent contamination of ground water.

AB 3781 (Sher), Chap. 1584 of 1984: Requires testing of underground tanks before and after installation to protect ground water from leaks.

AB 1156 (Areias), Chap. 1034 of 1985: Enacts the Groundwater Recharge Facilities Financing Act, authorizing DWR to make grants to local agencies for ground water recharge facilities.

SB 187 (Ayala), Chap. 268 of 1985: Confirms authority of DWR to build ground water storage facilities south of the Delta as part of SWP; requires DWR to contract with local agencies in such programs.

AB 2668 (O'Connell), Chap. 410 of 1986: Authorized an additional $100 million for the Safe Drinking Water Program.

AB 3127 (Areias), Chap. 1152 of 1986: Requires counties and cities to adopt water well abandonment ordinances that meet or exceed standards in DWR Bulletin 74-81.

Fish and Wildlife (State)

SB 512 (Hart), Chap. 6 of 1984: Enacts the Fish and Wildlife Habitat Enhancement Act of 1984, authorizing issuance of $85 million in bonds for fish and wildlife habitat enhancement. (Approved by voters in June 1984.)

AB 723 (Campbell), Chap. 1259 of 1985: Authorizes SWRCB to consider streamflow requirements in applications to appropriate water.

SB 400 (Keene), Chap. 1236 of 1985: Enacts the Fisheries Restoration Act of 1985 for restoration of fishery resources and habitat damaged by water diversions and projects.

SB 1086 (Nielsen), Chap. 885 of 1986: Requires the Wildlife Conservation Board, by January 1, 1988, to inventory land along the upper Sacramento River and determine priority of land valuable to fish and wildlife. Creates an Upper Sacramento River Fisheries and Riparian Habitat Council to develop, for submission to the Legislature, the Upper Sacramento River Fisheries and Riparian Habitat Management Plan to provide for the protection, restoration, and enhancement of fish and riparian and associated wildlife for the area between the Feather River and Keswick Dam.

Fish and Wildlife (Federal)

HR 1438 (Chappie, Bosco, Shumway), PL 98-541: Establishes the Trinity River Basin Fish and Wildlife Management Program to restore and maintain fish and wildlife populations in the basin.

HR 3113 (Miller, Coelho, Lehman), PL 99-546: Authorizes the Secretary of the Interior to enter into agreements for coordinated operation of the federal CVP and SWP and to preserve Suisun Marsh.

HR 4712 (Bosco), PL 99-552: Establishes the Klamath River Basin Conservation Area Restoration Program to restore anadromous fishery in the river.

Delta Levees

AB 955 (Peace), Chap. 1271 of 1985: Requires DWR to plan for continued water exports, should Delta levees fail.

AB 3473 (Johnston), Chap. 824 of 1986: Requires DWR to inspect local agencies' nonproject levees to ascertain degree of compliance with maintenance standards.

SB 2224 (Garamendi), Chap. 1357 of 1986: Authorizes DWR and The Reclamation Board to determine the need for State financial aid to Delta reclamation and levee districts to maintain levees that protect State highways.

wells. These laws also added several new provisions designed to protect ground water aquifers from contamination.

Water Quality

Historically, water quality has been an important consideration in water resources planning. Since the 1960s, however, quality has assumed even greater significance for resources managers at all levels of government and in the private sector.

In 1969 California enacted the Porter-Cologne Water Quality Control Act, which gave State government the authority and organizational structure to regulate the quality of surface and ground water. And, in 1972, the federal government enacted the Clean Water Act, which provided millions of dollars to control pollution -- primarily through the construction of municipal and industrial sewage treatment facilities.

Since the passage of the Clean Water Act, numerous State and federal laws have been passed to deal with such problems as land disposal, underground storage tanks, hazardous and toxic wastes, solid waste management, agricultural chemicals and pesticides, and -- what is probably the most far-reaching issue of all -- ground water protection.

The Toxic Enforcement Act (Proposition 65), approved by 63 percent of the voters in the November 1986 election, prohibits contamination of drinking water with chemicals known to cause cancer or reproductive sterility and requires that clear and reasonable warning be given before any exposure to such chemicals. There are a substantial number of exceptions in the law, as well as stiff penalties in the form of fines and jail terms. The administrative structure to implement the new law is presently being developed.

