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California's Most Significant Droughts:

Comparing Historical and Recent Conditions

State of California | California Department of Water Resources

Front cover: Folsom Lake in early 2014

Back cover: Lake Oroville in 2014

Executive Summary

The water years of 2012-14 stand as California's driest three consecutive years in terms of statewide precipitation, and as of this writing in February 2015 the drought is continuing on. This report was prepared to compare the hydrology and impacts experienced during 2012-2014 with those of California's largest historical droughts, in response to questions from local water agencies and others regarding the drought's relative severity and the changed conditions since our prior major droughts. California's immediately prior drought of statewide scale occurred in 2007-09; it was the first drought for which a statewide proclamation of emergency was issued. The 2012-14 period now marks the second time a statewide proclamation of emergency has been issued for drought.

California's most significant historical statewide droughts were the six-year drought of 1929-34, the two-year drought of 1976-77, and the six-year event of 1987-92. These droughts stand out in the observed record due to their duration or severe hydrology. The 1929-34 event occurred within the climatic context of a decades-plus dry period in the 1920s-30s whose hydrology rivaled that of the most severe dry periods in more than a millennium of reconstructed Central Valley paleoclimate data. The drought's impacts were small by present-day standards, however, since the state's urban and agricultural development was far less than that of modern times. The 1976-77 drought, although brief in duration, was notable for the severity of its hydrology. The 1987-92 drought was California's first extended dry period since the 1920s-30s, and provides the closest comparison for drought impacts under a present-day level of development.

The 2012-14 event set other records in addition to that of driest three-year period of statewide precipitation. The drought occurred at a time of record warmth in California, with new climate records set in 2014 for statewide average temperatures. Records for minimum annual precipitation were set in many communities in calendar year 2013. Calendar year 2014 saw record-low water allocations for State Water Project and federal Central Valley Project contractors. Reduced surface water availability triggered increased groundwater pumping, with groundwater levels in many parts of the state dropping 50 to 100 feet below their previous historical lows. These record-setting conditions speak to the need for continued improvement of our ability to respond to dry conditions. Knowledge of the impacts historically experienced in our past large droughts and the lessons learned during those events can help us be better prepared.

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Credits

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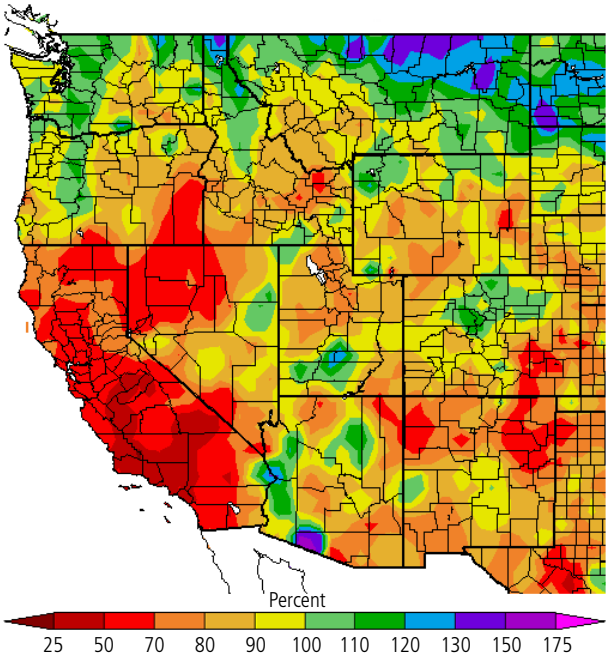
1 Introduction and Setting

This report was prepared in response to the dry conditions of 2012-14 (Figure 1.1) and particularly in response to the very dry hydrology of water year 2014. Water year 2014 ranked as the third driest on record in terms of statewide precipitation, with the three-year period of water years 2012-14 ranking as the driest consecutive three-year period on record in terms of statewide precipitation. Continuing dry hydrology in 2015 raises questions about the similarity of present conditions to those of prior droughts and changes in observed impacts as California's population increases and new institutional requirements are put in place. The purpose of this report is to compare present conditions with California's most significant droughts of statewide scope, to help answer questions about the comparative severity of drought hydrology and drought impacts. The report also summarizes lessons learned and commonalities seen in the state's most severe historical droughts.

Figure 1.1: Three-year Precipitation as a Percent of Average, September 2011 through September 2014



Generated 9/28/2014 using provisional data. Source: Western Regional Climate Center

California's most significant historical droughts of statewide scope were those with the longest duration or driest hydrology – the six-year drought of 1929-34, the two-year drought of 1976-77, and the six-year event of 1987-92. Although the two-year event of 1976-77 was brief in duration, water year 1977 was the single driest year of observed statewide runoff and 1976 was also extremely dry. The state's most recent drought was 2007-09, and it is briefly covered in this report to provide context for drought impacts under a recent institutional setting.

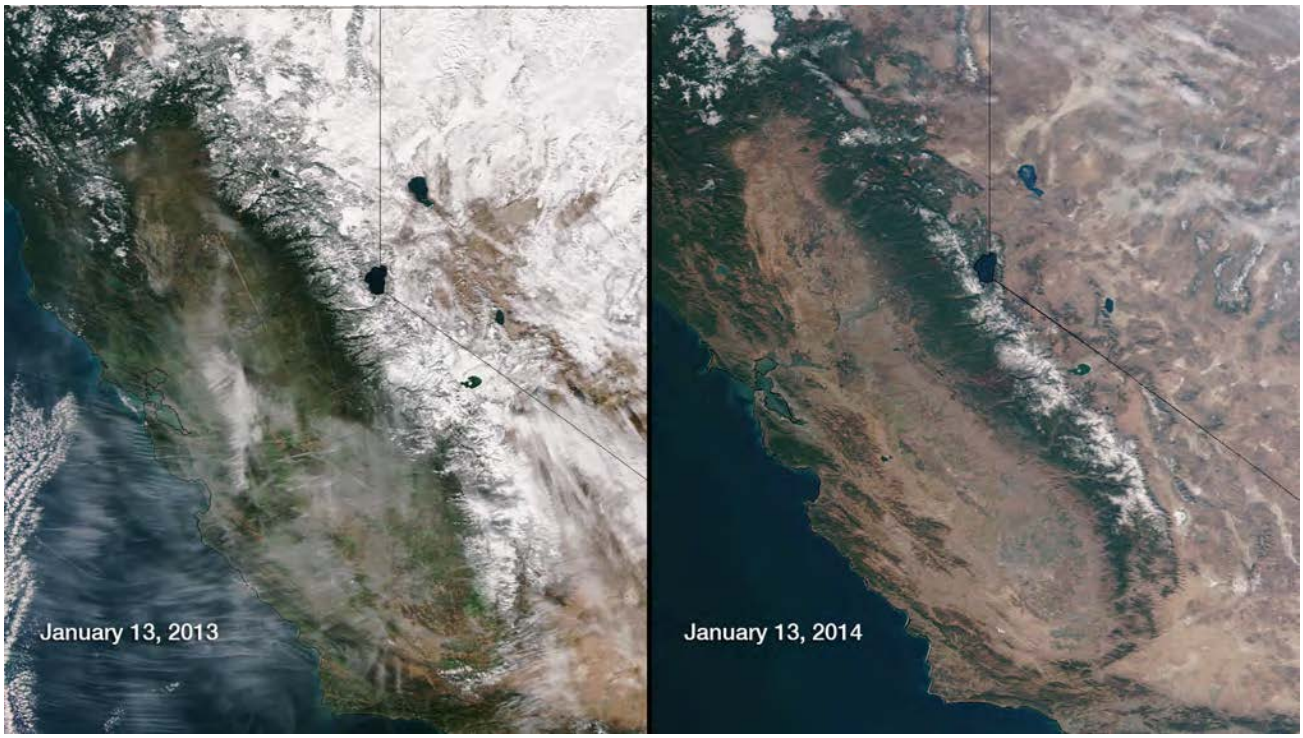
The report begins with background on defining drought and water shortage and provides a brief overview of the hydrologic framework for California water supply, to provide context for the following chapters. Chapter 2 summarizes hydroclimate conditions associated with historical droughts, reviews drought in the paleoclimate record, and discusses climate change considerations. Chapter 3 covers highlights of the hydrology and impacts experienced in the large historical droughts, together with brief background on physical and institutional setting in which they occurred. Chapter 4 compares the historical events to the present, describing changed conditions and comparing impacts; recurring themes observed in past droughts also are discussed.

THE DRY YEARS OF 2012-14

Following the dry water years of 2007-09, water year 2010 marked a return to slightly wetter than average conditions for most of the state. It was followed by a wet 2011, the first significantly wet year since 2006. Improvement in statewide reservoir storage provided by a wet 2011 helped cushion impacts of water year 2012, which reverted to dry conditions for most of the state, particularly for parts of the San Joaquin Valley and interior Southern California. Northern California had a wet start to water year 2013 thanks to a series of late November/early December storms, but a record dry January-May resulted in a return to dryness for most of the state, with parts of the San Joaquin Valley and Southern California again lagging well below Northern California in terms of percent of average precipitation. The wet early start to water year 2013 was helpful in replenishing reservoir storage depleted during 2012.

The impacts of a dry 2012 and 2013 were notably felt in the agricultural sector, especially for rangeland

Comparing Sierra Nevada snowpack in two Januaries, illustrating the extremely dry conditions in early 2014. Source: NASA



grazing. The U.S. Department of Agriculture (USDA) included all of California's counties in its drought disaster designations at various times over the course of 2012-14, either as primary counties or contiguous counties. Responding to reduced agricultural water supplies, particularly in parts of the San Joaquin Valley, the Governor issued Executive Order B-21-13 in May 2013, which directed the Department of Water Resources (DWR) and the State Water Resources Control Board (SWRCB) to expedite review and processing of water transfers.

With the advent of an exceptionally dry water year 2014, Northern California began experiencing the significantly below normal precipitation that had characterized the southern part of the state in the prior years. A blocking high pressure ridge diverted storms away from the state during the key winter precipitation months of December and January, resulting in record warmth and dryness for many areas of the state. Some Northern California locations went for more than 50 consecutive days with no measurable precipitation at a time when the year's maximum monthly precipitation totals should have been registered. The record dry December 2013, when combined with the also record dry January-May 2013, resulted in calendar year 2013 being the driest of record for many communities, including San Francisco, Sacramento, and Los Angeles.

The Colorado River Basin also was in a period of long-term dry conditions during this time; water year 2014 was just slightly below average in terms of inflow to Lake Powell. However, the Basin's substantial reservoir storage permitted full water deliveries to Lower Basin contractors. Full supplies on the Colorado River were a bright spot in California's otherwise diminished surface water supplies throughout 2012-14.

With no significant precipitation in late 2013, the Governor formed a state interagency Drought Task Force in December to provide a coordinated assessment of the dry conditions and to provide recommendations on state actions. The continuing absence of precipitation led to a Governor's proclamation of emergency in January 2014 that ordered state agencies to take specified actions and called on Californians to voluntarily reduce their water usage by 20 percent. Among other things, the order called on local urban water suppliers to immediately implement their water shortage contingency plans, directed the state's drinking water program to identify communities in danger of running out of water and to help them address shortages, and directed SWRCB to take various water rights administrative actions. In March, the Legislature enacted and the Governor signed measures to provide $687.4 million for drought relief, with the largest amount of that funding ($549 million) dedicated to accelerated expenditure of Proposition 84 and Proposition 1E bond funds for grants to local agencies for integrated regional water management projects. In April, the Governor issued an executive order to redouble state drought actions that, among other things, ordered SWRCB to adopt emergency regulations as necessary to direct urban water suppliers to limit wasteful outdoor water use practices and ordered DWR to conduct intensive outreach to local agencies to increase their groundwater monitoring in areas of significant impacts. Many local agencies also issued proclamations of emergency; Figure 1.2 shows county-level proclamations of emergency issued in 2014, comparing this year's conditions to those of dry years in prior droughts.

Above-normal late spring 2014 precipitation ameliorated some of the worst-case water supply scenarios that had been considered earlier in the year, including evaluation by DWR of the need to place temporary rock barriers in selected Delta channels to conserve upstream reservoir storage – an action last

Figure 1.2: Comparison of Counties with Emergency Proclamations

Data: California Office of Emergency Services

taken in 1977. Hydrologic conditions did not improve sufficiently, however, to avoid record low allocations for some Central Valley Project (CVP) and State Water Project (SWP) contractors – zero to the CVP's agricultural contractors both north and south of the Delta, zero to the CVP Friant Division contractors, and five percent to SWP contractors. Water year 2014 marked the first time that USBR's Friant Division contractors received a zero allocation of their Class 1 water. Reflecting the very dry hydrology, SWRCB imposed widespread curtailments of diversions in locations including parts of the Sacramento-San Joaquin River watershed and the Eel and Russian River watersheds, another action that had not been taken since 1977.

Close coordination among the water project operating agencies – USBR and DWR – with the regulatory agencies – SWRCB, the U.S. Fish and Wildlife Service (USFWS), and the National Marine Fisheries Service (NMFS) – was employed throughout the hydrologically challenging winter-spring water year 2014 runoff season. Decisions were made to balance impacts and to reserve water in storage to be able to meet critical needs such as cold water for salmon and health and safety needs for urban water users. Maintaining sufficient carry-over storage to meet health and safety needs should 2015 be dry was an important consideration in this process. As discussed later in this report, the scientific capability to predict whether 2015 will be wet or dry is limited, highlighting the need to be cautious when planning for the next year's water operations.

As the summer of 2014 wore on, increasing numbers of small water systems – often located on unreliable fractured rock groundwater sources in rural areas – were experiencing water shortages, as were rural residents dependent on private wells. Bulk water

The Water Year

Agencies such as DWR or the U.S. Geological Survey (USGS) report hydrologic data on a water year basis. The water year extends from October 1 through September 30. Water year 2014, for example, spanned from October 1, 2013 through September 30, 2014. The (water year) 1987-92 drought corresponds to the calendar period of fall 1986 through summer 1992. Hydrologic data contained in this report are presented in terms of water years. Water project delivery data (e.g. SWP deliveries) are presented on a calendar year basis. Precipitation data are reported by the National Weather Service (NWS) based on an annual season of July 1 to June 30. When this report refers to annual precipitation amounts, the data are based on the NWS reporting season unless otherwise indicated.

haulage and distribution of bottled water were used to help some rural communities. Executive Order B-26-14, issued in September, directed SWRCB, DWR, the Office of Emergency Services (OES), and the Office of Planning and Research to assist local agencies with identification of acute drinking water shortages and to work with local agencies in implementing solutions to shortages. The order also authorized OES to use California Disaster Assistance Act funds to provide temporary water supplies to households without water for drinking or sanitation.

DEFINING DROUGHT

There are many ways that drought can be defined. Some ways can be quantified, such as meteorological drought (period of below normal precipitation) or hydrologic drought (period of below average runoff); others are more qualitative in nature (shortage of water for a particular purpose). There is no universal definition of when a drought begins or ends, nor is there a state statutory process for defining or declaring drought (see sidebar).

