CHAPTER 2

CALIFORNIA'S WATER SCARCITY PROBLEMS

"Will anybody compare the idle Pyramids, or those other useless though much renouned works of the Greeks with these aqueducts, with these many indispensable structures?"
Julius Frontinus (97 AD), *The Water Supply of the City of Rome*, 16.

The challenge of supplying water to an increasing population and productive agricultural sector has occupied the focus of California water managers for several decades. More recently, environmental water requirements and mitigation measures also have engaged California's water managers. As competing demands increase on a finite water supply, reliability becomes more difficult to achieve for all water uses.

Traditionally, California met water supply challenges with ever increasing infrastructure. During much of this century through the 1970's, reservoirs were built to store water from wetter periods for use in drier seasons or years, thus dampening natural seasonal and annual fluctuations in water availability. A complex and extensive network of canals and pipelines now exists to tie the more humid and sparsely populated northern and eastern regions of California to southern and coastal farms and cities. New surface storage opportunities to increase supply are now quite limited and face increasing costs and environmental barriers. These restrictions, along with growing water demands, have lead to consideration of other alternatives to improve California's water system including: demand management, water marketing, groundwater banking, conjunctive use, and more coordinated operations of storage, conveyance, and treatment facilities. Major efforts are now underway to identify and implement an environmentally sound and politically and financially feasible mix of options.

This chapter reviews current and anticipated 2020 water supply problems facing California and introduces some of the institutional challenges involved in their resolution. Some of these institutional issues are taken up in more detail in other chapters. Both structural and non-structural statewide long-term options for resolving these problems are currently under consideration. The next chapter provides a survey of proposed structural options. Subsequent chapters of this report discuss important issues and options for more flexible and coordinated operations of infrastructure through various non-structural options and coordinated agreements.

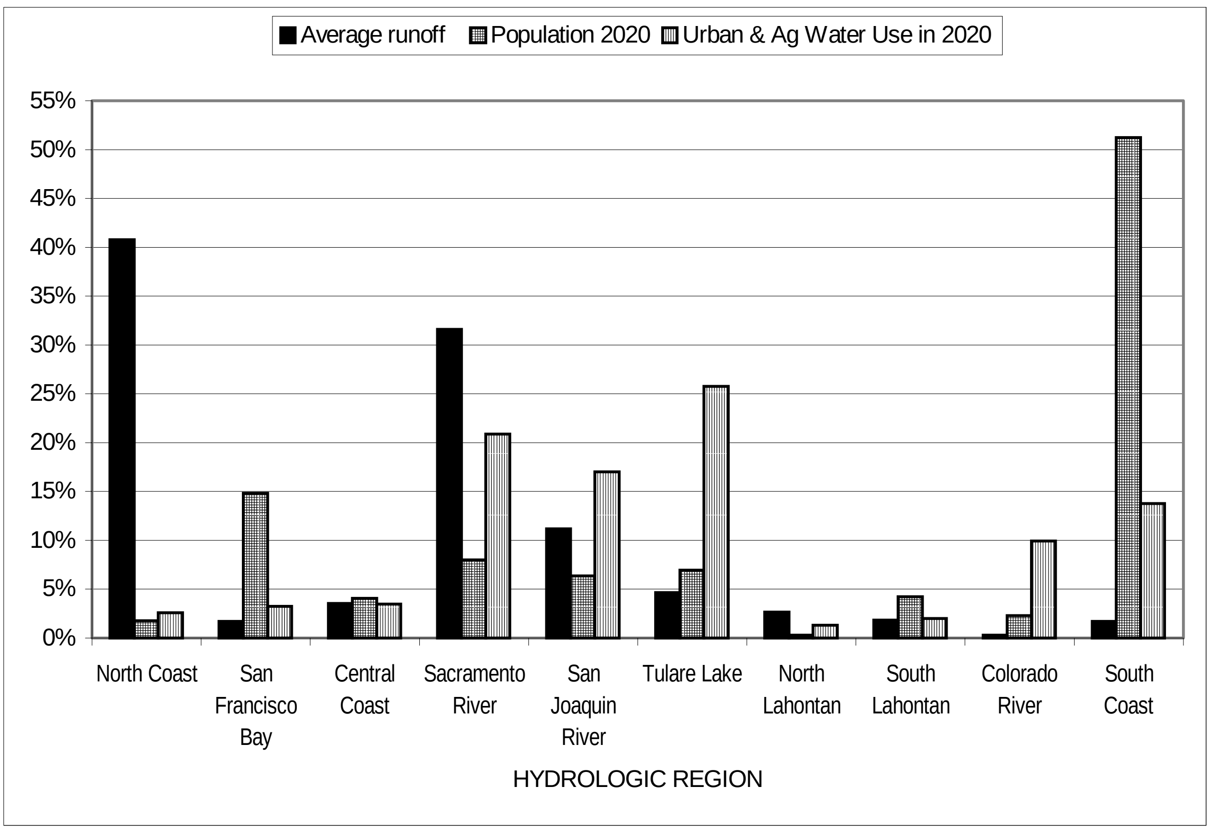
CURRENT PROBLEMS

Current and future predicted water scarcity in California is characterized by many inter-linked problems. These problems include the related issues of water supply availability and reliability, growing and competing water demands for urban, environmental, and agricultural sectors, water quality concerns, and groundwater overdraft. To water agencies, water supply reliability is a goal; to water contractors and individual customers, reliability is necessary for the success of most occupations and pursuits. Reliability changes with the balance between available supply and demand for water of a given quality and cost. Increased demand from urban, agricultural, or environmental sectors can lead to water shortages, as can natural reductions in precipitation and runoff. While less visible, water quality and groundwater are equally important aspects of water supply reliability in California. Many of the state's water supply reliability problems manifest themselves through groundwater overdraft and water quality degradation.

Water Supply Availability and Reliability

California's water availability varies regionally, seasonally, and annually. Precipitation and runoff are unevenly distributed with more than 70% of the 75 maf average statewide annual runoff occurring in Northern California (DWR 1998a). Most Californian's live where water is not plentiful and grow crops where climate and soils are advantageous but local water supply is limited. Figure 2-1 compares the distribution of anticipated population and water use (urban and agricultural) in 2020 to average annual runoff across the ten hydrologic regions of California shown in Figure 2-2. Receiving less than 2% of the average annual runoff, the South Coast hydrologic region is expected to have 51% of California's projected 2020 population. The North Coast and Sacramento River hydrologic regions with 72% of average runoff are expected to have less than 10% of the projected 2020 population.