The Water Conservation and Water Quality Bond Law, approved by the voters in June 1986, authorized the issuance of $150 million in general obligation bonds to help finance water conservation, ground water recharge, and agricultural drainage management. The Water Resources Control Board administers the agricultural drainage provisions of the new law, and the Department of Water Resources administers the water conservation and ground water recharge provisions. Under this act, local agencies may obtain low-interest loans to develop and build conservation projects and recharge facilities.

Litigation

Several major court decisions handed down in recent years are expected to have significant effects on the course of water resources management in California. These cases have dealt primarily with State and federal authority over water projects, environmental protection, and the role and authority of the Water Resources Control Board.

The most significant effect of this recent litigation is to increase the authority of the Board over water rights matters. Except in situations where its decisions would conflict with congressional directives, the Board may impose conditions on federal projects. In the past, the Board has tended to define its own role too narrowly and must now protect public trust values wherever feasible. In addition, it may both retain continuing jurisdiction and reconsider previous allocation decisions.

Recent decisions are tending to strengthen the State's water rights appropriation process, while conditioning the rights to water that are based on riparian and prescriptive rights doctrines. The Water Resources Control Board's authority to conduct adjudicatory hearings to prohibit waste and unreasonable use of water has recently been affirmed.

One area in which the Board's water allocation decisions may be weakening is the area of interstate transfers of water. Water has been determined by the U.S. Supreme Court to be a commodity in interstate commerce and a state may not generally restrict its export to another state.

Agreements

The Coordinated Operation Agreement

In May 1985, the U.S. Bureau of Reclamation and the Department of Water Resources reached accord on the Coordinated Operation Agreement (COA) for coordinated operation of the Central Valley Project and the State Water Project. Following lengthy negotiations among the many affected

SIGNIFICANT WATER POLICY LITIGATION

U.S. Supreme Court Cases

California v. United States (1978)

The U.S. Bureau of Reclamation, in operating New Melones Reservoir, must comply with State water rights law, unless it is inconsistent with congressional directives to do so. This is the leading Supreme Court decision requiring the United States, in most instances, to comply with the substance and procedures of State water rights law. The Ninth Circuit Court of Appeal later held that the conditions imposed by the State Water Resources Control Board (SWRCB) on New Melones were consistent with congressional directives (*United States* v. *State of California, State Water Resources Control Board*, 694 F.2d 1171 (1982)).

(438 U.S. 645, 98 S.Ct. 2985)

United States v. New Mexico (1978)

This case limited the amount of water the U.S. Forest Service could claim under the "reserved rights doctrine" to water necessary for the primary purposes for which the National Forests were reserved; that is, preservation of timber and securing favorable flows for private and public uses under state law. Water for secondary purposes -- for example, stock watering and environmental, recreational, or scenic purposes -- could be acquired only in the same manner as any other public or private appropriator under state law. The *California* v. *United States* and the *New Mexico* cases both emphasize Congress' historic deference to state water law.

(438 U.S. 696, 98 S.Ct. 3012)

California Cases

National Audubon Society v. Superior Court (1983)

The public trust doctrine applies to the City of Los Angeles' rights to divert water from streams tributary to Mono Lake. The State retains supervisory control over its navigable waters under the public trust to protect such uses as navigation, fisheries, commerce, recreation, and scenic and environmental values. This prevents any person from obtaining a vested right to appropriate water in a manner harmful to the public trust. As a matter of necessity, SWRCB may grant rights to take water needed in distant parts of the State, even if public trust uses are harmed, but it must take public trust into account and protect public trust values wherever feasible. SWRCB retains continuing supervision and may reconsider allocation decisions, even if the decisions were made after consideration of public trust values. SWRCB and California courts have concurrent jurisdiction to consider and protect public trust values.

(33 Cal.3d 419, 189 Cal.Rptr. 346)

Imperial Irrigation District v. State Water Resources Control Board (1986)

After an adjudicatory hearing, SWRCB found that failure to undertake additional water conservation measures was unreasonable under Article X, Section 2, of the California Constitution. The Court affirmed SWRCB's authority under the Constitution and Water Code Section 275 to conduct such a hearing and to enforce its order.