Drought is a gradual phenomenon, with slow onset. Impacts of drought are typically felt first by those most dependent on annual rainfall, such as ranchers engaged in dryland grazing or rural residents relying on wells in low-yield rock formations. Drought impacts increase with the length of a drought, as carry-over storage in reservoirs is depleted and levels in groundwater basins decline. Impacts of drought to water suppliers may be exacerbated by other factors such as regulatory requirements to protect environmental resources or to satisfy the rights of senior water right holders.

Drought may be defined by its impacts to a particular class of water users in a specific location.

Hydrologic conditions constituting a drought for water users in one location may not constitute a drought for water users in a different part of the state or with a different water supply. California's extensive system of water supply infrastructure greatly mitigates the effect of short-term (single year) dry periods to users of managed supplies, although impacts related to unmanaged systems (increased wildfire risk, stress on vegetation and wildlife) remain. Individual water suppliers may use criteria such as rainfall/runoff, amount of water in storage, decline in groundwater levels, or expected supply from a water wholesaler to define their water supply conditions. Criteria used to identify statewide drought conditions—such as statewide runoff and reservoir storage—cannot address these localized circumstances.

Agricultural Disaster Designations

USDA's Farm Services Agency administers financial assistance programs to help farmers and ranchers recover from losses due to drought, floods, other natural disasters, and quarantines. To be eligible for some programs, applicants' operations must be located in a county declared by the President or designated by the Secretary of Agriculture as a disaster area. Criteria for a secretarial designation include a finding that a minimum 30 percent production loss of at least one crop has occurred in the designated county. USDA streamlined its drought disaster designation process in response to widespread Midwestern drought in 2012 to make listing virtually automatic once a county had been has been classified as being in severe drought for eight consecutive weeks by the U.S. Drought Monitor. This brief qualifying period reflects the importance of seasonal rainfall to activities such as livestock grazing on non-irrigated rangeland and USDA's intent to provide rapid financial assistance.

Drought and Water Supply Reliability

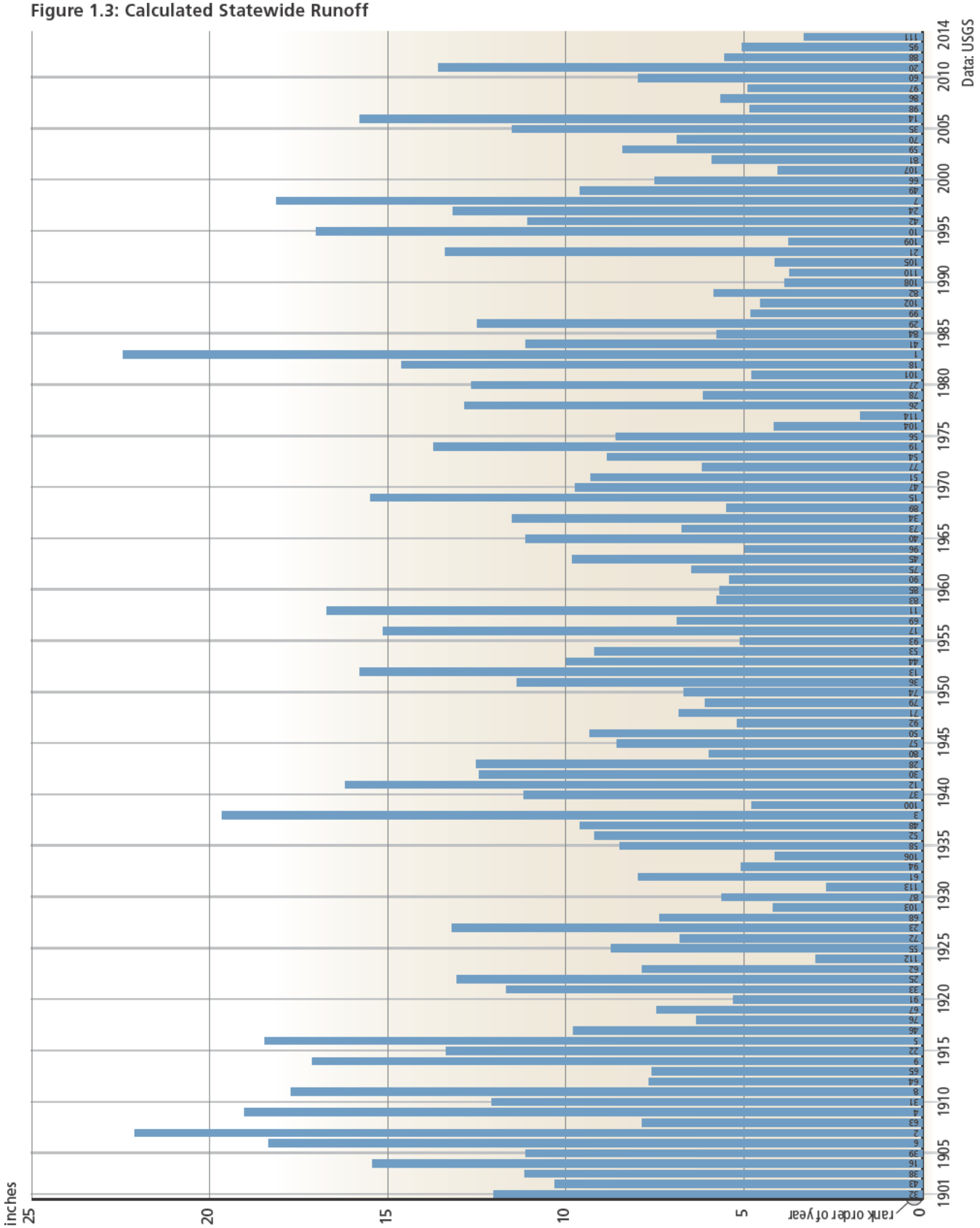
Drought reduces water supply reliability, potentially redefining areas that have had adequate water supplies under normal hydrologic conditions as areas of shortage under dry hydrology. The ability of water users to reduce the risk of shortage, or to minimize impacts if a shortage occurs, depends on the value of water to them and their ability to pay for a desired level of reliability. Large urban areas typically demand a high level of reliability and have the financial capability to ensure it. Farming businesses typically cannot afford to make the same level of investment in reliability, and customers of agricultural agencies thus typically must manage for a greater risk of shortage.

Vulnerability to shortage can change over time, due to factors such as increasing population or cropped acreage in a water agency's service area, or reallocation of historically available water supplies for other purposes. If increased vulnerability is not remediated through investments in improving reliability then drought impacts can be expected to worsen. As illustrated in the sidebar, the concept of what constitutes normal supplies is not necessarily static.

California's Most Significant Historical Droughts

This report's focus is on California's most significant droughts in the historical record, because information is available to quantify their hydrology and impacts, and they can provide valuable lessons about drought vulnerability and resilience. Figure 1.3 shows California's calculated historical statewide runoff, which is one metric for illustrating dry conditions at a statewide scale. The 1929-34 drought occurred in a climatic context that included severe drought conditions over much of the western United States, including the Great Plains region affected by the so-called Dustbowl drought. As discussed in Chapter 2, the 1920s-30s were a period of overall dryness that rivaled similar extreme events in the paleoclimate

Figure 1.3: Calculated Statewide Runoff



record. The two-year 1976-77 drought began with a very dry 1976 that provided the antecedent conditions to help 1977 rank as the driest year of statewide runoff. The 1987-92 drought was characterized by the duration of its dry conditions; California's population then was close to 80 percent of present levels.

The San Diego River gorge in 1930. The overall dry cycle of the 1920s-30s was on a par with the driest periods in a millennium, but its impacts were mitigated by California's relatively low level of development. Photo courtesy of the San Diego History Center.

CALIFORNIA WATER SUPPLY, AN OVERVIEW

California's proximity to the Pacific Ocean and major mountain ranges (Figure 1.4) define the state's hydroclimate setting. Most of the water vapor that provides the state's precipitation comes from the Pacific Ocean; as moist air moves over mountains such as the Sierra Nevada or Transverse Ranges the air is lifted and cooled, resulting in condensation and rain or snow. Snowpack in the Cascade Range and Sierra Nevada contributes to the runoff in the state's largest rivers and to the groundwater basin recharge that support much of California's urban and agricultural water use.

Much of California experiences a Mediterranean-like climate with dry summers that are warm or hot, and wet winters that are cool or cold. Westerly winds transport water vapor that provides winter precipitation; summers are characterized by a blocking high

Shortage or Normal?

There are a variety of ways that impacts of hydrologic drought can be measured, but the metric of supplies available to CVP or SWP contractors is not a direct indicator of hydrologic conditions, as discussed in Chapter 4. CVP south-of-Delta agricultural contractors received 100 percent of their contracted supply amounts in only three years during the 23-year period from 1990 through 2014, and 75 percent or better in only eight of those years. Prior to 1990, these contractors received full supplies in all years except 1977. SWP urban and agricultural contractors received 100 percent of their requested Table A contractual amounts in only six years from 1990 through 2014. As with the CVP, SWP urban and agricultural contractors received full requested deliveries in all years prior to 1990, excepting 1977. Annual variability in project allocation and long-term trends in allocations reflect factors in addition to hydrology, including changes in service area demands and changes in environmental regulatory conditions.

Figure 1.4: Location Map

State-Level Drought Definition

Most Western states, California included, do not have a state statutory definition or process for defining or declaring drought. The State of Washington is an exception; it defines a drought condition as when water supply for an area is below 75 percent of normal and the water shortage is likely to create undue hardships for various water uses and users (Revised Code of Washington, Chapter 43.83B.400).

During the 1987-92 drought, DWR used statewide runoff and reservoir storage as general guidelines for identifying drought conditions, considering a drought threshold to be runoff for a single year or multiple years in the lowest ten percent of the historical range and statewide reservoir storage during the same time period at less than 70 percent of average. (These criteria were inherently biased toward depicting water supply conditions in the wetter northern part of the state, and would not necessarily be reflective of local conditions in Southern California.) No formal criteria were used in deciding to issue the 2009 statewide drought emergency proclamation; the driving factors cited in the proclamation were impacts of dry hydrology and cutbacks in SWP and CVP allocations due to changed Endangered Species Act (ESA) compliance requirements. The 2014 statewide emergency drought proclamation was triggered by cumulative impacts of multiple dry year years and record or near-record low precipitation at the start of what would become a third consecutive dry year.

pressure zone that diverts atmospheric moisture away from the state. On average, about 75 percent of the state's average annual precipitation of 23 inches falls between November and March, with 50 percent occurring between December and February. The state's annual water budget is determined by a small number of storms. A shortfall of a few major winter storms usually results in a dry year; conversely, a few very wet storms usually lead to a wet year. The proximate cause of droughts of statewide scale is a persistent Pacific high-pressure zone during the winter's normally wettest months.

California experiences high annual variability in precipitation, as illustrated by Figure 1.5. Much of this variability stems from the role of a relatively small number of storms in making up the state's water budget. Recent research has identified the key role played by extreme precipitation, such as atmospheric river storms, in contributing to the state's water supply. On average, atmospheric river storms – storms fueled by narrow regions in the atmosphere that transport a concentrated stream of water vapor across the Pacific to the West Coast – are estimated

Figure 1.5: Comparative Variability of California Precipitation

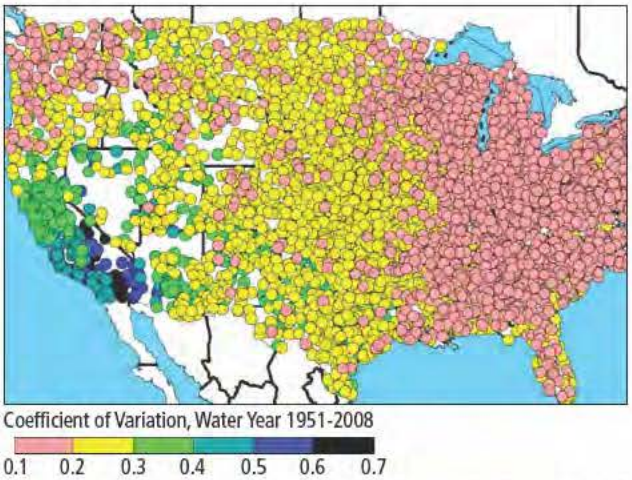


Figure provided courtesy of Mike Dettinger, USGS

to contribute about 40 percent of California's annual precipitation (Dettinger, 2013) (Figure 1.6). One atmospheric river storm series in December 2010, for instance, provided about half of the average annual precipitation for many Southern California communities within a week's time.

As illustrated in Figure 1.7, precipitation and runoff are greater in Northern California than they are in

For More Information on Historical Droughts

Detailed information on California's historical droughts is available in DWR reports documenting the hydrology, impacts, and response actions associated with these events. The reports listed below are available on DWR's website or at the California State Library, Government Publications Section.

» *The California Drought – 1976.* May 1976

» *The California Drought 1977, An Update.* February 1977

» *The Continuing California Drought.* August 1977

» *The 1976-77 California Drought – A Review.* May 1978

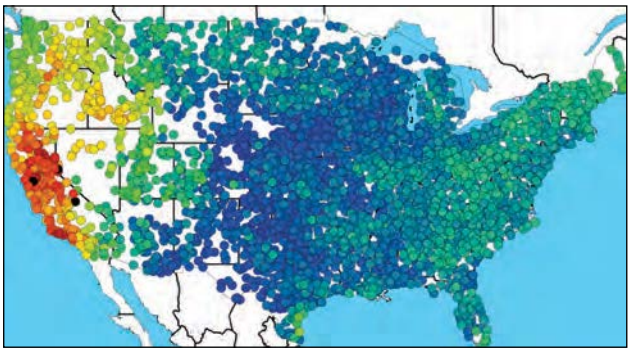
» *California's 1987-92 Drought, A Summary of Six years of Drought.* July 1993

» *Preparing for California' s Next Drought, Changes Since 1987-92.* July 2000

» *California's Drought of 2007-09, An Overview.* November 2010

Figure 1.6: Contribution of Atmospheric Rivers to California Precipitation

Contributions to total precipitation of precipitation on days when atmospheric rivers made landfall on the California coast (or day after, to allow for differences between Coordinated Universal Time reporting of satellite data and local reporting of cooperative time series) at NWS cooperative weather stations, with atmospheric river days between October 1997 and September 2006.



Percentage of total precipitation from atmospheric rivers: 0 10 20 30 40 50

Figure provided courtesy of Mike Dettinger, USGS

Southern California. An imbalance between surface water supplies and the location of major population centers and agricultural production areas has been central to the history of water development in California, leading to the development of major federal, state, and local water projects (Figure 1.8). The state's largest rivers, in terms of average annual runoff, are the Sacramento and the Klamath, reflecting their sizable drainage areas and locations in the water-rich part of the state. The Eel River is the next-largest in Northern California; south of the Delta, only the San Joaquin River is of comparable size to the Eel. The Sacramento and San Joaquin River watersheds supply (either directly as surface water or indirectly via groundwater recharge) much of the water used by California cities and farms. Figures 1.9 and 1.10 show the variability of estimated annual unimpaired runoff in the Sacramento and San Joaquin basins. The hydrology of these basins often is used as a benchmark for Northern California water year conditions because of their importance to California's developed water supplies.