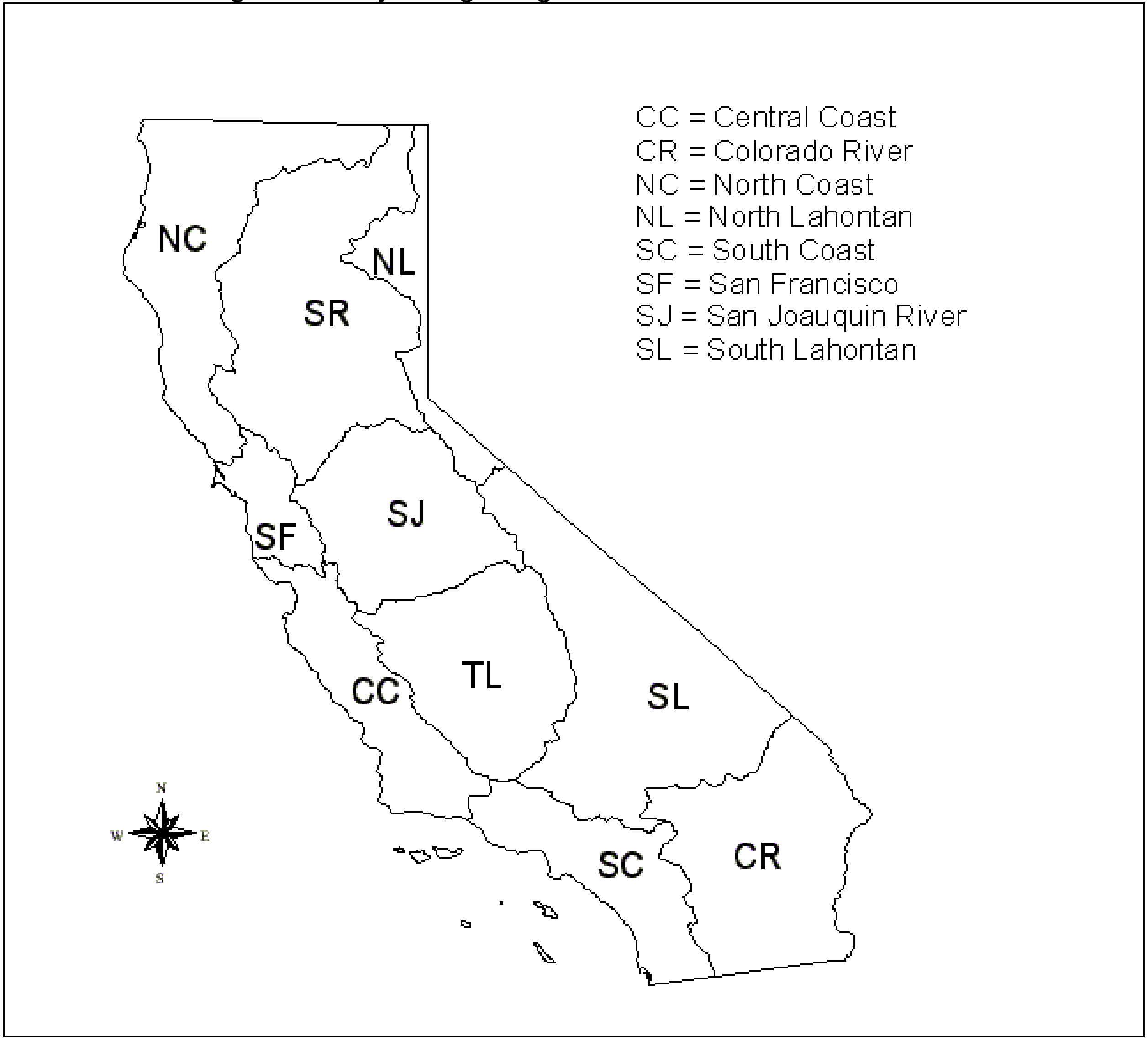
Figure 2-1. Demographics and Hydrology



Source: DWR (1998a)

These regional disparities in water availability and demand in California are compounded by a strong disparity in the seasonal pattern of water supplies and demands. The general pattern of a dry season from May to October and a wet season from November to April is opposite the cycle of high summer and low winter water use in urban and agricultural sectors (DWR 1994a). This mismatch drives the need for water storage to hold runoff for seasonal demands distant in time and place from natural precipitation.

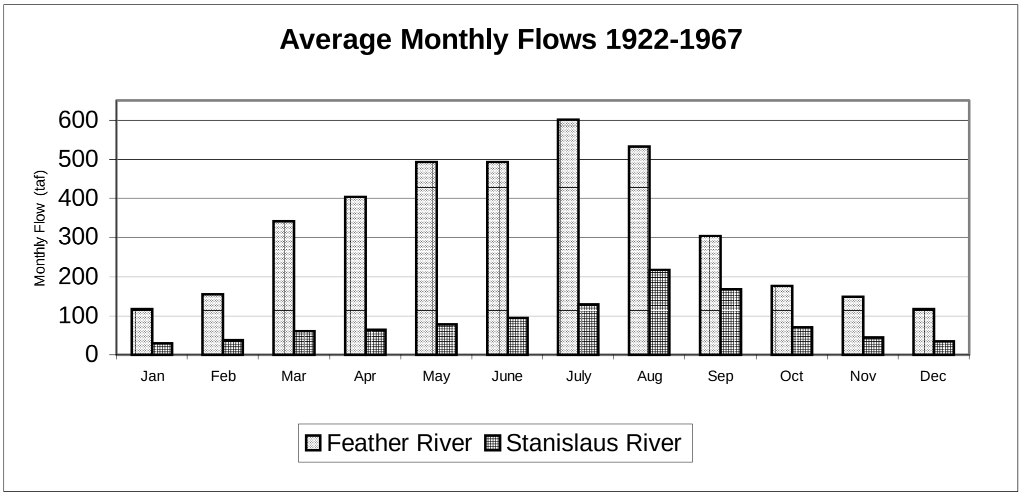
Figure 2-2. Hydrologic Regions and Counties of California



Source: DWR (1998a)

The natural or unimpaired flow in the Feather and Stanislaus Rivers illustrates the wet and dry extremes of California hydrology (Figure 2-3). Monthly flows increase steadily from November to April, when snowmelt usually commences, and then drop precipitously. Some rivers with smaller watersheds, such as the Stanislaus, show a more drastic transition to the dry season after snowmelt, with little or no natural flow in August and September (USBR 1997). Before dam construction, many other Central Valley rivers followed a similar runoff pattern, limiting crop options for Sacramento and especially San Joaquin Valley farmers. After dam construction, river runoff became more predictable and downstream water availability increased during dry seasons. Large imports of stored surface water are now used to supplement local water for most major urban and agricultural areas of the state.

Figure 2-3. Feather and Stanislaus River Monthly Flows



Source: USBR (1997)

Water supply reliability, the ability to meet demands in drought years as well as average years, is often more involved than the construction of a dam to regulate river flow. Major water projects, such as the State Water Project (SWP) and the Central Valley Project (CVP), depend on rainfall, snowpack, carryover storage, pumping capacity from the Delta, and regulatory constraints to meet south of Delta contractor requests (DWR 1998a). With existing facilities, DWR (1998a) predicts the CVP has a 20% chance of making full south of Delta deliveries under 1995 and 2020 levels of development, while the SWP has a 65% chance of making full 1995 deliveries and less than a 25% chance of making full 2020 deliveries. Under the present water supply system in California, Table 2-1 shows predicted shortages for both average and drought water years in 2020.