(186 Cal.App.3d 1160, 231 Cal.Rptr. 283)

United States v. State Water Resources Control Board (1986) [The Consolidated Delta Cases]

This decision (Racanelli) covers eight cases challenging SWRCB's Decision No. 1485, issued in 1978, and its Water Quality Control Plan for the Sacramento-San Joaquin Delta and Suisun Marsh. The decision recognizes SWRCB's broad authority and discretion over water rights and water quality issues, including jurisdiction over the federal CVP.

(182 Cal.App.3d 82, 227 Cal.Rptr. 161)

Fullerton v. State Water Resources Control Board (1979)

(90 Cal.App.3d 590, 153 Cal.Rptr. 518)

California Trout, Inc. v. State Water Resources Control Board (1979)

(90 Cal.App.3d 816, 153 Cal.Rptr. 672)

These two cases hold that an appropriation of water cannot be made for instream flows because some physical control over the water is a necessary element of the doctrine of appropriation.

interests, federal legislation authorizing the agreement was approved in October 1986. Authorization to execute the Suisun Marsh Agreement was included in the legislation. The Department and the Bureau signed the COA in November 1986.

The Coordinated Operation Agreement sets forth the basis upon which the CVP and the SWP will be operated to ensure that each project receives an equitable share of the Central Valley's available water. This apportioning guarantees that the two systems will operate more efficiently in combination than they would if they were operated independently of one another. The major provisions of the agreement are:

- Both parties will meet present Delta water quality standards set by the Water Resources Control Board. The Bureau of Reclamation will meet future standards set by the Board, unless the Secretary of the Interior determines those standards are inconsistent with congressional directives. In that case, the Secretary is to ask the Department of Justice to bring suit to see whether the new standards apply to the United States.

- It allows the State to buy interim water from the CVP for SWP contractors.

- It allows the Bureau to contract to transport federal water in the California Aqueduct for the Bureau's contractors in amounts equal to the amount the Department of Water Resources buys from the federal project. The Department may also move additional federal water, as long as doing so does not cut into State project supplies or increase the cost of water to State contractors.

- It clears the way for the Bureau of Reclamation to initiate the contract process for sale and delivery of additional CVP water. (A moratorium had been placed on new contracts, pending signing of the COA.)

The Department of Water Resources and the U. S. Bureau of Reclamation capped more than 25 years of negotiation on November 24, 1986, when they agreed to coordinate the operations of the State Water Project and the Central Valley Project. The Coordinated Operation Agreement was signed by David N. Kennedy (left), DWR Director, and David G. Houston (right), USBR Regional Director, Mid-Pacific Region. Looking on are Governor George Deukmejian (center) and Robert J. Moore, the Resources Agency's Washington, D.C. representative.

Suisun Marsh Preservation Agreement

The Suisun Marsh consists of a 55,000-acre wetland area in southern Solano County, just beyond the confluence of the Sacramento and San Joaquin Rivers. One of the largest contiguous brackish water marshes in the United States, the marsh is a unique and irreplaceable resource. During the fall and winter, waterfowl traveling along the Pacific Flyway depend on the marsh as a feeding and resting area. Because upstream water diversions have reduced the Delta outflows that keep the marsh viable, water rights Decision 1485, issued by the Water Resources Control Board in 1978, ordered the Bureau and DWR to develop a plan to protect the marsh. The plan was subsequently developed by DWR, and the initial facilities were completed in 1981. Completion of the plan depended on the outcome of negotiations among the Suisun Resource Conservation District, the Department of Fish and Game, the Bureau of Reclamation, and DWR.

Subsequent to completion of the initial facilities, the four agencies worked toward an agreement that would moderate the adverse effects of all upstream diversions on the water quality in the marsh. The agreement, approved in March 1987, describes facilities proposed to be constructed, a construction schedule, cost-sharing responsibilities of the State and federal governments, water quality standards, soil salinity, water quality monitoring, and purchase of land to mitigate the impacts of the Suisun Marsh facilities themselves.

An interesting feature of the agreement is that it defines a schedule and sequence of construction for the facilities of the Plan of Protection and provides for test periods during which the effectiveness of the constructed facilities are to be evaluated. Assessments will then be made to determine whether additional facilities will be needed to meet the water quality standards of the agreement.