Imported surface water – the Colorado River

Imported surface supplies make up only a small part of the state's water budget. The Colorado River is by far the largest of the imported surface water sources. The state has consistently received its basic interstate apportionment of 4.4 million acre-feet (MAF) of consumptive use annually, and up until 2003 was also able to receive additional water from hydrologic surpluses or from the unused apportionments of Nevada and Arizona. The Colorado River has been the most reliable of the three major sources of imported water used by urban Southern California, thanks to the ample storage capacity in the reservoir system. The river basin is distinguished from most watersheds in California by its reservoir storage capacity – equivalent to about four times the river's average flow.

Although the basin has been exhibiting persistent

Figure 1.7: Average Annual Precipitation and Runoff by Hydrologic Region

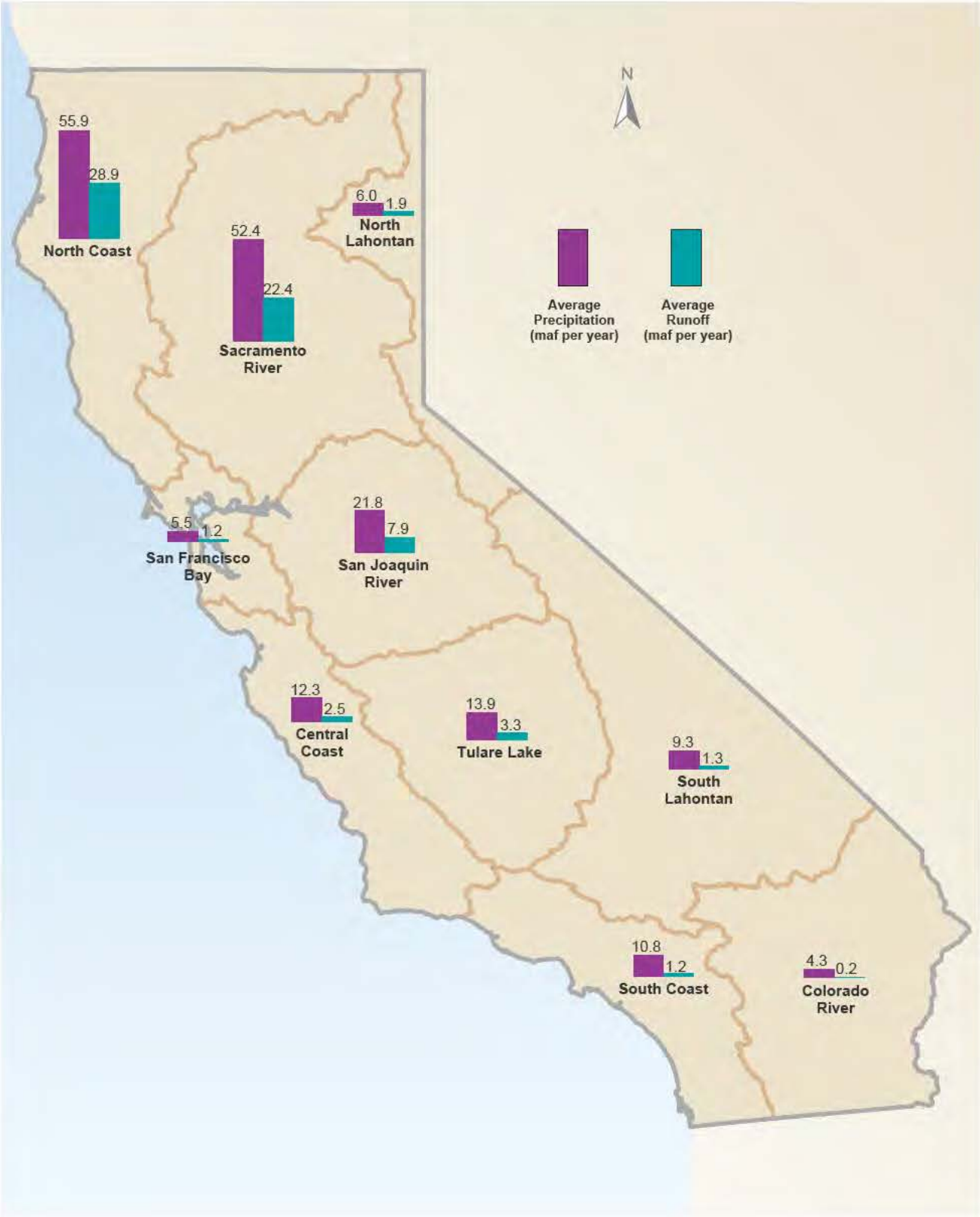
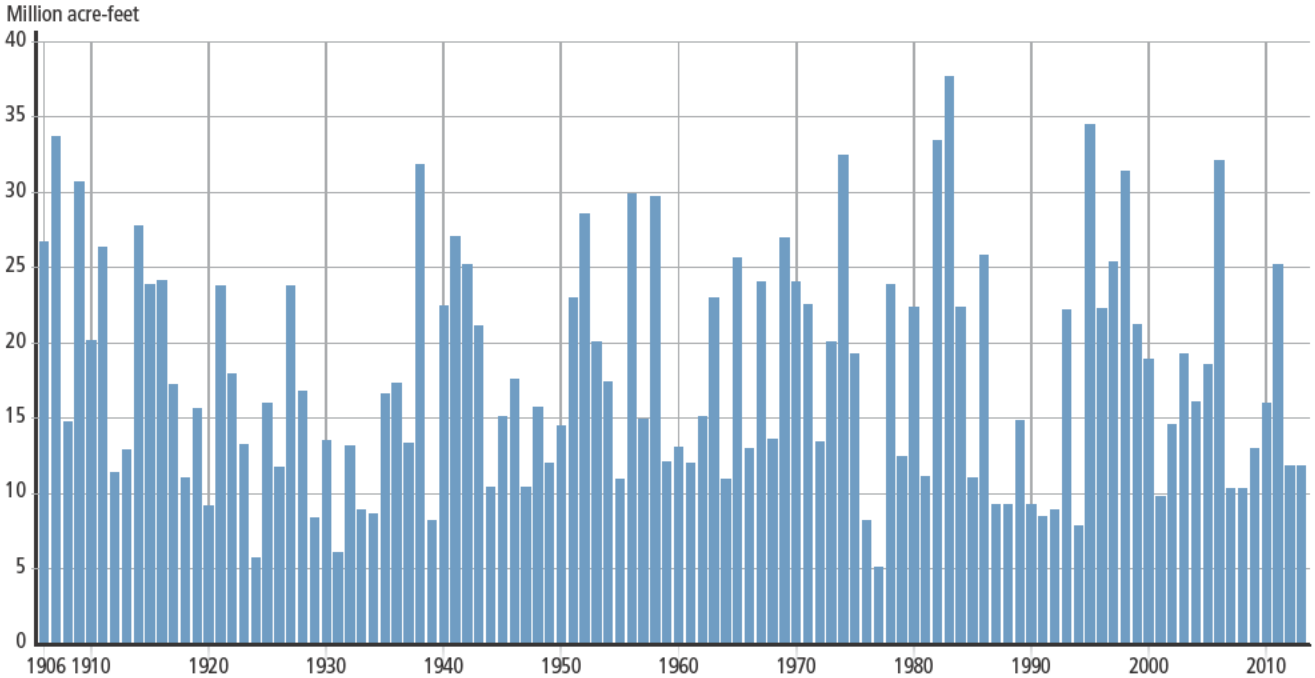


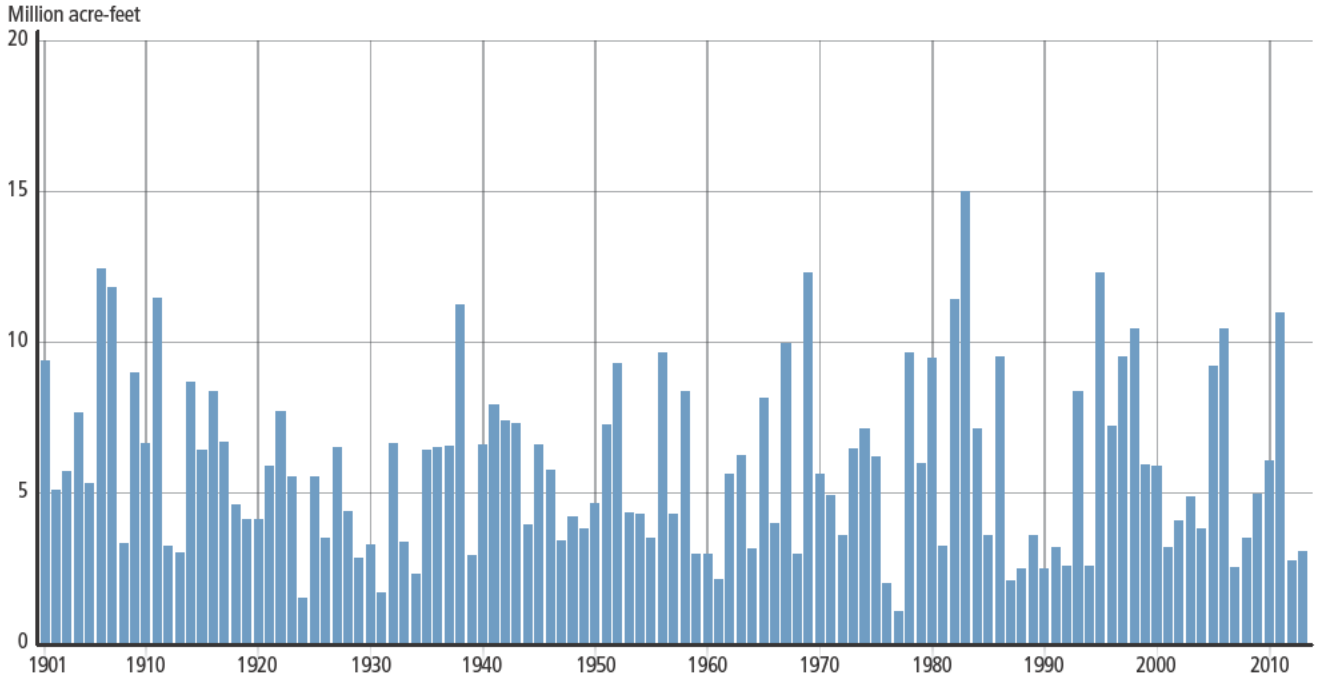
Figure 1.8: California Water Projects

Figure 1.9: Sacramento River Unimpaired Runoff



Sacramento River Runoff is the sum of Sacramento River flow at Bend Bridge, Feather River inflow to Lake Oroville, Yuba River flow at Smartville, and American River inflow to Folsom Lake

Figure 1.10: San Joaquin River Unimpaired Runoff



San Joaquin River Runoff is the sum of Stanislaus River inflow to New Melones Lake, Tuolumne River inflow to New Don Pedro Reservoir, Merced River inflow to Lake McClure, and San Joaquin River inflow to Millerton Lake

drought for the last decade and a half, its substantial reservoir storage capacity permitted full deliveries to the Lower Basin states. Recent prolonged dry conditions in the Colorado River Basin are the driest period of the historical record in terms of inflow to Lake Powell; Figure 1.11 illustrates the historical variability of river flow. Lake Powell inflow was below average in 11 of the past 14 water years through water year 2013, with water year 2014 wrapping up at just under average. The single driest year of record for inflow to Lake Powell was 2002 (the prior dry year record had been set in 1977). The decade of the 2000s (2000-2009, inclusive) was the driest decade in the historical record. During these prolonged dry conditions, total system storage dropped to just below half of capacity.

Groundwater

Under average hydrologic conditions, close to 40 percent of California's urban and agricultural water needs are supplied by groundwater, an amount that increases in dry years when water users whose surface supplies are reduced increase their reliance on groundwater. Figure 1.12 shows the state's 515 designated groundwater basins, the alluvial basins that support the majority of California's groundwater development. An estimated 90 percent of the groundwater used in California is extracted from only 126 of these 515 basins (DWR, 2014). The amount of water stored in California's aquifers is far greater than that stored in the state's surface water reservoirs, although only a fraction of that groundwater can be

Figure 1.11: Colorado River Unimpaired Flow at Lees Ferry
Provisional data courtesy of USBR, subject to change; estimated values for 2011-2014