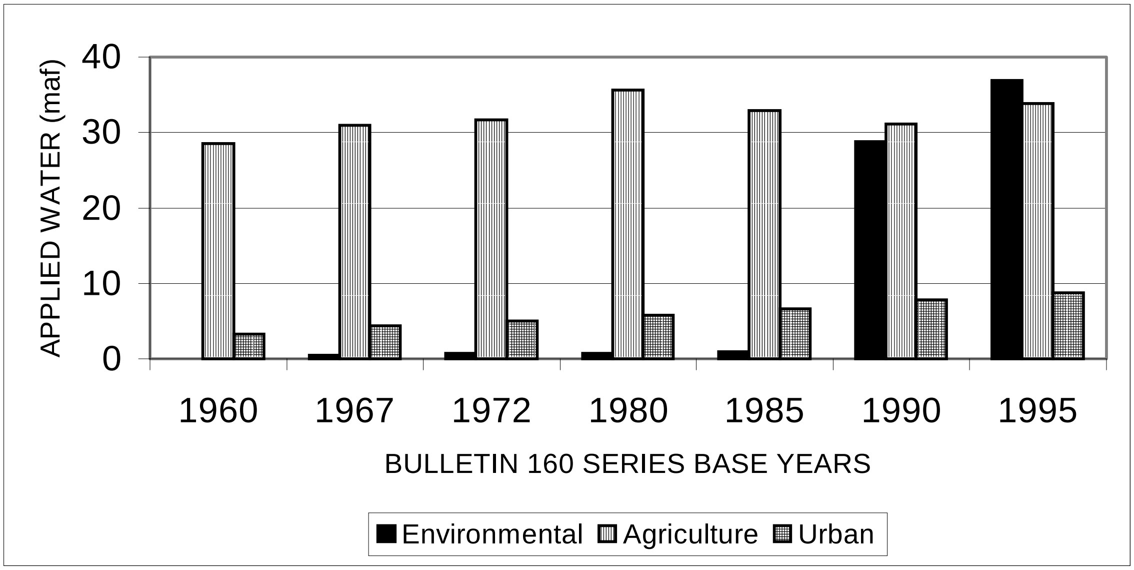
Table 2-1. State-wide Water Supply Shortages

With existing facilities and programs (maf)			
1995 Average	1995 Drought	2020 Average	2020 Drought
1.6	5.1	2.4	6.2
With options likely to be implemented (maf)			
1995 Average	1995 Drought	2020 Average	2020 Drought
1.6	5.1	0.2	2.7

Source: DWR (1998a)

The California Department of Water Resources (DWR) separates California water demand into three categories: agricultural, urban, and environmental. Water demands for all three categories have changed over time, with the greatest changes occurring in the definition and requirements of environmental water demands. Agricultural water use is estimated by multiplying the irrigated acreage of each crop by applied water use per acre. Urban water use is determined by estimates of per-capita use which include residential, commercial, industrial, and governmental portions of applied urban water. Environmental water allocation has increased steadily since approval of the 1957 California Water Plan (Figure 2-4). The most recent California Water Plan update (DWR 1998a) defines environmental water use as: dedicated flows in State and Federal wild and scenic rivers, Bay-Delta outflows, instream flow requirements, and applied water delivered to managed freshwater wildlife areas. The original purposes of most storage infrastructure in the state did not include environmental purposes. Consequently, conflicts have arisen for most of these reservoirs between original and evolving purposes of operation.

Figure 2-4. California Water Allocation Since 1960



Source: DWR (1966, 1970, 1974, 1983, 1987, 1993, 1998a)

<u>Agricultural Water Demands</u>

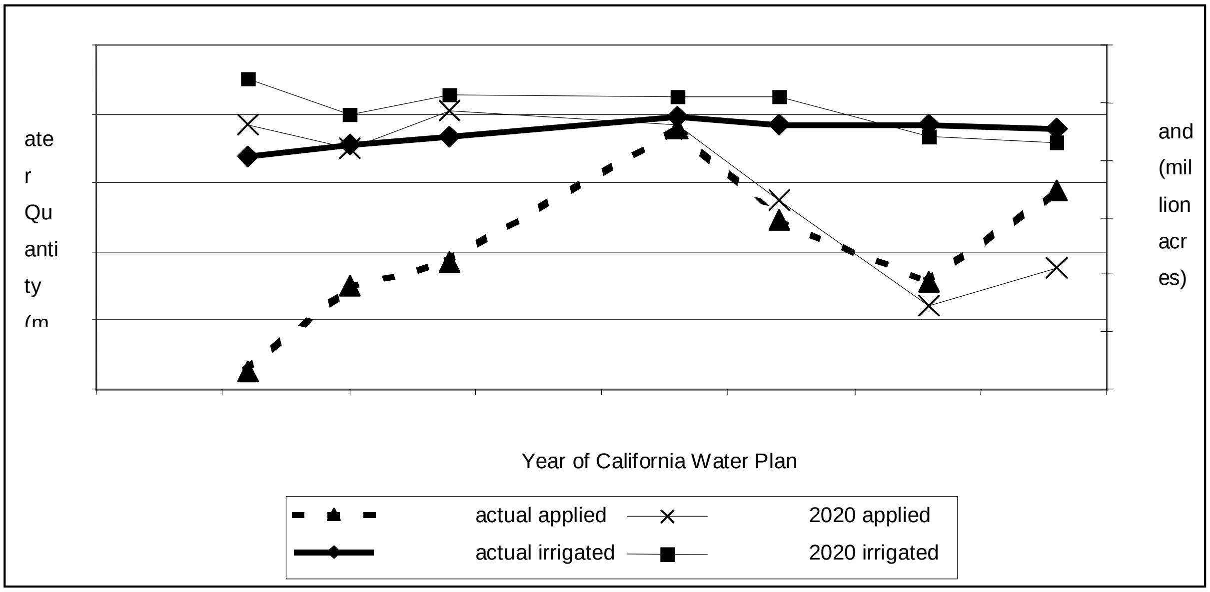
Figure 2-5 shows the evolution over time of "actual" (base year of the update) and 2020 forecasted total agricultural water demands in California according to updates of the California Water Plan starting in 1966. Both irrigated acres (not including double cropping) and applied water are shown. The forecasted 2020 applied water use in 1983 and 1987 is actually for the year 2010 (DWR 1983, 1987).

Before the 1993 update, the acreage of irrigated croplands in California was expected to continue growing as population increased. However, the peak in total irrigated land of 9.7 million acres occurred in 1981, one year after the base year of the 1983 update. Irrigated land declined to 9.1 million acres by 1995, the base year for the 1998 update (DWR 1998a). The last two updates to the California Water Plan (1993 and 1998) forecast a decrease in 2020 agricultural land as urbanization spreads. The latest update indicates a statewide decrease of 325,000 acres by 2020 (DWR 1998a). A regional example is Tulare Lake, which is expected to double in population and lose 5% of its cropland by 2020.