Fish Protection Agreement

The Harvey O. Banks Delta Pumping Plant lies at the head of the California Aqueduct near the city of Tracy. It lifts water 244 feet from the Clifton Court Forebay in the Sacramento-San Joaquin Delta to Bethany Reservoir, where it begins its journey west to the southern San Francisco Bay area and south to the San Joaquin Valley and Southern California. When the plant was initially constructed, seven of the eleven pumping units planned were installed. The remaining four units were to be installed in later years when the demand for water had increased.

Development of an environmental impact report for the additional units began in the early 1980s. In January 1986, the Department of Water Resources released the final EIR; however, the next action, the filing of a Notice of Determination, was delayed until negotiations were completed for an agreement between the Departments of Fish and Game and Water Resources for preservation of fish affected by the operation of the pumps.

A unique aspect in the development of this agreement was the assistance provided by an advisory group made up of representatives from United Anglers, the Pacific Coast Federation of Commercial Fishermen's Associations, the Planning and Conservation League, and the State Water Contractors.

The agreement, signed by the directors of the two departments in December 1986, identifies the steps needed to offset adverse fishery impacts of the State Water Project. It sets up a procedure to calculate direct fishery losses annually and requires the Department of Water Resources to pay for mitigation projects that would compensate for or offset the losses. Losses of striped bass, chinook salmon, and steelhead will be mitigated first. Losses of other species will be mitigated later, as impacts are identified and appropriate mitigation measures found. Water Resources will also provide $15 million to begin a restoration program to bring fishery levels back to what they would have been, had the project not been in operation.

Federal Waterway and Wetland Protection

In recent years, federal laws regarding protection of wetlands, protection of environmental quality, and preservation of endangered species have played an increasingly greater role in the planning, development, and operation of water projects. Even in the absence of state regulations, federal law can require major undertakings to protect natural resources.

Federal law specifically regulates activities that may affect navigable waters or wetlands. These laws apply, whether or not a state also regulates these activities. There have been cases in which federal law has stopped or substantially modified a project that had received authorization by a state with few or no wetland protection policies. Federal regulations can exert a significant influence on water projects that may affect navigable waters, wildlife habitat, or wetlands. Waterways and wetlands are affected by two programs, both administered by the U.S. Army Corps of Engineers, that bring into play many other federal laws designed to protect environmental quality, fish and wildlife, water quality, and endangered species.

Corps of Engineers' Permits

The Corps of Engineers has been charged by Congress with protecting navigable waters and adjacent wetlands. It does this through two statutes, Section 10 of the Rivers and Harbors Act of 1899 and Section 404 of the Clean Water Act of 1972.

Section 10, Rivers and Harbors Act, makes it unlawful to obstruct navigable waters, or to excavate, fill, or otherwise modify the course, location, or navigable capacity of any navigable body of water in the United States without first obtaining permission from the Corps of Engineers. Section 10 applies to waterways that carry interstate commerce or that could carry interstate commerce, either in their natural condition or with reasonable modification. This definition includes all tidal waters to the mean high tide line and all navigable rivers and lakes to the ordinary high water mark.

Section 404, Clean Water Act, requires a permit from the Corps of Engineers for any activity that results in disposal of dredged material or placement of fill material in the waters of the United States. This requirement is deceptively simple, but in actuality, the Clean Water Act, including Section 404, has been given the broadest possible interpretation in the federal courts, which have found that it also refers to *any* structures or fills introduced into U.S. bodies of water. Moreover, Section 404 governs all interstate waters and waters within a state that may affect interstate or foreign commerce, including those that interstate travellers may use for recreation, those from which fish may be taken and sold in interstate commerce, or those that could be used for industrial purposes by industries in interstate commerce. This may include virtually all significant water bodies within a state.

When Section 404 was first carried out by the Corps, some argued that its jurisdiction should be the same as that of Section 10, applying only to traditionally navigable waters. However, the first court to interpret Section 404 held that it should apply as broadly as the U.S. Constitution permits because that was the intent of Congress in enacting the Clean Water Act. That interpretation was confirmed by the U.S. Supreme Court in *United States* v. *Riverside Bayview Homes, Inc.* (1985). Many other court decisions have since confirmed that protection of wetlands is one of the major purposes of Section 404, and the Corps' regulations and policies for Section 404 emphasize nondegradation of wetlands.