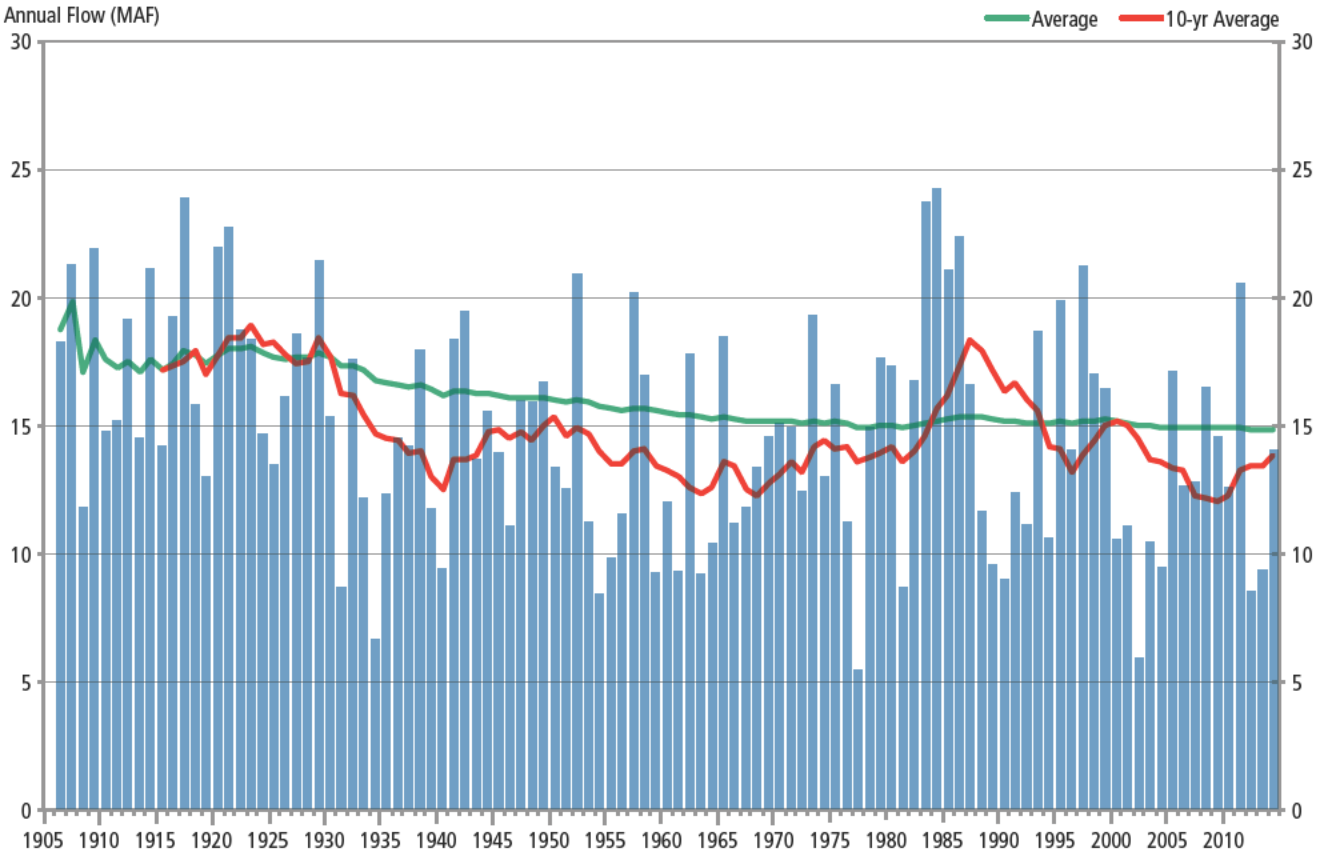
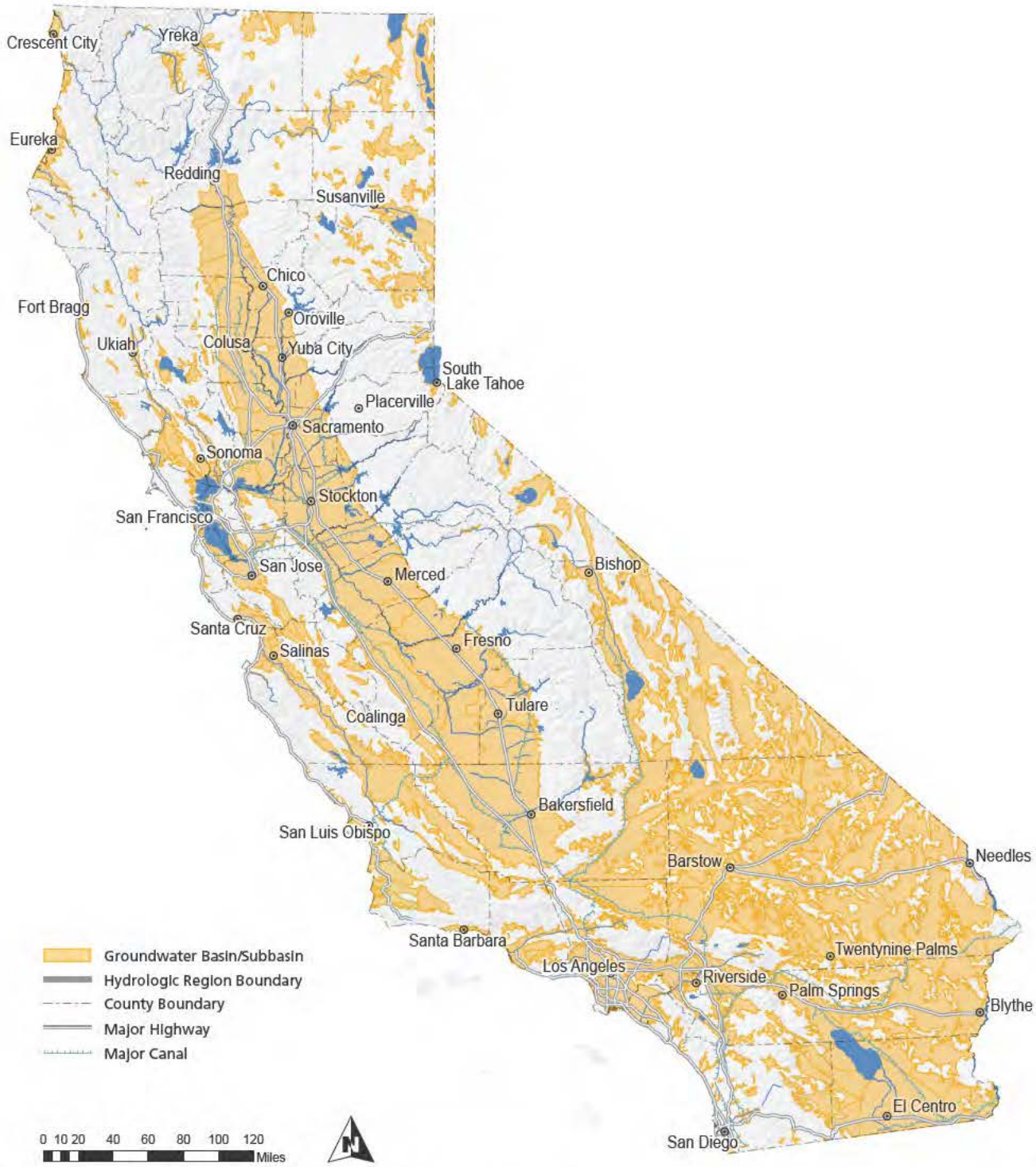
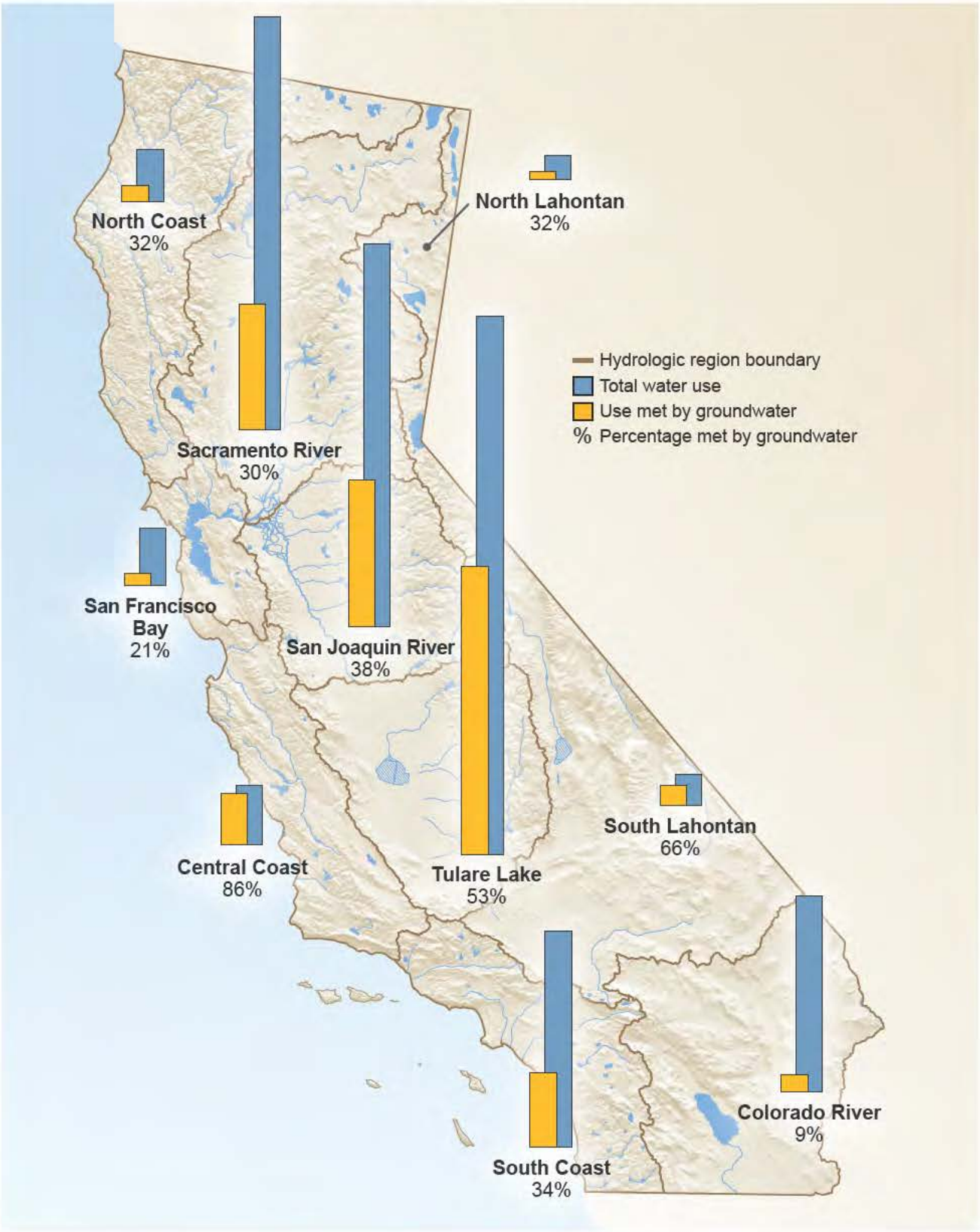


Figure 1.12: California Groundwater Basins



Map based on groundwater basin boundaries established in Bulletin 118 Update 2003, Department of Water Resources

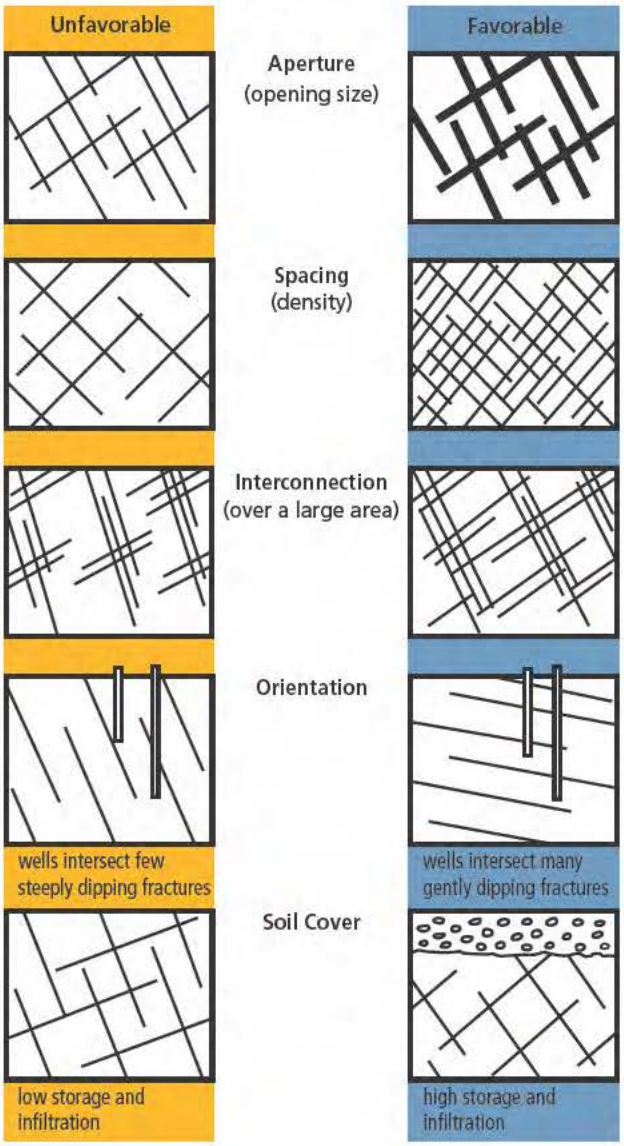
Figure 1.13: Groundwater Contribution to Total Water Use by Hydrologic Region



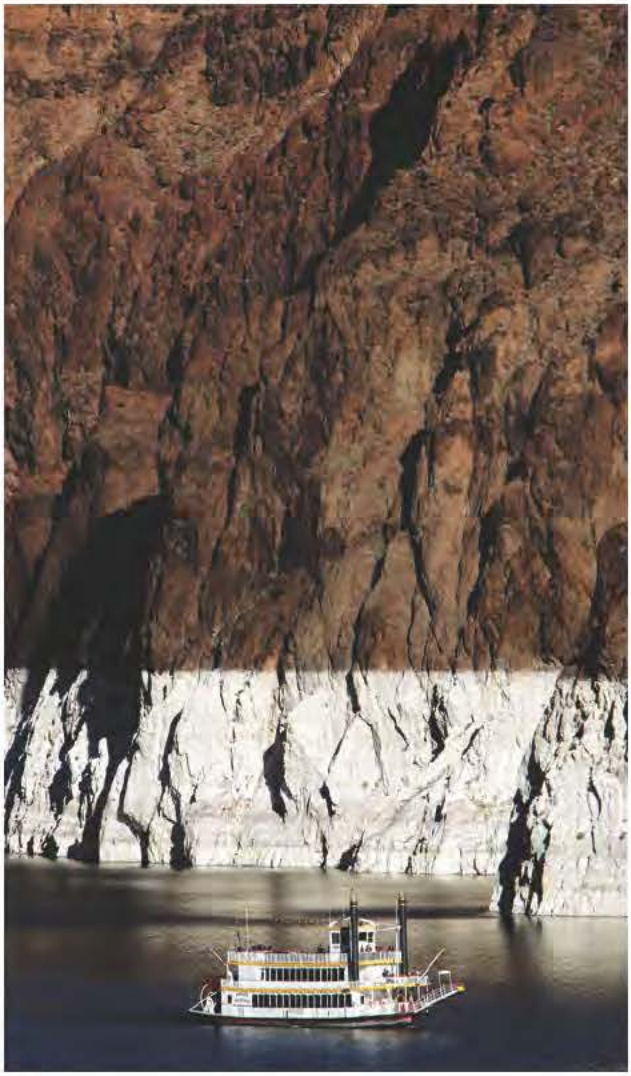
economically and sustainably extracted for use. Figure 1.13 illustrates relative reliance on groundwater at a regional level.

Although large alluvial basins support most of California's groundwater use on a volumetric basis, groundwater extracted from fractured bedrock (fractured rock groundwater) is the sole source of supply for many small water systems and private well owners in foothill and mountain areas. Generally speaking, fractured rock groundwater systems store far less water than do alluvial basins and are markedly dependent on annual to interannual precipitation for recharge. Yield of wells drilled in fractured rock can vary greatly over short distances due to highly site-specific geologic conditions. Figure 1.14 shows how local conditions affect wells drilled in fractured bedrock. Vulnerability to drought-related shortages increases with unfavorable bedrock conditions such as small size of the fractures that provide a pathway for groundwater movement, or absence of soil cover that helps promote infiltration of precipitation.