Trends in applied water in Figure 2-5 differ from those for irrigated acreage. An increase in agricultural acreage of 1.4 million acres between the 1966 and 1983 Water Plan updates was accompanied by an applied water increase of 7.1 maf. Much of the increase in agricultural acreage was due to the conversion of previously dry-farmed barley land to irrigated wheat (DWR 1983). Double cropping during this period also increased. Although the 1987 and 1993 California Water Plan updates both report a total irrigated land area of around 9.2 million acres for their respective base years, the amount of actual applied water in 1993 was around 1.8 maf less than in 1987. DWR (1994a) attributes this reduction in applied water to changes in cropping patterns and an average improvement in irrigation efficiency from 60% to 70% during the 1980s.

Actual applied water use then increased more than 2 maf by 1995, the base year of the 1998 update, to nearly 34 maf. The lowest forecasted 2020 applied water quantity was in the 1993 update to the California Water Plan. That forecast was increased by about 1 maf in the 1998 update as a result of increases in actual applied water. Currently, projections for 2020 indicate that average year total agricultural applied water use is expected to decline 7% or 2.3 maf from the current base year of 1995 (DWR 1998a).

Figure 2-5. Agricultural Land Use and Applied Water in California



Source: DWR (1966, 1970, 1974, 1983, 1987, 1993, 1998a)

Notes: Base years for updates are 1960, 1967, 1972, 1980, 1985, 1990, and 1995. The forecasted 2020 applied water use from Bulletins 160-83 and 160-87 is for the year 2010. The 1974 projected 2020 water use and population values are for scenario III, “most reasonable”. Applied water is for average water years (if the Bulletin makes a distinction between average and drought years). Bulletin 160-93 agricultural acreage is normalized, based on averages of the 1980s.

Environmental Water Demands

Environmental regulation has greatly changed water resources planning and management. “Before 1960…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” (DWR 1987). “Taming” rivers was simply one aspect of making a region more suitable for human habitation and pursuits. A change in the common perception of wild rivers, perhaps instigated by alarm over the few remaining, occurred in the late 1960s and early 1970s. Two of the first major actions taken were enactment of the Federal and State Wild and Scenic Rivers Acts in 1968 and 1972, respectively (DWR 1970,1974,1998a). These acts effectively cancelled planned development and potential supply on rivers, especially in the North Coast hydrologic region.

Since the Davis-Dolwig Act of 1961 declared “ that recreation and enhancement of fish and wildlife are among the purposes of state water projects…” (DWR 1966), defining and quantifying environmental water demand has been a challenge. Simultaneous with the struggle to quantify environmental demand has been the development of an appropriate definition of what to include. Each successive update to the California Water Plan (see Table 2-2) has made some progress in meeting the challenge, beginning with mention in 1966 of the environmental benefits, especially to anadromous fish, of various mitigation measures. Typically, instream flow requirements are now established to support aquatic and riparian wildlife through maintenance of water temperature and oxygen levels, and the removal of sediments and waste, as well as for recreation. Because the water needs of ecosystems and particular species of concern are not completely understood, decisions on instream flows continue to change with the development of new knowledge.

Table 2-2. Current[a] and Predicted Quantified Environmental Water Use (maf)

Water Plan Update	Current Use	2020 Use	Description
1966	Not quantified	Not quantified	
1970	0.5	0.9	recreation, fish, and wildlife (consumptive use)
1974	0.7	0.8	recreation, fish, and wildlife (consumptive use)
1983[b]	0.7	0.8	recreation, fish, and wildlife (consumptive use)
1987[b]	0.9	1.0	wildlife refuges, energy, conveyance loss, non-urban public parks (consumptive use) <?>
1993	28.8	29.3	instream flows, wetlands, Bay-Delta outflows, some wild & scenic rivers
1998	36.9	37.0	instream flows, wetlands, Bay-Delta outflows, wild & scenic rivers

Notes:
[a] Current refers to the actual water use estimated in the base year of the Water Plan Update; see notes Figure 2-4.
[b] For 1983 and 1987, 2020 use in this table is actually use forecasted for 2010 from these two updates

Source: DWR (1966, 1970, 1974, 1983, 1987, 1993, 1998a)

Environmental water demand was not quantified in the 1966 update of the California Water Plan. However, monthly fish flow requirements below Lewiston (Trinity River), Whiskeytown (Clear Creek), Keswick (Sacramento River), Nimbus (American River), and Thermolito AfterBay (Feather River) Dams had already been determined by the California Department of Fish and Game and operating agencies. These flows totaled around 2.9 maf per year. The 1970 update listed the consumptive use of water reserved for wildlife management areas. Listed separately in 1970 were streamflow maintenance agreements with the California Department of Fish and Game totaling some 5 maf and including 9 hydrologic regions. It was recognized that these agreements were not sufficient for achieving fishery maintenance or adequate water quality levels.

Prior to the 1993 California Water Plan Update, environmental water demand was defined by consumptive use. Since then computations are similar to consumptive use analysis applied to quantify urban and agricultural water demands. For the first time in the 1993 update, recreation and fishery flow requirements were determined on a statewide basis when DWR presented a summary of present and proposed fishery flows for major California river systems. Based on inter-agency agreements and the "Instream Flow Incremental Methodology" (IFIM), these flows totaled 27.4 maf at the 1990 level of development, the base year for the 1993 update (DWR 1993). The unimpaired flows of some wild and scenic rivers such as those of the North Coast (18.9 maf) were included in this total. The five years between Bulletins 160-93 and 160-98 saw further changes and an increase in environmental water management concerns (see Table 2-2). Ten new waterways were added to the list of rivers with instream flow requirements and several other streams had their required flows increased (DWR 1998a). More changes are likely in the future with passage of the Central Valley Project Improvement Act (CVPIA) in 1992 and other environmental legislation.

The CVPIA, with 800 taf of CVP "yield" dedicated primarily for doubling the Central Valley's anadromous fish population, could mean a significant increase in instream flow for some rivers (DWR 1998a). Because the Environmental Impact Statement (EIS) process for the CVPIA is still underway, and it is not known if supplemental water will be acquired to meet the flow requirements, impacts of this change remain speculative. The implementation of the CVPIA raises many questions, particularly if the water used for instream flow needs can also be used for downstream Bay-Delta purposes.

Water quality concerns began to be addressed in the early 1970s with the Porter-Cologne Water Quality Control Act and Water Rights Decision 1379. The Porter-Cologne Act required implementation of a statewide program to control water quality. Decision 1379 was concerned with Delta water quality and started the process of quantifying necessary outflows. It culminated in 1977 with Decision 1485, the result of over 15 years of research on the development of relationships between Delta water quality and outflow that set new higher water quality standards for the Delta and Suisun Marsh. More recently, the interim order WR 95-6 amended Decision 1485 to better address water quality and flow in the Delta.

Urban Water Demands

Between 1960 and 1995, California's population increased 51% while statewide applied urban water use rose 63% (see Figure 2-6). In the 1960s population increased by 23%, slowed to 14% in the 1970s, and then rose to 21% in the 1980s. Most population growth in California is now due to natural increase rather than immigration. Population-of-birth forecasts during the 1960s and 1980s also were large (Figure 2-6). The latest 2020 forecast population is 47.5 million from a 1995 base year population of 32 million (DWR 1998a).