Although Section 404 is administered by the Corps, the Environmental Protection Agency has a veto power over a Corps determination to issue a permit. This power is rarely exercised. In one case, however, the courts confirmed an EPA veto of a permit for a shopping center in Attleboro, Massachusetts, that would have been constructed in an undisturbed deciduous wetland. The project had received all state permits, but EPA and the U.S. Fish and Wildlife Service recommended that the Corps deny the permit. When the Corps did issue the permit, EPA suspended it by initiating proceedings under Section 404. Two U.S. District Courts have upheld EPA's actions. The matter is still in litigation.

Several federal laws apply to most permits issued by agencies of the United States, including the Corps of Engineers. The best known include the National Environmental Policy Act, the Endangered Species Act, the water quality certification required by Section 401 of the Clean Water Act, and the Fish and Wildlife Coordination Act. In addition to meeting the requirements of Section 10 or Section 404, applicants must comply with these other laws before the Corps may issue a permit. These laws also play an important part in the development and operation of water projects. Most of them apply to actions taken directly by federal agencies and to nonfederal projects funded or permitted by federal agencies.

The National Environmental Policy Act

The National Environmental Policy Act (NEPA) is substantially similar to the California Environmental Quality Act (CEQA). It declares that the federal government must use all practicable means, consistent with other considerations of national policy, to protect and enhance the quality of the environment. It requires all federal agencies to prepare an environmental impact statement (EIS) for major federal actions significantly affecting environmental quality. The content of a federal EIS is very similar to that required by CEQA for a State environmental impact report. Federal agencies must interpret their statutory authorities and traditional policies to carry out NEPA's objectives.

The Endangered Species Act

The federal Endangered Species Act is designed to conserve ecosystems essential to endangered and threatened species, promote conservation of such species, and fulfill the purposes of international treaties and conventions of the United States. (The State of California has an Endangered Species Act that resembles the federal act.) The federal act includes animals, fish, insects (other than pests), and plants. An endangered species is one in danger of extinction in all or a significant portion of its range; a threatened species is one likely to become endangered. The act protects endangered species through three major mechanisms: (1) listing of endangered or threatened species, (2) federal agency consultation and protection responsibilities, and (3) a prohibition of takings of endangered species. One of the major strategies of the act is preserving habitat that is critical to the survival of an endangered or threatened species.

The Endangered Species Act requires the Secretary of the Interior to list all species that are threatened or endangered. Interested citizens may also initiate the listing process. A listing is accomplished through the rule-making process, with a proposed listing being noticed in the Federal Register. Final lists are published in the Federal Register and ultimately in the Code of Federal Regulations. These lists are revised often. Recently, citizens have requested a listing of the winter run of salmon in the Sacramento River under these procedures.

The act's second major protection is the interagency consultation requirement. All federal agencies are required to use their existing authorities to further the act's purposes. Each agency, including the Corps of Engineers, must ensure that any action it authorizes, funds, or carries out is not likely to jeopardize threatened or endangered species or critical habitat. The agency engaged in any such activity must consult with the U.S. Fish and Wildlife Service and the National Marine Fisheries Service on the extent to which the action will cause such jeopardy. The Secretary of the Interior must determine the extent to which jeopardy exists, including suggestions for reasonable and prudent alternatives. These alternatives must be implemented, either by the federal agency or by the applicant for a license.

Following the controversy over the Tellico Dam in Tennessee and the snail darter fish, Congress amended the Endangered Species Act to provide a very limited exemption procedure. An Endangered Species Committee, consisting of Cabinet officers, may grant an exemption if it finds that there are no reasonable or prudent alternatives, that the benefits of the proposed action clearly outweigh the benefits of other courses of action, that the action

San Joaquin Antelope Squirrel

has regional or national significance, and that reasonable mitigation or enhancement measures are adopted.

The act's third major protection is its prohibition on taking endangered or threatened species within the United States or its territories. Related acts, such as transportation or possession of listed species or their parts, are also unlawful.