Figure 1.14: Characteristics of Fractured Bedrock Controlling Groundwater Availability



Prolonged dry conditions have had a visible effect on reservoir levels in Lake Mead and Lake Powell. Source: Getty Images



2

Hydroclimate Background on Drought in California

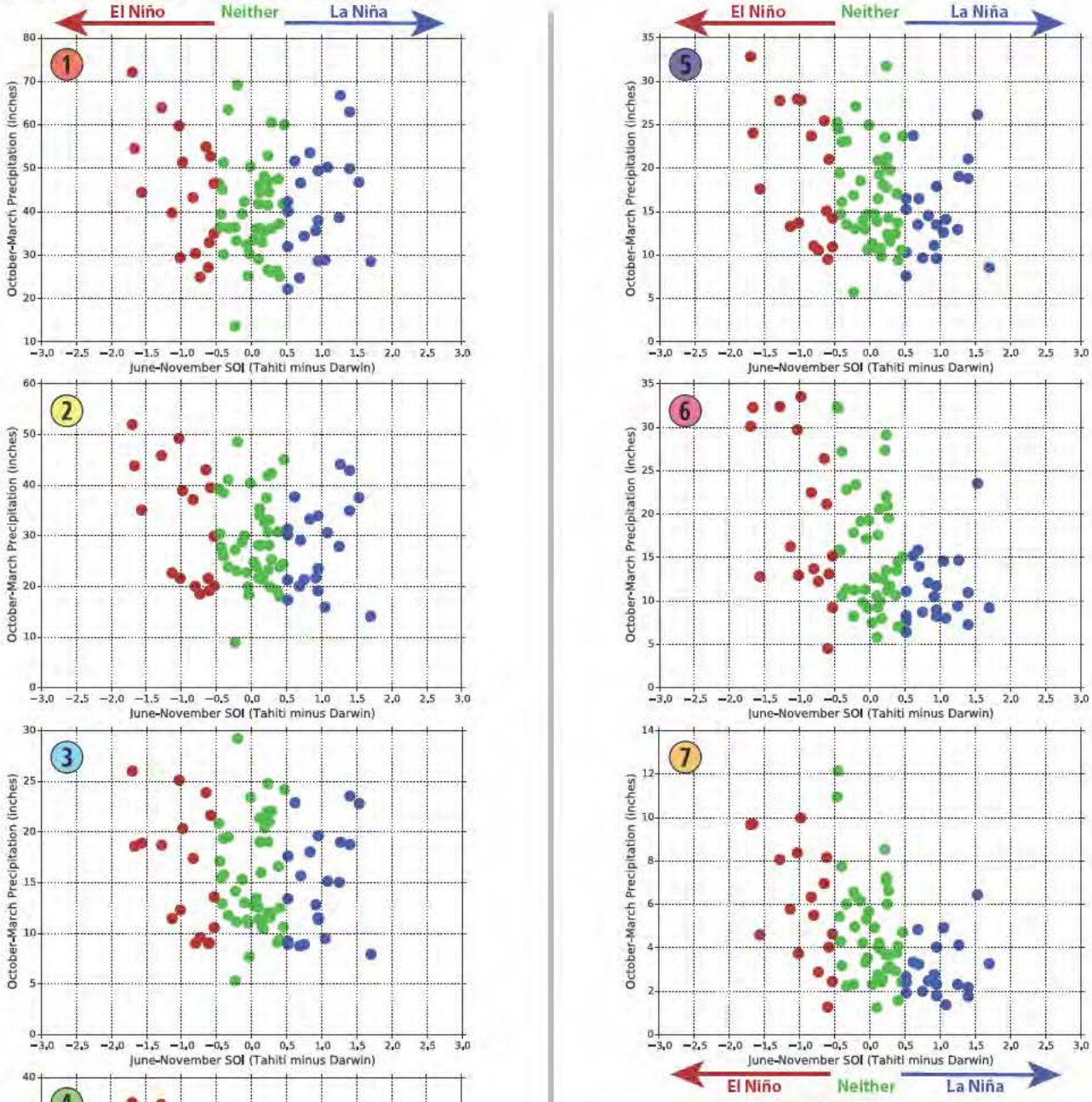
This chapter briefly summarizes hydroclimate conditions associated with past California droughts. Drought is a normal part of the water cycle in California. Dry years happen periodically; sometimes dry conditions persist over multiple years, eventually resulting in sufficient impacts for these dry conditions to be termed a drought. Sustained multi-year dry periods have been relatively infrequent in the historical record. It is important to remember, however, that California hydrologic data cover a limited period of historical record – relatively few stream gages have a period of record in excess of 100 years, and only a few precipitation records extend as much as 150 years. Efforts to go beyond the historical period must rely on tools such as paleoclimate analysis or climate models.

WHAT CAUSES DROUGHT?

Ultimately, drought in California stems from an absence of winter precipitation. At the weather timescale this occurs when an atmospheric high pressure ridge blocks winter storms from reaching the state, shunting them to other areas. In the longer-term climate timescale many other aspects come into play; the chaotic interaction of atmosphere-ocean dynamics and land processes combine at varied spatial and temporal scales to ultimately set the stage for the weather we experience. Many efforts have been made to identify particular climate patterns, or teleconnections (see sidebar), that could be used to predict or diagnose drought conditions. The National Oceanic and Atmospheric Administration (NOAA) defines a climate teleconnection as:

> *a recurring and persistent, large-scale pattern of pressure and circulation anomalies that spans vast geographical areas…. All teleconnection patterns are a naturally occurring aspect of our chaotic atmospheric system, and can arise primarily as a reflection of internal atmospheric dynamics. Additionally, some of these patterns, particularly those over the North Pacific, are also sometimes forced by changes in tropical sea-surface temperatures and tropical convection… Teleconnection patterns reflect large-scale changes in the atmospheric wave and jet stream patterns, and influence temperature, rainfall, storm tracks, and jet stream location/ intensity over vast*

Figure 2.1: ENSO and California Precipitation



Data courtesy of Western Regional Climate Center

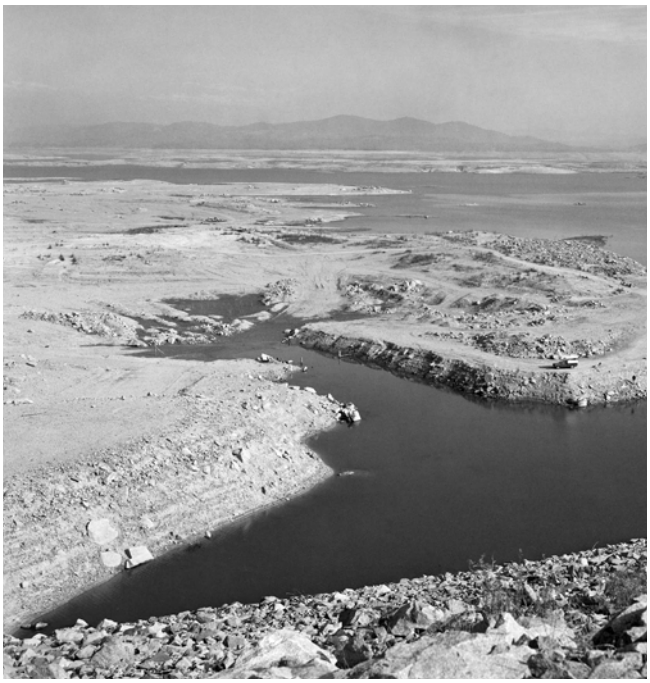
areas. Thus, they are often the culprit responsible for abnormal weather patterns occurring simultaneously over seemingly vast distances (NOAA, 2014).

The El Niño-Southern Oscillation (ENSO) is an example of a teleconnection, one that has been extensively studied because of its potential for informing seasonal forecasting.

ENSO status is presently the chief factor now offering some (limited) predictive capability for seasonal climate outlooks such as those performed by NOAA's Climate Prediction Center. La Niña conditions, for example, tend to favor a drier outlook for Southern California, but the predictive capabilities provided by ENSO events are related to the strength of an event; stronger events yield better predictive signals. Figure 2.1 shows relationships between ENSO and precipitation at localized scales within California, the scale of NOAA climate divisions. Figure 2.2 provides similar information for selected climate divisions in the Upper Colorado River Basin that provide much of the basin's runoff.

Interactions among teleconnections or other climate forcings influence the weather actually experienced in any given year, illustrating why ENSO conditions alone are not necessarily predictive. California's experience in water years 2011 (the last wet year) and 2012 (the present drought's initial year) shows how multiple factors influence seasonal precipitation. Both were years of moderate La Niña conditions, with forecasters calling for drier than average precipitation for much of California. Actual water conditions were dramatically different between the two years, with a major reason for the difference being attributed to the phase of the Arctic Oscillation (AO). Researchers cannot yet predict how different teleconnections may either amplify or cancel each other's expression at the scale of local weather. Fluctuations in Pacific sea surface temperatures may influence transitions from long-term dry to long-term wet conditions at interannual to decadal time scales, but there are presently no operational predictions for these transitions.

Folsom Lake in water year 1977 (an El Niño year) and in water year 2014 (an ENSO-neutral year).



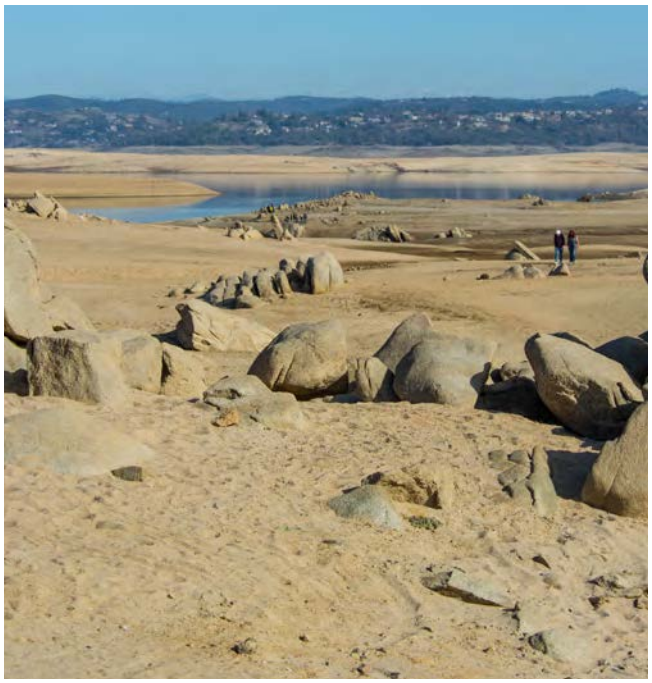
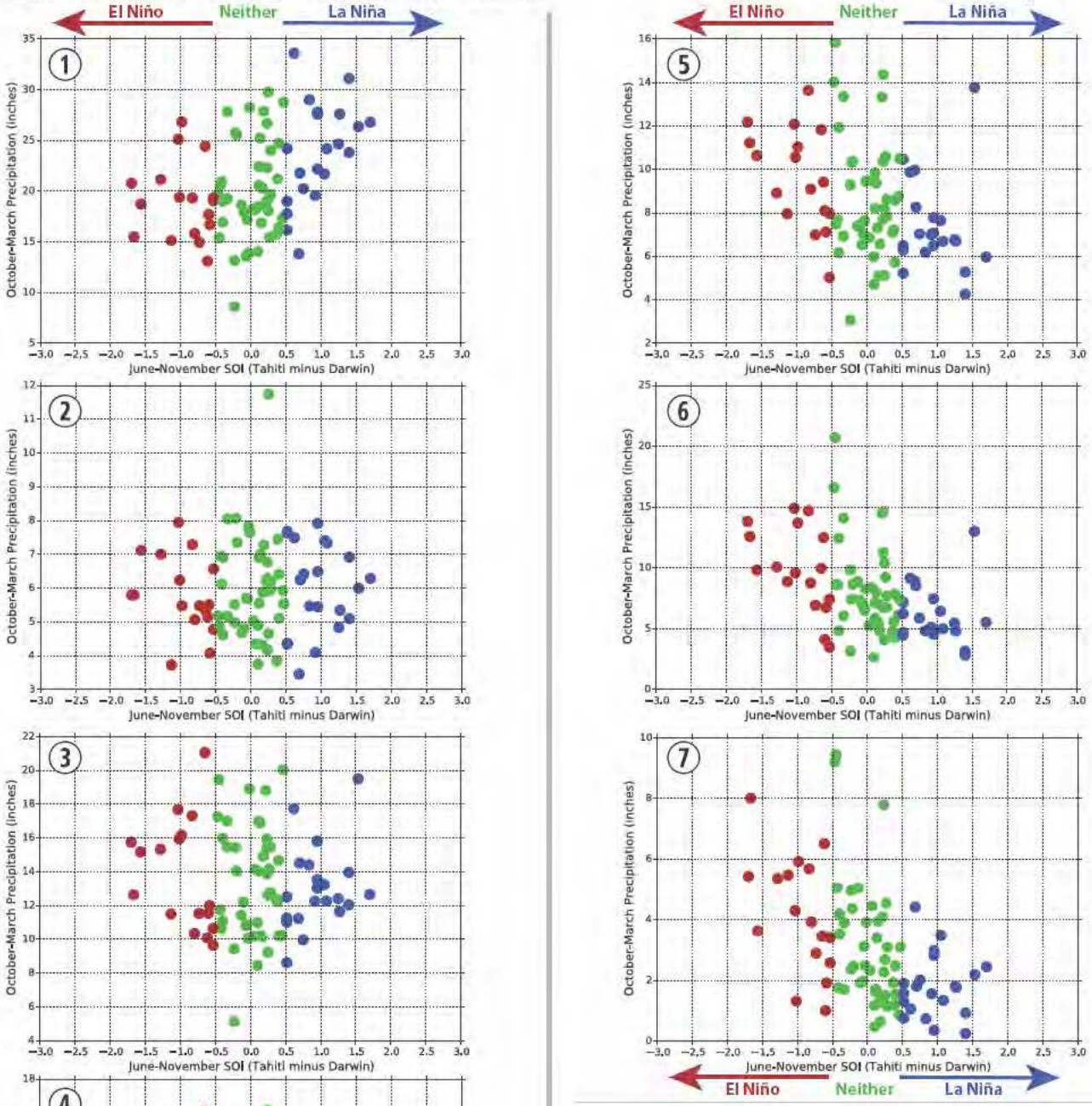


Figure 2.2: ENSO and Colorado River Basin Precipitation



NOAA climate divisions map: selected parts of Colorado Ricver Basin highlighted.

Data courtesy of Western Regional Climate Center

Climate Teleconnections

Researchers have identified a variety of climate teleconnections that influence weather patterns in different areas of the globe. Examples of ones relevant to North America and potentially useful for understanding weather patterns in California are listed below. Some of these teleconnections are being actively used or studied to provide predictive capability at weather or subseasonal/seasonal climate timescales; others are primarily diagnostic in nature. Monitoring the status of these teleconnections is done through large-scale measurements of parameters such as ocean temperatures or atmospheric pressures; satellite observations are fundamental for this monitoring due to the global scale of meteorological processes. The historical record available for large-scale measurements is thus limited to the satellite era, although researchers have made efforts to reconstruct some earlier records through use of global climate models and limited direct observations (e.g., temperature records from ships).

The **Arctic Oscillation (AO)** is a pattern of fluctuating sea-level atmospheric pressure at polar and mid-latitudes. The positive phase of the AO brings lower-than-normal pressure over the polar region and higher-than-normal pressure at mid-latitudes, steering storms to the north and potentially resulting in drier conditions for California. This pattern can persist from years to decades.

The **Atlantic Multidecadal Oscillation (AMO)** is a long-term fluctuation in sea surface temperatures in the Atlantic Ocean that can affect air temperatures and precipitation. The AMO has been in its warm phase since the mid-1990s; the Dustbowl drought occurred during a warm phase.

The **El Niño-Southern Oscillation (ENSO)** characterizes year-to-year fluctuations in sea surface temperatures in the equatorial Pacific Ocean and concomitant fluctuations in sea level air pressures between Tahiti and Darwin, Australia. The predictive capabilities provided by ENSO events are related to the strength of an event; stronger events tend to yield better predictive signals.

The **Madden-Julian Oscillation (MJO)** is a sub-seasonal fluctuation (30-60 days) that has been called the bridge between weather and climate because of its short-term nature. It occurs in the global tropics and is characterized by eastward propagation of areas of enhanced or suppressed tropical rainfall over the Indian and Pacific oceans. The MJO may speed or enhance ENSO episodes, and preliminary research suggests that it may be correlated to formation of the atmospheric river storms that are important for California's water supply. It thus offers potential predictive capability (when active) at sub-seasonal timescales for drought onset or persistence, and provides a promising near-term research opportunity for improving drought prediction.