During the 1960s through 1980s, actual applied urban water increased more quickly than population in California at around 25% per decade. The trend of a greater rate of increase in water use than that of population is not expected to continue. Statewide, urban water use is expected to increase, but the per capita use by 2020 should decline in all hydrologic regions (DWR 1998a). Implementation of urban "Best Management Practices" (BMPs) is estimated to slow the growth of urban water use to 27% for a projected population increase of 33% by the year 2020. CALFED (1999a) expects to further decrease per-capita use of water beyond implementation of BMPs, resulting in a statewide 2020 projected average urban per-capita demand of 203 gpcd, 9% less than the 1995 rate of 224 gpcd.

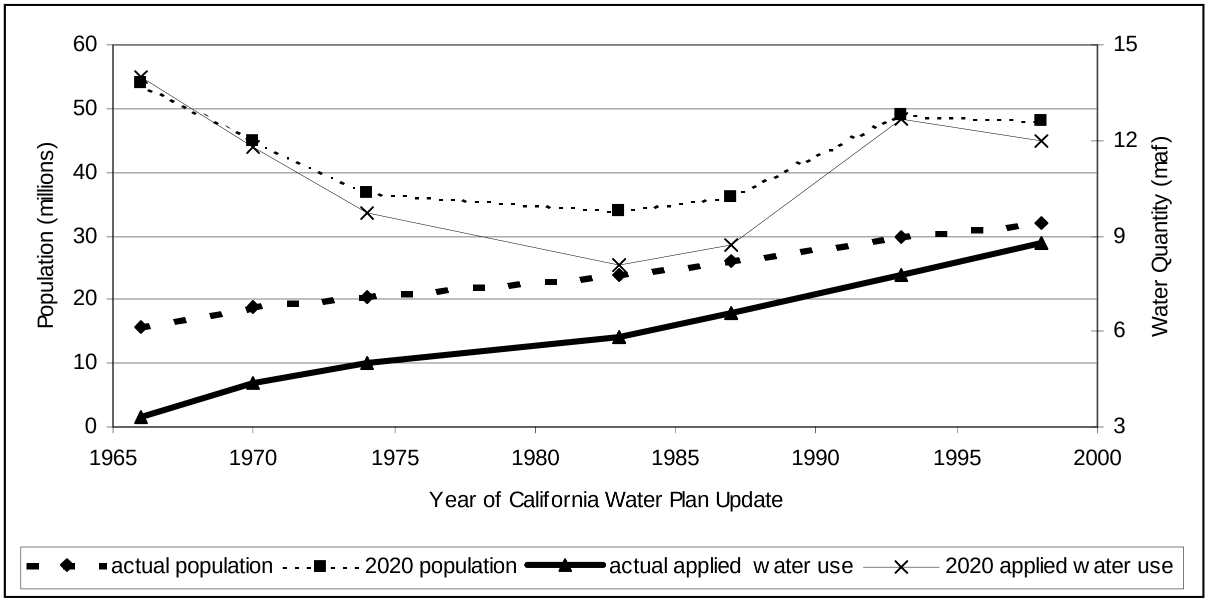
2020 Water Demand Situation

Projected water demands for agricultural, urban and environmental water use reflect several key trends in future statewide water demands (DWR 1998a):

1) stabilization or slight decline of agricultural water demands resulting from land conversion to urban use;
2) agricultural drainage problems in western San Joaquin Valley;
3) greater crop competition in agriculture;

4) significant population increases and urbanization of drier hotter inland and southern areas of the state raising urban water use and the demand for imported water supplies; and increasing water requirements for environmental purposes.

Figure 2-6. Population and Urban Applied Water Use in California



Source: DWR (1966, 1970, 1974, 1983, 1987, 1993, 1998a)

Notes: Base years for updates are 1960, 1967, 1972, 1980, 1985, 1990, and 1995. The forecasted 2020 applied water use in Bulletins 160-83 and 160-87 is for the year 2010. The 1974 projected 2020 water use and population values are for scenario III, "most reasonable". Applied water is for average water years (if the Bulletin makes a distinction between average and drought years).

Groundwater Overdraft

Groundwater provides about 30% of California's agricultural and urban water supplies in an average year. During drought years, more groundwater is extracted, supplying 40% or more of agricultural and urban use. The production of groundwater at the 1995 level of development on average is estimated at 12.5 maf per year (DWR 1998a). Of this amount, 1.46 maf/yr is estimated to be what is called overdraft (see Table 2-3).

A groundwater basin experiences overdraft if extraction is not replenished over time. Overdraft can diminish use of a basin as a supply or as storage. Higher pumping costs, changes in water quality, and subsidence are common consequences of overdraft. Land subsidence affects not only the structures and roads on the land surface, often with negative consequences for flooding, but can also permanently reduce water storage capacity of the aquifer. Banking groundwater for later use has been proposed and used as one remedy to mitigate overdraft. Banking groundwater during wet years is also a water storage option to improve system reliability in dry years.

The expected decreases in average annual groundwater overdraft from 1995 to 2020 levels of development in Table 2-3 are attributed to reductions in irrigated agricultural lands in the San Joaquin River and Tulare Lake hydrologic regions and to conveyance of SWP water through the

Coastal Branch of the California Aqueduct to the Central Coast hydrologic region (DWR 1998a). Increased overdraft in the Sacramento River hydrologic region may be due to expected increases in population, from 2.4 million in 1995 to 3.8 million in 2020.

Table 2-3. 1995 and 2020 Regional Groundwater Overdraft by Hydrologic Region

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

Source: DWR (1998a)

Water Quality Concerns

A reliable water supply delivers not only sufficient quantity, but also water of adequate quality for intended uses. Water quality impacts of urban and agricultural activities, through groundwater overdraft, waste disposal, and other generated pollutants, as well as seawater intrusion, are major concerns in California. Quality determines the utility of water and its environmental impact. Most uses of water are accompanied by quality standards that safeguard the health of communities and ecosystems.

Some of the major constituents and characteristics used to determine water quality are shown in Table 2-4. Different uses have different quality requirements. For example, drinking water standards are more stringent than those designated for irrigation or certain aquatic species. Additionally, urban water quality concerns encompass distribution system requirements. High salinity and total dissolved solids (TDS) levels in municipal water supply can reduce recycling and groundwater recharge opportunities, and decrease the useful life of water system equipment through corrosion (CALFED 1999b).

Table 2-4. A Partial List of Water Quality Constituents and Characteristics

Chemical constituents	Pesticides
Tastes and odors	pH
Human health and ecological toxicity	Radioactivity
Bacteria	Salinity
Biostimulatory substances	Sediment
Color	Settleable material
Dissolved oxygen	Suspended material
Floating material	Temperature
Oil and grease	Turbidity

Source: DWR (1998a)

Each water source has its own particular water quality issues that depend upon its flow history and environmental surroundings, and affect its practical use and reliability. The following water quality issues illustrate the complexity of California's water quality problems. Such problems are likely to increase and expand as water demand, activities, and water quality standards intensify in the future.