The Corps of Engineers has denied several permits for subdivisions or other developments within tidal or former tidal areas because these projects would have been detrimental to the habitat of endangered species, including the salt-marsh harvest mouse and the light-footed clapper rail. Any water project that requires a permit from the Corps of Engineers would trigger the requirements of the Endangered Species Act, if it were found to endanger a listed species or its critical habitat.

The Endangered Species Act can also affect the design, construction, and operation of water or flood control projects. Stampede Reservoir was constructed in the late 1960s on the Little Truckee River by the U.S. Bureau of Reclamation as a water supply facility. The Secretary of the Interior subsequently determined that the entire yield of the reservoir was required to conserve endangered and threatened species of fish in Pyramid Lake, Nevada. A federal court in Reno and the Ninth Circuit Court of Appeal have upheld the Secretary's authority to refuse to execute water contracts and instead use the yield for the endangered and threatened fish in the lake.

The Endangered Species Act may affect operation and maintenance of existing facilities. For example, the valley elderberry longhorn beetle, a threatened species, lives only on elderberry growing along streambanks in some parts of the Sacramento and San Joaquin valleys. The U.S. Fish and Wildlife Service has designated a portion of the American River parkway as critical habitat for this species. This has necessitated specialized vegetation management practices within the American River floodway and training for persons performing vegetation management so that they can recognize the protected elderberry habitat. If the winter run of salmon in the Sacramento River were also to be listed under the act, it could significantly affect the operation of existing water facilities, as well as the construction of new facilities.

Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act and related acts express the will of Congress to protect the quality of the aquatic environment as it affects

Bald Eagle

Swainson's Hawk

San Joaquin Kit Fox

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 therefor, must first consult with the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the California Department of Fish and Game. The Corps' informal practice is to refrain from acting on a permit until the applicant and the fish and wildlife agencies have attempted to identify appropriate mitigation measures.

Section 401 of the Clean Water Act

Section 401 of the Clean Water Act requires any applicant for a federal permit or license that may result in a discharge of a pollutant to waters of the United States to obtain a certification from the Regional Water Quality Control Board where the discharge would occur (in California). The certification must find that the discharge will comply with all applicable effluent limitations and water quality standards. A certification obtained for construction of a facility must also pertain to its operation.

Other Federal Acts

Other federal acts that may apply to Corps permits include the Coastal Zone Management Act of 1972, which requires compliance with approved state coastal zone management programs; the Federal Power Act; the National Historic Preservation Act of 1966; the Deepwater Port Act of 1974; the Marine Mammal Protection Act; and the Wild and Scenic Rivers Act.

Mouth of the Klamath River in Del Norte County

CONVERSION FACTORS

Quantity	To Convert from Metric Unit	To Customary Unit	Multiply Metric Unit By	To Convert to Metric Unit Multiply Customary Unit By
Length	millimetres (mm)	inches (in)	0.03937	25.4
	centimetres (cm) for snow depth	inches (in)	0.3937	2.54
	metres (m)	feet (ft)	3.2808	0.3048
	kilometres (km)	miles (mi)	0.62139	1.6093
Area	square millimetres (mm^2)	square inches (in^2)	0.00155	645.16
	square metres (m^2)	square feet (ft^2)	10.764	0.092903
	hectares (ha)	acres (ac)	2.4710	0.40469
	square kilometres (km^2)	square miles (mi^2)	0.3861	2.590
Volume	litres (L)	gallons (gal)	0.26417	3.7854
	megalitres	million gallons (10^6 gal)	0.26417	3.7854
	cubic metres (m^3)	cubic feet (ft^3)	35.315	0.028317
	cubic metres (m^3)	cubic yards (yd^3)	1.308	0.76455
	cubic dekametres (dam^3)	acre-feet (ac-ft)	0.8107	1.2335
Flow	cubic metres per second (m^3/s)	cubic feet per second (ft^3/s)	35.315	0.028317
	litres per minute (L/min)	gallons per minute (gal/min)	0.26417	3.7854
	litres per day (L/day)	gallons per day (gal/day)	0.26417	3.7854
	megalitres per day (ML/day)	million gallons per day (mgd)	0.26417	3.7854
	cubic dekametres per day (dam^3/day)	acre-feet per day (ac-ft/day)	0.8107	1.2335
Mass	kilograms (kg)	pounds (lb)	2.2046	0.45359
	megagrams (Mg)	tons (short, 2,000 lb)	1.1023	0.90718
Velocity	metres per second (m/s)	feet per second (ft/s)	3.2808	0.3048
Power	kilowatts (kW)	horsepower (hp)	1.3405	0.746
Pressure	kilopascals (kPa)	pounds per square inch (psi)	0.14505	6.8948
	kilopascals (kPa)	feet head of water	0.33456	2.989
Specific Capacity	litres per minute per metre drawdown	gallons per minute per foot drawdown	0.08052	12.419
Concentration	milligrams per litre (mg/L)	parts per million (ppm)	1.0	1.0
Electrical Conductivity	microsiemens per centimetre (uS/cm)	micromhos per centimetre	1.0	1.0
Temperature	degrees Celsius (°C)	degrees Fahrenheit (°F)	(1.8 × °C)+32	(°F−32)/1.8