Ocean temperatures needed for climate and weather modeling can be estimated by satellite-based remote sensing or directly obtained by measurements from buoys and ships. Real-time data collected from an array of moored buoys installed for the Tropical Atmospheric Ocean project is used for understanding and monitoring ENSO conditions. Photo courtesy of NOAA

The **North Atlantic Oscillation (NAO)** is a fluctuation in atmospheric pressure between a low-pressure center located near Iceland and a high-pressure center located near the Azores. It is closely related to the AO, in that both phenomena characterize pressure gradients that can affect storm tracks in North America.

The **Pacific Decadal Oscillation (PDO)** was originally developed as part of understanding relationships between salmon populations and Pacific Ocean temperatures. The PDO is an up-to-decades-long pattern of fluctuation in sea surface temperatures, similar to ENSO but at longer timescales. From about 1998 onward, the PDO has fluctuated from negative to positive temperature conditions at timescales of only a few years, in comparison to its prior multi-decadal cycle.

CLIMATE CHANGE

The 2012-14 drought has occurred at a time of record warmth in California. The state set new monthly and seasonal records in 2014, based on NOAA National Climate Data Center records. This also was a time of elevated warmth in the Colorado River Basin (Figure 2.3). Figure 2.4 shows a historical plot of statewide departure from the mean temperature, and Figure 2.5 illustrates another way of looking at changes in statewide mean temperatures over time. Increasing warmth is an expected result of anthropogenic climate change, and one for which global climate model studies generally show good agreement. Agreement among climate model studies is not as good for precipitation as it is for temperature.

The 2013 Southwest Climate Assessment (Garfin et al., 2013) describes expected drought-related outcomes of climate change, and provides a few specific examples:

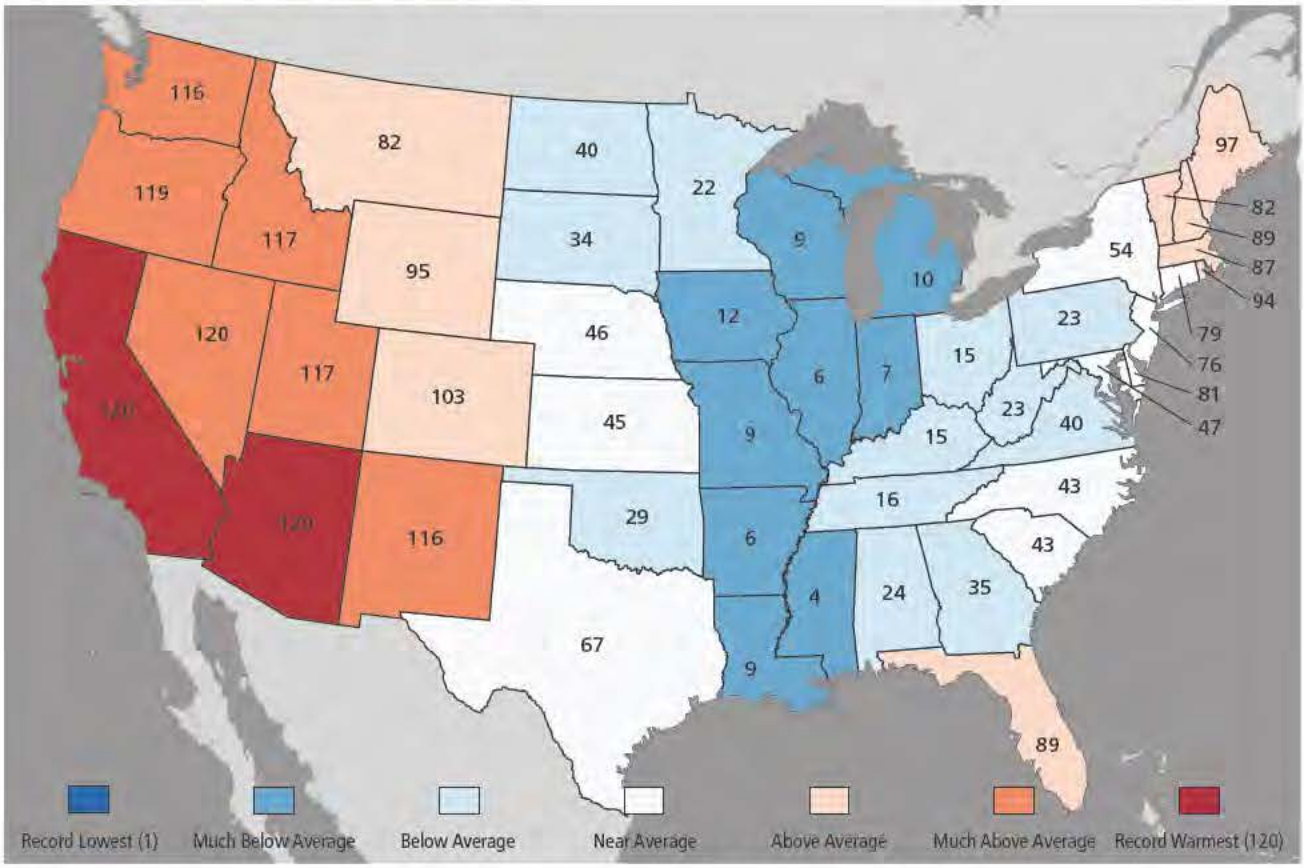
» *Drought, as expressed in Colorado River flow, is projected to become more frequent, more intense, and longer-lasting, resulting in water deficits not seen during the instrumental period. (high confidence)*

» *Northern Sierra Nevada watersheds may become wetter, and in terms of flow, somewhat less drought-prone with climate change. (medium-low confidence)*

» *In terms of soil moisture, drought is expected to generally intensify in the dry season due to warming. (high confidence)*

With regard to the observed record, the Southwest Assessment also notes that the period since 1950 has

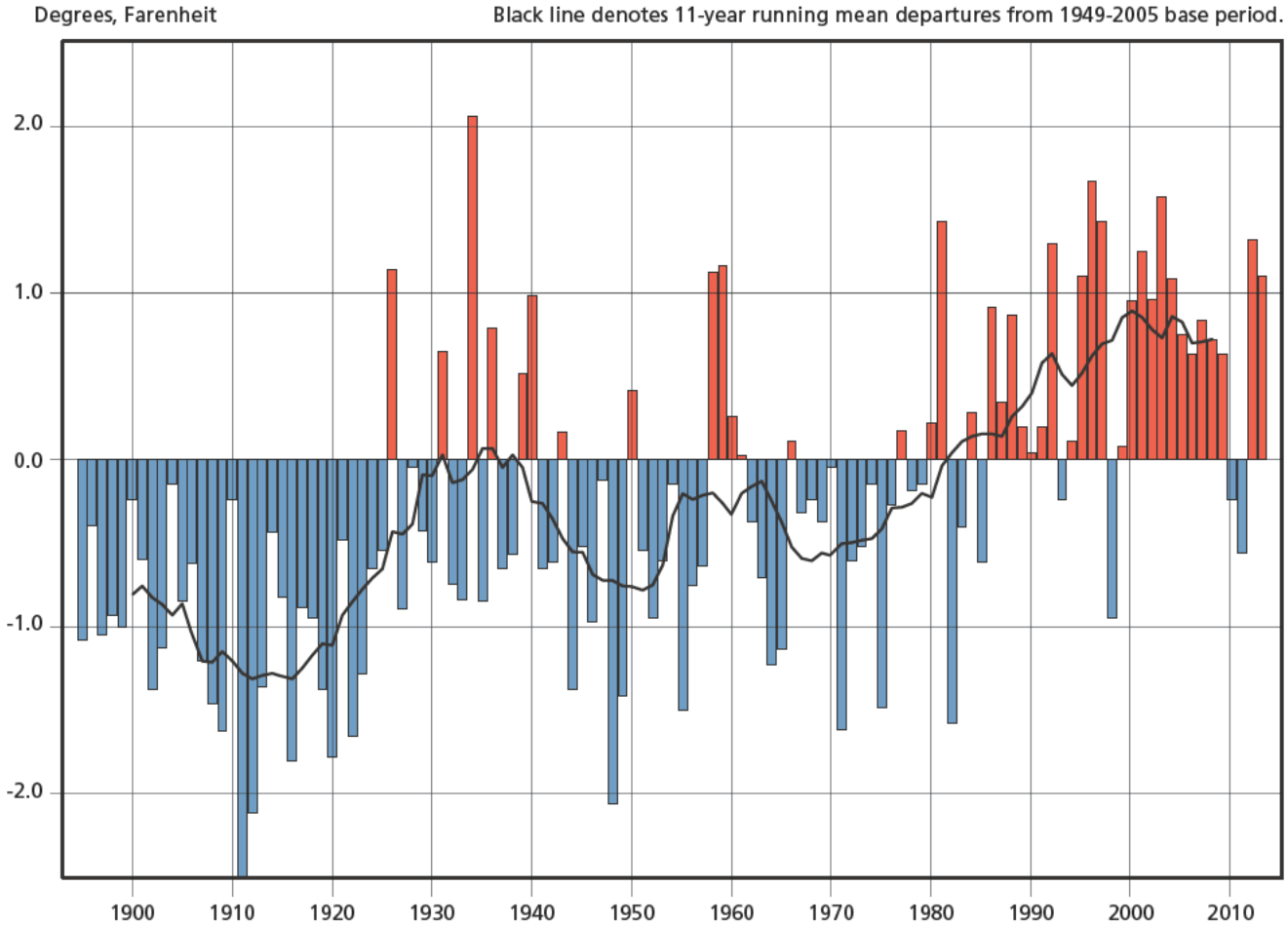
Figure 2.3: NOAA Statewide Average Temperature Ranks
December 2013 – November 2014. Period: 1895 – 2014



been warmer in the Southwest (including California and the Colorado River Basin) than in any comparable period in at least 600 years, and that the decade of 2001-2010 was the warmest and fourth driest of all decades from 1901 to 2010. A warmer temperature affects the percentage of precipitation that falls as rain or snow, and the spatial and temporal extent of mountain snowpack. Figure 2.6 illustrates how warmer temperatures have affected the freezing level in the Sierra, using the Lake Tahoe area as an example. Figures 2.7 and 2.8 show historical trends in the timing of spring runoff in the Sacramento and San Joaquin river basins. An expected long-term impact of warming is reduction of spring snowmelt runoff due to less precipitation occurring in the form of snow and earlier melting of snowpack.

Extensive material has been published about expected impacts of future anthropogenic climate change in California – loss of Sierra Nevada and Cascades snowpack, increased aridity in Southern California, and increased water demands due to warmer temperatures. In terms of timing of impacts, climate modeling generally shows very pronounced impacts – such as loss of half or more of Sierra Nevada snowpack – by the end of the century, with notable impacts being observed by mid-century (Knowles and Cayan, 2002). Climate change impacts on water supplies and demands also have been