The sensitivity of plants to salinity encourages the practice of leaching salts from agricultural lands to prevent plant toxicity. In the San Joaquin Valley, a salinity cycle (CALFED, 1999b) occurs where salts from the Delta are applied to crops as they are irrigated while the drainage water flowing back to the Delta through the San Joaquin River accumulates more salts from the soil. Attempts to break this cycle have been unsuccessful. For example, when San Joaquin Valley farm drainage was diverted to Kesterson Wildlife Refuge, unintended harm occurred to wild fowl due to high selenium levels in the agricultural drainage water (DWR 1983; Hundley 1992).

Water exported from the Delta is an important supply to southern portions of the state, especially urbanized southern California. As it is transferred through the Delta, water dissolves and accumulates organic compounds (often measured as total organic compounds (TOC)) that then react with the disinfectants used in municipal water treatment. Bromide present in Delta water from tidal mixing with seawater also can react with disinfectants. These disinfectant byproducts (DBPs) are a public health concern which has led to a lowering of maximum levels for some of them and a requirement to remove a high percentage of the DBP precursors (CALFED 1998a; DWR 1998a). The annualized capital and operating cost of removing DBPs and their precursors such as TOC and bromide from Delta drinking water supplies would be close to $0.5 billion dollars annually (CALFED 1999d).

The Colorado River illustrates another water quality problem in California. Colorado River water collects minerals both from natural and agricultural sources and, consequently, has a relatively high salinity level. To meet drinking water standards, the Metropolitan Water District of Southern California (MWD) blends Colorado River water with less salty Delta water before urban distribution (DWR 1998a). The economic costs of blending and salinity damage in the urban sector are large (MWD and USBR 1998).

Along California's coast, seawater intrusion can accompany groundwater overdraft. The four coastal hydrologic regions all experience some seawater intrusion into their freshwater aquifers used for water supply (DWR 1998a). Measures used to control or reverse salinity intrusion include hydraulic barriers produced by injection wells or percolation artificial recharge, the replacement of groundwater with water from other sources ("in-lieu recharge") usually imported, and groundwater management programs.

INSTITUTIONAL CHALLENGES

Compounding the interdependent water supply reliability problems discussed in the previous section are institutional issues that are critical parts to current and future resolution. These institutional challenges include:

- regulatory uncertainty created by an evolving institutional context for water management in California, particularly concerning long-term drinking water standards and resolution of the Delta;

- water rights and the need for more flexible water allocation when faced with decreasing water availability and reliability;
- wheeling and access to water supply through more coordinating operations as local, regional, and statewide systems become increasingly interconnected;
- lengthy time required to resolve these uncertain issues, provide institutional assurances, and develop long-term statewide solutions; and
- mechanisms and methods to acquire the substantial financing such plans are likely to require.

The following sections introduce these institutional challenges, several of which are discussed in more detail in subsequent chapters of this report as they affect achievement of alternative option solutions.

Regulatory Uncertainty

The management of water resources is characterized by uncertainty. Climate and hydrology are fundamental uncertainties. Changes in demand for water due to population growth, market changes for agricultural products, environmental concerns, and re-evaluation of the rules regulating water use contribute additional uncertainty. Climate is perceived as beyond control, not so with rules and regulations. As struggles continue to define the least environmentally and socially harmful methods of economically using water, changing regulations are inevitable. Many of the current regulatory disputes that create substantial uncertainty for water supply planning involve water rights and the Delta.

Water Rights

Water rights uncertainty has been a historical impediment to water development and many forms of water management. Such uncertainties data back to the long disputes between riparian and appropriative doctrines in the 1800s and early 1900s (Hundley 1992) and persist today in terms of water rights quantification, specification, and enforcement. Among the many on-going water rights issues are: quantification of pre-1914 and reserved Indian and Federal water rights; Colorado River "Law of the River" implementation; the public trust doctrine; area of origin protections; third party impacts; and groundwater rights (Pisani 1984; Hundley 1992; DWR 1998a).

Water contracts have an unusually significant role in California's water supply. Often, thick hierarchies of lengthy legal contracts are required to allow water to pass from a water rights holder to a final user. These contracts provide a vital source of flexibility for California's water management; think how much more complex water rights would be without contracts. However, contracts inherit the uncertainties of their sources' rights as well as additional ones associated with contract interpretation and implementation. The presence of uncertainties in water rights and contracts will continue to hinder innovation and flexibility, as they have historically.

The Delta

The Sacramento-San Joaquin Delta was identified as the "hub" of the California water system in the 1957 State Water Plan. Most Californians depend on the health and integrity of the Delta for their water supply. The rules and regulations governing the Delta affect its entire watershed and beyond. Inflows of water from both the north and southeast are transferred through and around the Delta to destinations south and west. Both of California's major water projects (CVP and

SWP) draw their water supply through the Delta. The North and South Bay Aqueducts, the Delta Mendota Canal, the Contra Costa Canal, and the California Aqueduct connect directly to Delta flows, while the Mokelumne Aqueduct traverses the Delta (see Figure 2-7 below). At the moment, the Delta's rules and regulations are in flux and highly uncertain, discouraging cross Delta transfers by the "lack of predictability in the timing or availability of project facilities for pumping, conveyance, and storage" (CALFED 1999c).

In 1957, the efficient movement of supply water through the Delta was the main focus of the first California Water Plan. Prevention of "undue loss in transit and impairment in quality" of project water being transported to contractors were the stated goals of a proposed "Trans-Delta System" (DWR 1957). This early Delta solution consisting of an isolated cross-Delta canal on the east side and running through the Delta, plus an Antioch crossing on the west side which siphoned under the Sacramento and San Joaquin Rivers. This concept was replaced by a "Peripheral Canal" in the 1966 Water Plan update which, although authorized by the State, was rejected by voters in a 1982 referendum. Since then, Delta issues have only increased in complexity with time as every update to the California Water Plan has recommended an option for Delta conveyance while none has yet been implemented.