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The California Water Commission serves as a policy advisory body to the Director 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.

ACKNOWLEDGMENTS FOR PHOTOGRAPHS

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Statistics of Major Reservoirs and Aqueducts

SURFACE WATER STORAGE RESERVOIRS

75,000 acre-feet or larger

Reservoir (Dam)	Area in acres	Capacity in acre-feet	Owner	Year Completed
Clear Lake (Modoc County)	24,800	388 000	USBR	1910
Tahoe	122,000	745,000[1]	USBR	1913
Clear Lake (Lake County)	43,000	420,000[1]	YCFCWCD	1914
Huntington Lake	1,440	89,000	SCE	1917
Big Sage	5,270	77,000	HSVID	1921
Pillsbury	2,000	94,000	PGandE	1921
Copco Lake	1,000	77,000	PP&L	1922
Hetch Hetchy	1,960	360,000	SF	1923
Calaveras	1,450	100,000	SF	1925
Shaver	2,180	135,000	SCE	1927
Almanor	28,260	442,000	PGandE	1927
Bucks	1,830	103,000	PGandE	1928
Pardee	2,130	210,000	EBMUD	1929
Salt Springs	920	139,000	PGandE	1931
El Capitan	1,560	113,000	SD	1934
Havasu (Parker)	20,400	648,000	USBR	1938
Mathews	2,750	182,000	MWD	1938
Crowley	5,280	184,000	LADWP	1941
San Vicente	1,070	90,000	SD	1943
Shasta	29,500	4,552,000	USBR	1945
Millerton (Friant)	4,900	520,000	USBR	1947
Anderson	980	91,000	SCVWD	1950
Isabella	11,400	570,000	USCE	1953
Cachuma	3,090	205,000	USBR	1953
Edison	1,890	125,000	SCE	1954
Pine Flat	5,970	1,000,000	USCE	1954
Piru	1 240	100,000	UWCD	1955
Folsom	11 450	1,010,000	USBR	1956
Lloyd (Cherry Valley)	1 760	268,000	SF	1956
Beardsley	650	98,000	OID-SSJID	1957
Nacimiento	5,370	350,000	MCFCWCD	1957
Berryessa (Monticello)	20,700	1,602,000	USBR	1957
Twitchell	3,670	240,000	USBR	1958
Wishon	1,000	128 000	PGandE	1958
Courtright	1,480	123,000	PGandE	1958
Casitas	2,720	254,000	USBR	1959
Mendocino (Coyote Valley)	1,960	130,000	USCE	1959
Mammoth Pool	1,100	123,000	SCE	1960
Little Grass Valley	1 430	93,000	OWID	1961
Success	2,400	85,000	USCE	1961
Clair Engle (Trinity)	16,400	2,448,000	USBR	1962
Kaweah (Terminus)	1,940	150,000	USCE	1962
Black Butte	4 560	160,000	USCE	1963
Camp Far West	2,680	103,000	SSWD	1963
Union Valley	2,860	271,000	SMUD	1963
Camanche	7,700	431,000	EBMUD	1963
New Hogan	4,410	325,000	USCE	1963
Whiskeytown	3,200	241,000	USBR	1963
Loon Lake	1,450	77,000	SMUD	1963
French Meadows	1,420	134,000	PCWA	1965
San Antonio	5,720	348,000	MCFCWCD	1965
Hell Hole	1,250	208,000	PCWA	1966
Davis (Grizzly Valley)	4,000	84,000	DWR	1966
San Luis	12,700	2,039,000	DWR-USBR	1967
McClure (New Exchequer)	7,130	1,026,000	MID	1967
Oroville	15,800	3,538,000	DWR	1968
New Bullards Bar	4,810	970,000	YWCA	1970
Stampede	3,440	225,000	USCE	1970
Mojave	1 980	90,000	USCE	1971
New Don Pedro	12,960	2,030,000	TID-MID	1971
Silverwood (Cedar Springs)	980	75,000	DWR	1971
Castaic	2,240	324,000	DWR	1973
Perris	2,320	131,000	DWR	1973
Pyramid	1,360	171,000	DWR	1973
Indian Valley	4,000	300,000	YCFCWCD	1976
Buchanan	1,780	150,000	USCE	1979
Hidden	1,570	90,000	USCE	1979
New Melones	12,500	2,400,000	USCE	1979
Sonoma (Warm Springs)	3,600	381,000	USCE	1984