Figure 2.4: California Statewide Mean Temperature Departure



Source: Western Regional Climate Center

Figure 2.5: California Statewide Mean Temperature Trend

Source: Western Regional Climate Center

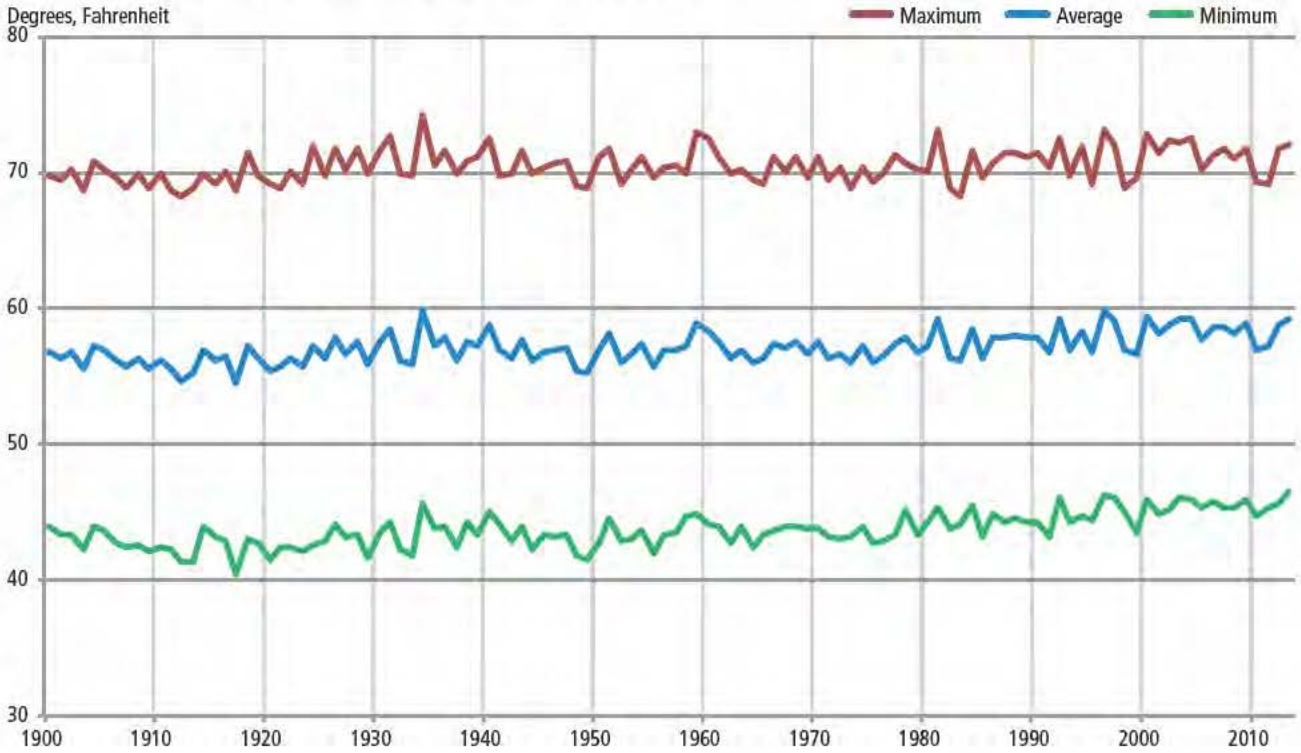


Figure 2.6: Annual Elevation of Freezing Level Over Lake Tahoe

Source: Western Regional Climate Center

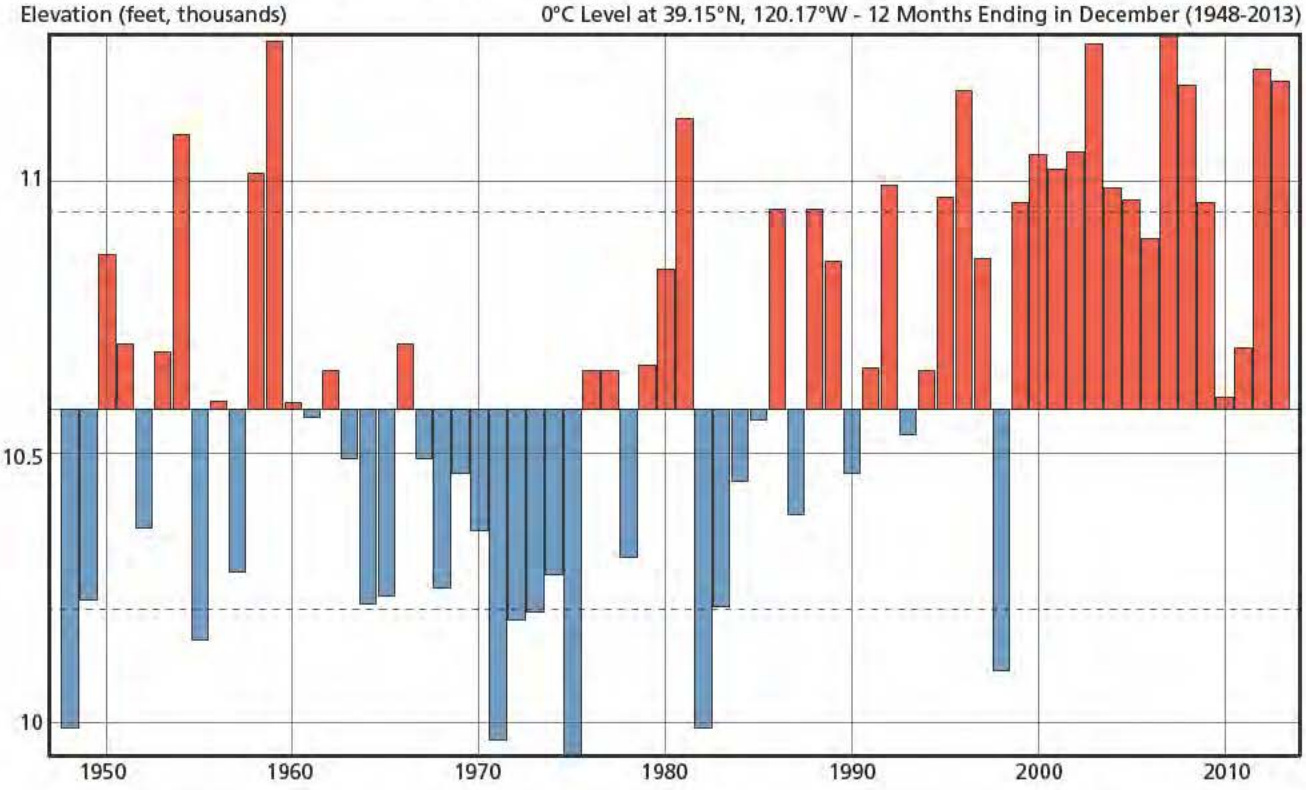
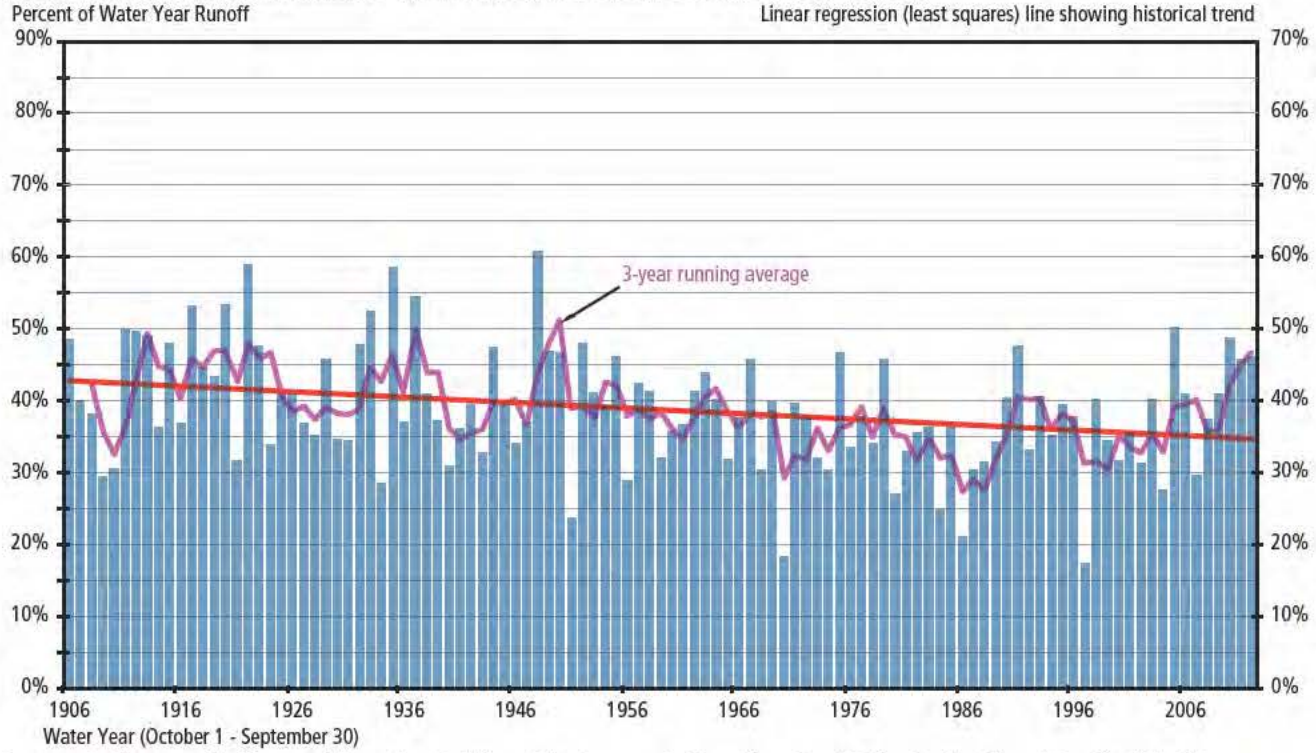
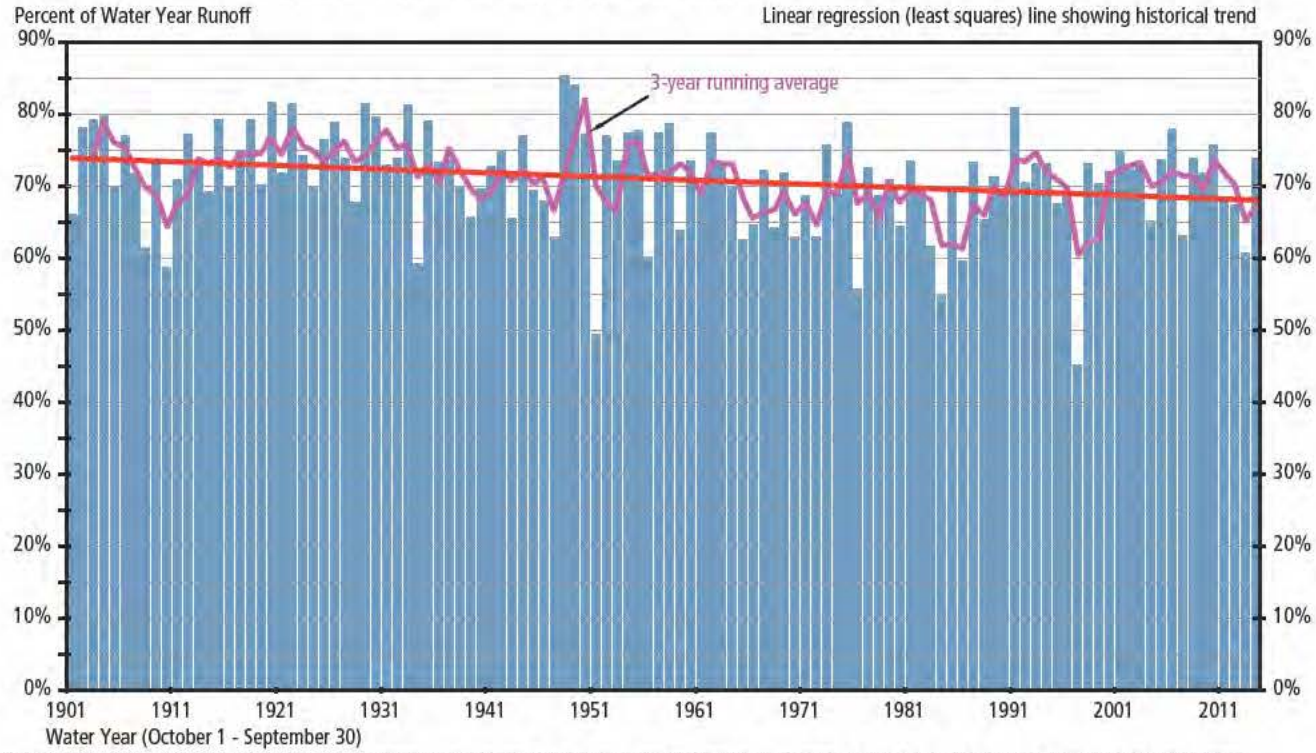


Figure 2.7: April-July Sacramento River Runoff as Percent of Water Year Runoff



Sacramento River runoff is the sum of the unimpaired flow at the Sacramento River above Bend Bridge, Feather River at Oroville, Yuba River near Smartville, and American River below Folsom Lake.

Figure 2.8: April-July San Joaquin River Runoff as Percent of Water Year Runoff



San Joaquin River runoff is the sum of the unimpaired flow at the Stanislaus River below Goodwin Reservoir, Tuolumne River below La Grange, Merced River below Merced Falls, and San Joaquin River inflow to Millerton Lake.

estimated for the Colorado River Basin (USBR, 2012), where increased water demands due to warming and other factors are projected to result in a significant gap between 2060-level supplies and demands. Future droughts in California and the Colorado River Basin will be occurring in a climate setting that differs from the context experienced in the state's historical droughts.

Trends even within the relatively brief historical record offer a cautionary message about using observed drought hydroclimate data for predicting the water supply impacts of future droughts at long-term planning time scales. It is important to recognize, however, that climate variability and change should be examined in the context of a defined part of the historical (or paleoclimate) record, whether the entire record or only some recent subset of it. As discussed below, paleoclimate records provide a long-term perspective on natural climate variability. In some cases the natural variability seen in the long-term records shows drier conditions than those projected by climate models for late 21st century conditions.

DROUGHTS IN AND NEAR CALIFORNIA – THE LONG-TERM PICTURE

A period of historically recorded hydrology of little more than a century does not represent the full range of the climate system's natural variability. Paleoclimate information, such as streamflow or precipitation reconstructions developed from tree-ring chronologies, provides a long-term perspective on climate variability. Perhaps the earliest recognition of the relative severity of earlier paleodroughts dates back to the modern drought of 1929-34, when Lake Tahoe dropped below its natural rim and exposed tree stumps rooted in place on the lake bottom. University of California, Berkeley professor S. T. Harding recognized the stumps as indicating much drier past conditions, and many years later used radio-carbon dating

National Geographic submersible examining relict tree stumps in situ on bottom of Lake Tahoe. Photo courtesy of National Geographic.

to estimate their age (Harding, 1965). Subsequent studies of relict tree stumps rooted in place in other central Sierra Nevada lakes, rivers, and marshes – including Fallen Leaf Lake, Independence Lake, and the West Walker River – identified chronic dry periods (e.g., Stine, 1994; Kleppe et al, 2011) prior to the modern record. Prolonged lowstands of Lake Tahoe dating back to the mid-Holocene times also have been identified (Lindstrom, 1990).

Thanks to interest in dating archaeological sites in the Four Corners area, paleodroughts and paleostreamflow have been particularly well studied in the Colorado River Basin. Reconstructions of Colorado River inflow to Lake Powell show multidecadal periods when flows were below the long-term average (Figure 2.9). The driest period in the Colorado's observed record (the present long-term drought conditions) is surpassed in severity by conditions prior to the historical record (Meko et al., 2007). DWR recently funded reconstructions for Sacramento, San Joaquin, and Klamath River streamflows to improve the understanding of the severity of droughts in these basins (Meko et al., 2014); these