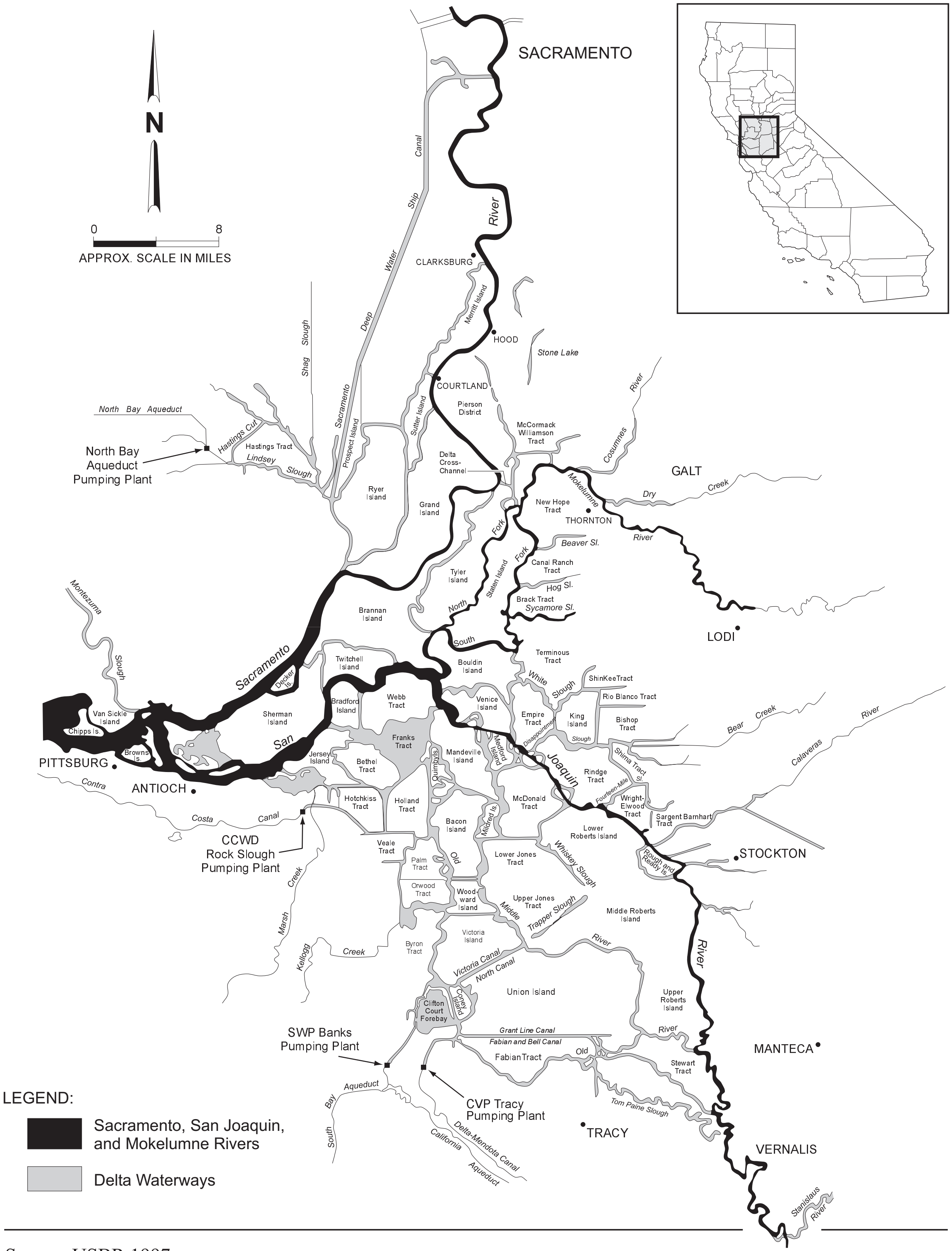
Today, efficient transport is still desirable but not at further expense of the Delta environment. In their *Blueprint for an Environmentally and Economically Sound CALFED Water Supply Reliability Program,* the Environmental Water Caucus (1998) attributes declining species and habitats to regulatory uncertainty in the Delta. Regulatory uncertainty also reduces water supply reliability, and the Delta is where many of California's water problems converge. Much of that uncertainty exists because piecemeal and single-focus projects, surrounded by competing interests, have failed to solve the environmental crisis in the Delta.

The CALFED Bay-Delta Program, a joint state-federal effort, was established in May of 1995 to develop a comprehensive long-term program to deal with four major conflicts in the Delta:

- fish mortality due to water diversions;
- habitat conversion to agricultural or urban use and habitat restoration;
- instream versus out-of-stream needs and the timing of those needs; and
- effect of human activities on water quality and water use.

These conflicts give some insight into the complexity and fragility of the Delta for all parties involved, and the timeline of the CALFED adaptive management process. The many interests in the Delta increases the time required to reach agreement and the likelihood of amendment, adaptation and controversy during or implementation.

Figure 2-7. Sacramento-San Joaquin Delta



Source: USBR 1997

Flexibility in Water Supply Allocation

The allocation of water in California is governed by a myriad of state and federal statutes, court decisions, water rights, contracts, and agreements (DWR 1998a). Reasonable and beneficial use is the basic requirement for all water allocation. Although water rights, contracts, and rules regulating water allocation form the institutional structure of the water system, they often do not adapt well to changing demands and extreme hydrologic events.

Water marketing is a commonly advocated method for flexibly reallocating water, although the transfer of water via statewide water marketing is a relatively new water management option (Lund et al. 1992). Emerging water transfers and markets are being developed by experience, by need, and by regulation. Storage and conveyance requirements are in discussion, as are the associated impacts on the water system and the environment of water transfers. As regulation of water marketing is being refined, so is regulation of other aspects of the State's water resources. Some important water transfer problems are summarized in Table 2-5. More detailed discussion of these issues and the potential role of water marketing and transfers as long-term options for California's water supply appears in Chapter 4.

Table 2-5. Issues in Efficient Water Transfer Development

Category	Issues
Environmental, Socioeconomic, and Water Resources Protections	third-party impacts, groundwater protection, local environmental protection
Technical, Operational, and Administrative Rules	defining transferable water, carriage water, reservoir refill criteria, regulatory process, real vs. paper water
Wheeling and Access to Facilities	cross-Delta conveyance, state or federal facilities use

Source: CALFED (1999c)

Operating Flexibility and Wheeling Water

Institutional arrangements across a variety of water sources can promote operational flexibility and reliability of water deliveries. Several water districts and others have used their access to a variety of water sources advantageously, especially when their supplies proved insufficient. Limits to East Bay Municipal Utility District (EBMUD) supplies were revealed in 1992 when EBMUD informed Dougherty Valley developers that it could not provide reliable service to their recently approved Contra Costa County development. Anxious to begin building homes, the Dougherty Valley developers purchased SWP water from the Berrenda Mesa Water District, water which will be stored in the Semitropic Water Storage District groundwater basin in Kern County until needed (DWR 1998a). Being connected to the SWP through the South Bay Aqueduct allowed them to purchase and store water in Kern County for later delivery to Contra Costa County. Access to the inter-tied water system delayed the need to construct new water supply infrastructure to meet future demand by allowing use of available storage elsewhere in the state.

Both the Metropolitan Water District of Southern California (MWD) and the Mojave Water Agency have found that the potential of local water supply infrastructure can be enhanced by connection to the inter-tied water supply system. The MWD's Eastside Reservoir in Riverside County is expected to fill with both Colorado River and SWP water. Once completed in 2004, the Inland Feeder connection of the East Branch of the California Aqueduct to the Colorado

River Aqueduct will deliver water by gravity to the new reservoir. The intertie between the SWP and Colorado River water gives MWD access not only to two different water sources but also two very different watersheds. Since the 1994 completion of the Morongo Basin Pipeline, the Mojave Water Agency also has access to two very different water sources: their local groundwater basin supply (now in overdraft) and SWP entitlement water. This connection also makes possible a multi-year banking and exchange agreement with the Solano County Water Agency allowing SCWA to bank up to 10 taf of its annual SWP entitlement with the Mojave Water Agency (DWR 1998a).