Above natural outlet

MAJOR AQUEDUCTS

	Capacity in cubic feet per second	Length in miles	Owner	Initial Year of Operation
Los Angeles	710	244	LADWP	1913
Mokelumne River	590	90	EBMUD	1929
Hetch Hetchy	460	152	SF	1934
All American	15,100	80	USBR	1938
Contra Costa	350	48	USBR	1940
Colorado River	1,600	242	MWD	1941
Friant-Kern	4,000	152	USBR	1944
Coachella	2 500	123	USBR	1947
San Diego No 1	200	71	SD	1947
Delta-Mendota	4,600	116	USBR	1951
Madera	1,000	36	USBR	1952
Putah South	960	35	USBR	1957
Santa Rosa-Sonoma	62	31	SCWA	1959
San Diego No 2	1,000	93	SD	1960
Corning	500	21	USBR	1960
Petaluma	16	26	SCWA	1961
Tehama-Colusa	2,530	113	USBR	1961[2]
South Bay	360	43	DWR	1965
North Bay	46	27	DWR	1968[3]
California	13,100	444	DWR	1972[4]
Folsom South	3,500	27	USBR	1973[5]
Cross Valley	740	20	KCWA	1975

A number of major canals in the Central Valley some as large as those shown on the map, could not be included for lack of space

[1] Initial reach only for most irrigation canals

[2] Tehama and Glenn Counties

[3] Interim facilities

[4] To Southern California

[5] Reaches 1 and 2

OWNERS OF RESERVOIRS AND AQUEDUCTS

DWR	California Department of Water Resources
EBMUD	East Bay Municipal Utility District
HSVID	Hot Springs Valley Irrigation District
KCWA	Kern County Water Agency
LADWP	Los Angeles Department of Water and Power
MCFCWCD	Monterey County Flood Control and Water Conservation District
MID	Merced Irrigation District
MWD	Metropolitan Water District of Southern California
OID-SSJID	Oakdale Irrigation District—South San Joaquin Irrigation District
OWID	Oroville-Wyandotte Irrigation District
PCWA	Placer County Water Agency
PGandE	Pacific Gas and Electric Company
PP&L	Pacific Power and Light
SCE	Southern California Edison
SCVWD	Santa Clara Valley Water District
SCWA	Sonoma County Water Agency
SD	City of San Diego
SF	City and County of San Francisco
SMUD	Sacramento Municipal Utility District
SSWD	South Sutter Water District
TID-MID	Turlock Irrigation District—Modesto Irrigation District
USCE	U S Army Corps of Engineers
USBR	U S Bureau of Reclamation
UWCD	United Water Conservation District
YCFCWCD	Yolo County Flood Control and Water Conservation District
YCWA	Yuba County Water Agency

Major Storag
and Conveyan

Reservoirs
ce Facilities

Legend

- LOCAL PROJECTS
- STATE WATER PROJECT
- FEDERAL PROJECTS
- DASHED LINES DELINEATE AUTHORIZED FACILITIES NOT YET CONSTRUCTED.