Blending water from different sources has been one MWD strategy for improving water quality. MWD tries to limit the TDS content of their urban deliveries to between 500 and 550 mg/L. Colorado River water has a higher TDS content (700mg/L) than other MWD sources of water, in particular, SWP water that averages 300 mg/L (DWR 1998a). Blending Colorado River and SWP water can be accomplished in the Eastside Reservoir and by carefully trading and balancing deliveries. MWD has increased its quantity of lower salinity SWP water by trading some of their Colorado River water to Coachella Valley Water District (CVWD) and Desert Water Agency (DWA) for CVWD and DWA's SWP entitlement water. The trade benefits these two agencies who lack the facilities to accept delivery of SWP entitlement water while giving MWD greater opportunity to blend Colorado River water.

Coordination of Water Supplies

Infrastructure options are constructed locally; a dam, canal, recharge area, or water recycling plant has a fixed location. However, any facility may have statewide impact since California is interconnected via the SWP, CVP, and other federal projects. California's inter-tied water system makes possible operational flexibility and an array of coordinated solutions to particular supply problems. To achieve this flexibility and manage impacts in an interdependent system, coordination is needed. The 1957 California Water Plan declares that "future development of the State's water resources must rely, to a constantly increasing extent, on coordinated, comprehensive planning on a state-wide level if the needs of all areas and all uses are to be met in the most effective and economical manner". The coordinated functioning of California's federal, state, and local water supply systems has thus far been made possible through various piecemeal institutional arrangements. More coordinated/cooperative agreements and arrangements are increasingly necessary for consistent, reliable, and efficient water management.

Coordination of operations requires interties between systems. System interties must be both hydraulic and institutional, allowing the system to function physically as well as legally and financially. The 1986 Coordinated Operation Agreement (COA) (see Table 2-6) began the process of cooperation and coordinated operations for the CVP and the SWP to improve both systems' efficiencies beyond what could be accomplished separately. The benefits of cooperation were extended to SWP contractors in the 1995 Monterey Agreement that provided more ways for local water agencies to increase water management flexibility and reliability of existing SWP water supplies. AB 3030 and Chapters 330 and 854 encourage organized planning as the basis for local involvement in the coordinated operations and planning of regional or statewide inter-tied water supply systems.

Table 2-6. Major Statewide Institutional Arrangements in California

Agreement	Description
1986 Coordinated Operation Agreement (SWP and CVP)	SWP wheels water for the CVP CVP water can be sold to the SWP CVP operation in conjunction with SWP to meet Delta water quality standards
1995 Monterey Agreement (SWP)	No initial agricultural water supply reduction in Drought Contractors can transport non-project water in SWP facilities Contractors may store water outside service area
1992 AB 3030	Local agency authority to adopt groundwater Management plans
Statutes of 1995, Chapters 330 and 854	Urban water management plans every 5 years (for 3 taf use or 3000 customers)
CALFED	Wheeling across the Delta is addressed

Source: DWR (1987, 1993, 1998a), Central Coast Water Authority (1995), CALFED (1999c)

Time Requirements of Water Supply Planning

Water supply planning has always been a complex and lengthy process. This is illustrated in Table 2-7 by the long time spans from the beginning of planning to the start of construction for major water supply development projects in California, at federal, state, and local levels.

Table 2-7. California Water Planning Time Requirements

Project Type	Description	Planning Begins	Construction Begins
Statewide	Federal - CVP (final plan in 1931) State - SWP (final plan in 1957)	1873 1873	1937 1960
Urban	Los Angeles - Los Angeles Aqueduct San Francisco - Hetch-hetchy MWD - Colorado River Aqueduct	1904 1901 1928	1908 1913 1933
Irrigation	Imperial Valley[a] - All-American Canal MID/TID[b] - La Grange Dam MID/TID - Don Pedro Dam MID/TID - New Don Pedro Dam	1901 1890 1908 1931	1929 1891 1921 1967
CALFED	Delta Solution	1995	?

Notes:
[a] *Turn of the century settlers began the struggle, became organized in 1911 with the Imperial Irrigation District*
[b] *Joint project of Modesto and Turlock Irrigation Districts*

Sources: Hundley (1992), DWR (1998a), and Barnes (1987)

Shortly after California was admitted to the Union in 1850, the need for a state water plan was recognized (Pisani 1984). Subsequent discussion, by individuals and a federal commission, spanned nearly sixty years before the state legislature began considering a plan. Following the water conference authorized for 1916, a general hydrographic survey was completed in 1923. Preliminary state water plans were introduced in 1923, 1927, and 1931. The 1923 plan was considered too narrow in focus and the 1927 plan failed to define costs and their financing. The more comprehensive 1931 plan was approved, but southern California chose to build the Colorado River Aqueduct on its own and the Central Valley portion of the plan formed the basis of the federal CVP in 1935 (Hundley 1992). Finally, after a century of discussion, design, population growth, politics, California weather, and underlying vision, the 1957 California Water Plan succeeded in getting SWP construction underway in 1960.

Irrigation districts and cities were the earliest groups to implement long-term water planning decisions for water resources in California. Los Angeles, San Francisco, and EBMUD acquired new water supplies each within about 12 years of planning commencement. The three joint Merced Irrigation District/Turlock Irrigation District irrigation dam projects on the Tuolumne River in Table 2-7 demonstrate the increased amount of time between planning and construction commencement with each successive project, as size increased and the 20th century progressed. The last one, New Don Pedro Dam, required more than 30 years to get from planning to the beginning of construction.

The complexity and need for a long-term perspective for water planning remain true today as evidenced by recent California planning activities leading to creation of the CALFED Bay-Delta Program and those now underway as part of this program.

Financing Water Supply Development

Major water supply projects and their management require substantial financing to assure their implementation and continued operations. Historically, this financing has been secured by a variety of traditional methods (see Chapter 4) including large amounts of federal financing. Many of these methods succeeded because, historically, water was viewed as a public good necessary for economic development and federal funding was relatively common. As a more comprehensive worldview has developed, the public good aspect of water has enlarged to include multiple and often conflicting purposes. Consequently, water projects are more thoroughly scrutinized and funding less easily won by voter approval. State referenda and regulations that make many of the traditional financing methods more difficult compound these financial difficulties. Furthermore, federal aid for water resources projects has decreased greatly since the 1980s.

The fundamental financing philosophy of the CALFED program is that the beneficiary, once identified, pays (CALFED 1998a). In anticipation of that identification, cost sharing agreements between beneficiaries and the state and federal governments must be developed, user fees evaluated, and the possibility of private investment considered. Having reasonable insight (such as is available through scenario modeling) into potential economic and other project impacts and how a project works within the context of the entire water system could reveal benefits attractive to different financing options. These ideas are further developed in Chapter 4.

CONCLUSIONS

California's water supply problems are diverse and long-standing. These are summarized as follows:

1) Water is scarce-- water is less available and water quality more impaired than many users would like.
2) Major environmental problems remain unsolved, particularly those associated with the Delta and fish migration and habitat.
3) Water demands for each sector are changing and growing overall.
4) Long-term availability of water for California is decreasing somewhat due to reductions in Colorado River availability, groundwater overdraft in many areas of the state, and increasing water quality requirements.

5) These conditions increase the need for and controversy of long-term and short-term changes in water infrastructure and management.
6) Given the complexity of the system, solutions will require an integration of systematic technical-engineering solutions with political, institutional/legal, economic and financial solutions.