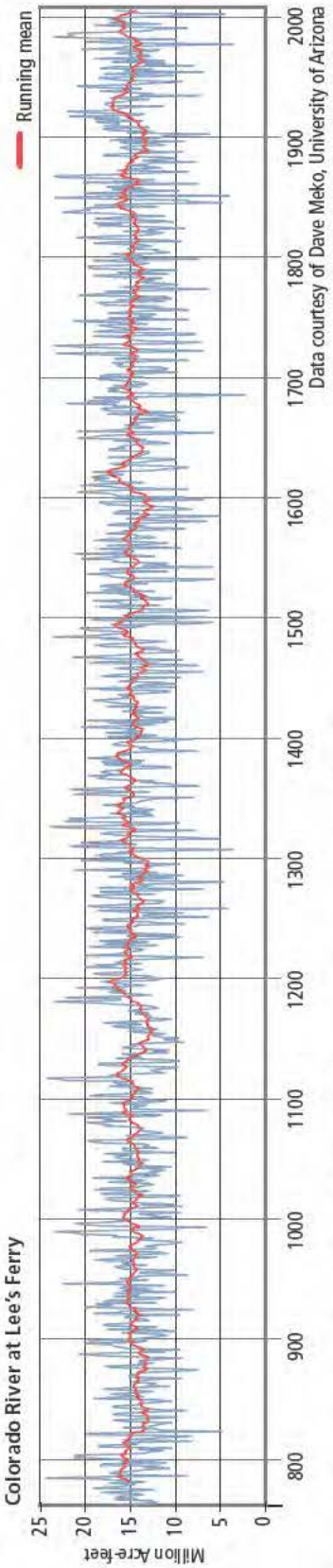


Figure 2.9: Reconstructed Inflow to Lake Powell

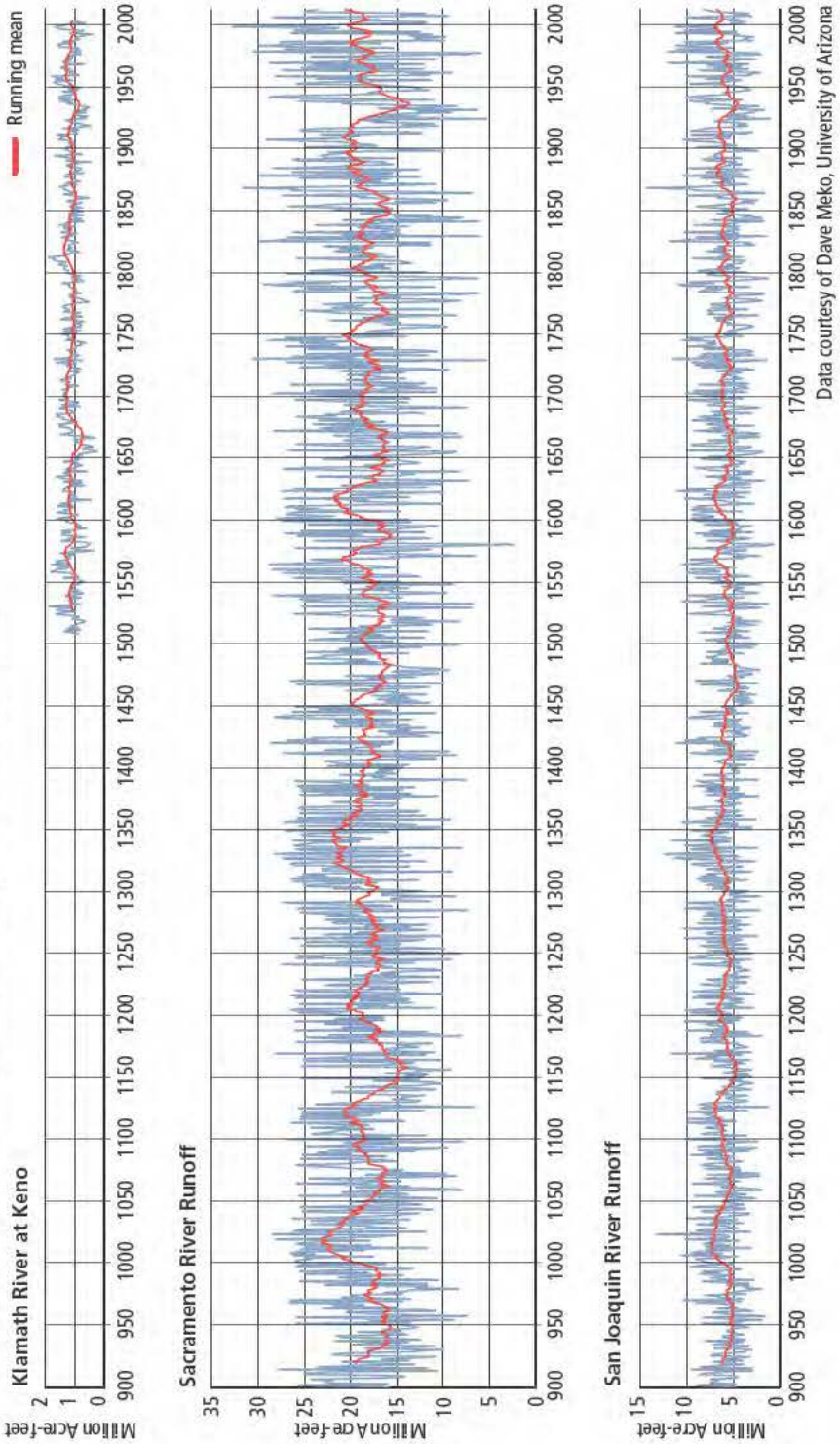
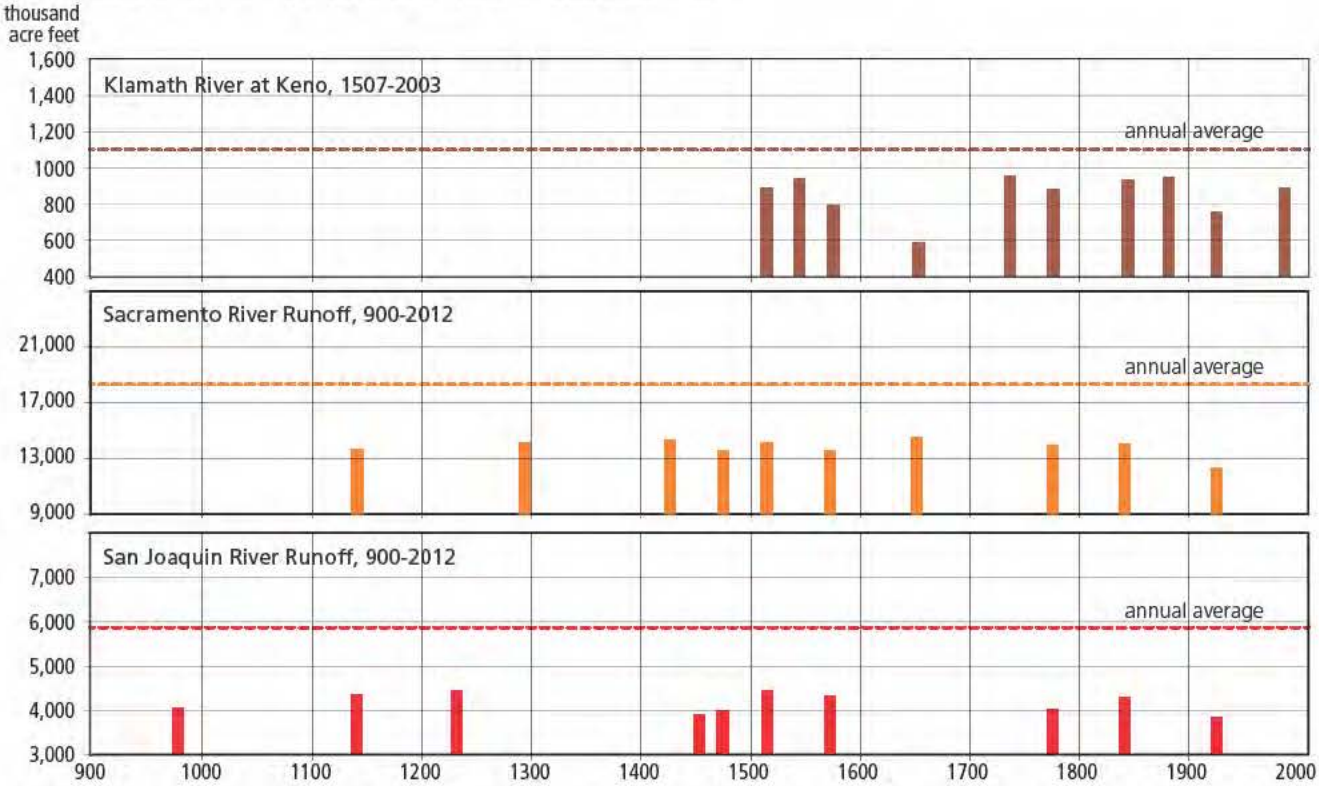


Figure 2.10: Reconstructed flows in Sacramento, San Joaquin, and Klamath Rivers

Figure 2.11: Driest 10-Year Periods in Reconstructed Records



Sacramento River runoff is the sum of the unimpaired flow at the Sacramento River above Bend Bridge, Feather River at Oroville, Yuba River near Smartville, and American River below Folsom Lake.

San Joaquin River runoff is the sum of the unimpaired flow at the Stanislaus River below Goodwin Reservoir, Tuolumne River below La Grange, Merced River below Merced Falls, and San Joaquin River inflow to Millerton Lake.

Figure provided courtesy of Connie Woodhouse, University of Arizona

Collecting a tree-ring sample near Ebbetts Pass. Data from multiple trees at one site are combined into a single record representative of the site.

reconstructions are shown in Figure 2.10. Figure 2.11 highlights the most severe 10-year periods in the records, and Table 2.1 shows dry sequences of four or more consecutive years where flows were below the median. The Sacramento and San Joaquin rivers share 1580 as their single driest year in the combined reconstructed and instrumental record; the reconstructed flow in 1580 was only about half of that of the driest year (1924) in the observed record. Considering both drought duration and estimated runoff magnitudes, the exceptional droughts that stand out in the reconstructed records for the Central Valley drainages are those of the mid-1100s, latter 1500s, and 1920s-30s.

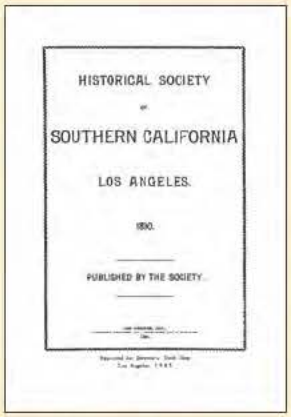
Table 2.1: Dry Periods in Combined Reconstructed and Instrumental Periods

Klamath River at Keno		Sacramento River Runoff		San Joaquin River Runoff	
Years	Length, years	Years	Length, years	Years	Length, years
1515-1522	8	921-924	4	946-950	5
1540-1543	4	945-950	6	977-981	5
1547-1552	6	975-981	7	1072-1075	4
1578-1582	5	1072-1075	4	1143-1148	6
1592-1597	6	1130-1136	7	1155-1158	4
1642-1646	5	1143-1148	6	1172-1177	6
1648-1668	21	1150-1158	9	1210-1213	4
1738-1744	7	1170-1177	8	1233-1239	7
1756-1761	6	1233-1239	7	1294-1301	8
1764-1767	4	1292-1301	10	1395-1402	8
1775-1779	5	1390-1393	4	1407-1410	4
1783-1787	5	1395-1400	6	1425-1428	4
1792-1798	7	1407-1410	4	1450-1461	12
1843-1846	4	1425-1432	8	1463-1466	4
1848-1852	5	1451-1457	7	1471-1483	13
1873-1876	4	1475-1483	9	1505-1508	4
1880-1884	5	1515-1521	7	1518-1523	6
1912-1915	4	1540-1543	4	1540-1545	6
1917-1920	4	1569-1572	4	1569-1572	4
1924-1935	12	1578-1582	5	1578-1582	5
1987-1992	6	1592-1595	4	1592-1595	4
		1636-1639	4	1629-1632	4
		1645-1648	4	1645-1648	4
		1652-1655	4	1652-1655	4
		1753-1760	8	1688-1691	4
		1780-1783	4	1753-1757	5
		1783-1846	4	1780-1783	4
		1856-1859	4	1793-1796	4
		1917-1922	6	1843-1846	4
		1926-1935	10	1855-1859	5
		1946-1951	6	1928-1931	4
		1959-1962	4	1946-1950	5
		1987-1992	6	1959-1962	4
				1987-1992	6
				2000-2004	5

Data courtesy of Dave Meko, University of Arizona

The Medieval Climate Anomaly

The Medieval Climate Anomaly in North America (sometimes called the medieval warm period or medieval climate optimum) is considered to span from as early as about 800 AD to as late as 1300 AD depending on the specific location. The warmer (and in some places, drier, climate) has been linked with historical events such as Norse settlement of Greenland and Iceland and changing settlement patterns in some Southwestern ancestral Pueblo communities whose agricultural production may have been affected by drought conditions. This time period is associated with severe droughts in the Southwest and California. Paleoclimate data and climate modeling suggest that this period was characterized by cool surface waters in the eastern Pacific Ocean, or La Niña-like conditions (e.g., Seager et al. 2007).



HISTORICAL SOCIETY

OF

SOUTHERN CALIFORNIA

LOS ANGELES.

1890.

PUBLISHED BY THE SOCIETY.

The Great Drought of 1863-64

An excerpt from ***Exceptional Years: A History of California Floods and Droughts*** J.M. Guinn, 1890

1862-63 did not exceed four inches, and that of 1863-64 was even less. In the fall of 1863 a few showers fell, but not enough to start the grass. No more fell until March. The cattle were dying of starvation.... The loss of cattle was fearful. The plains were strewn with their carcasses. In marshy places and around the cienegas, where there was a vestige of green, the ground was covered with their skeletons, and the traveler for years afterward was often startled by coming suddenly on a veritable Golgotha – a place of skulls – the long horns standing out in defiant attitude, as if protecting the fleshless bones.

MEASURING DROUGHTS IN CALIFORNIA'S HISTORICAL RECORD

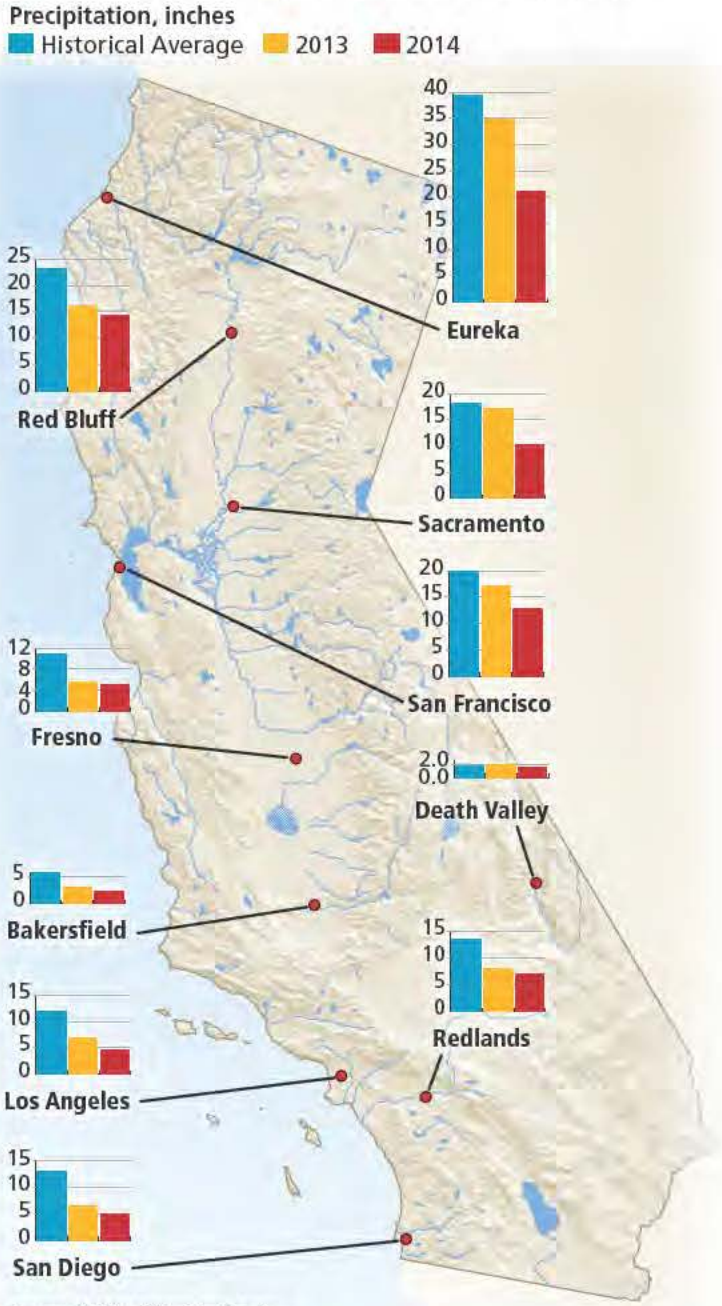
The so-called Great Drought of 1863-64 (as it was named at the time) played a major role in shaping the state's historical development by contributing to the demise of the cattle rancho system, especially in Southern California. We have only sparse precipitation information to characterize that event, and primarily anecdotal descriptions of its impacts (see sidebar for Southern California example). The widespread economic damage that this drought caused to California agriculture reflects the dominance of non-irrigated agriculture at the time, the limited extent of water infrastructure, and the absence of groundwater pumping technology.

California's more recent large droughts can be evaluated by metrics such as precipitation, streamflow, or storage in surface reservoirs or groundwater basins. It is important to recognize that although the large droughts discussed in this report are all of statewide geographic extent, there can be significant variation in their hydrology at the regional or local scale. For example, California's historical climatology of a wetter Northern California and a drier Southern California is often intensified by drought, with parts of the San Joaquin Valley and Southern California being drier in terms of percent of average precipitation than the northern part of the state. Similarly, although most of the state may be experiencing drought, some areas subject to mesoscale (localized) weather conditions may not be abnormally dry. This is often the case in California's southeastern desert region, where summer monsoonal moisture and the influence of tropical cyclones can contribute much of the region's average annual precipitation.

Spatial variation in precipitation is shown in Figure 2.12, which compares historical averages with water year 2013 and 2014 amounts for selected cities. Figures 2.13 and 2.14 show seasonal plots of the Northern Sierra 8-station and Southern Sierra 5-station precipitation indices for the wettest and driest years of their records, to illustrate regional conditions in the Sacramento and San Joaquin river basins. Water years 1977 and 2014 are also included in the plots to provide examples of other dry years.

Figure 1.4 showed the effects of droughts on calculated statewide runoff. Streamflow integrates

Figure 2.12: Water Year Precipitation at Selected Cities



Source: National Weather Service

Figure 2.13: Northern Sierra 8-Station Precipitation Index for Selected Years

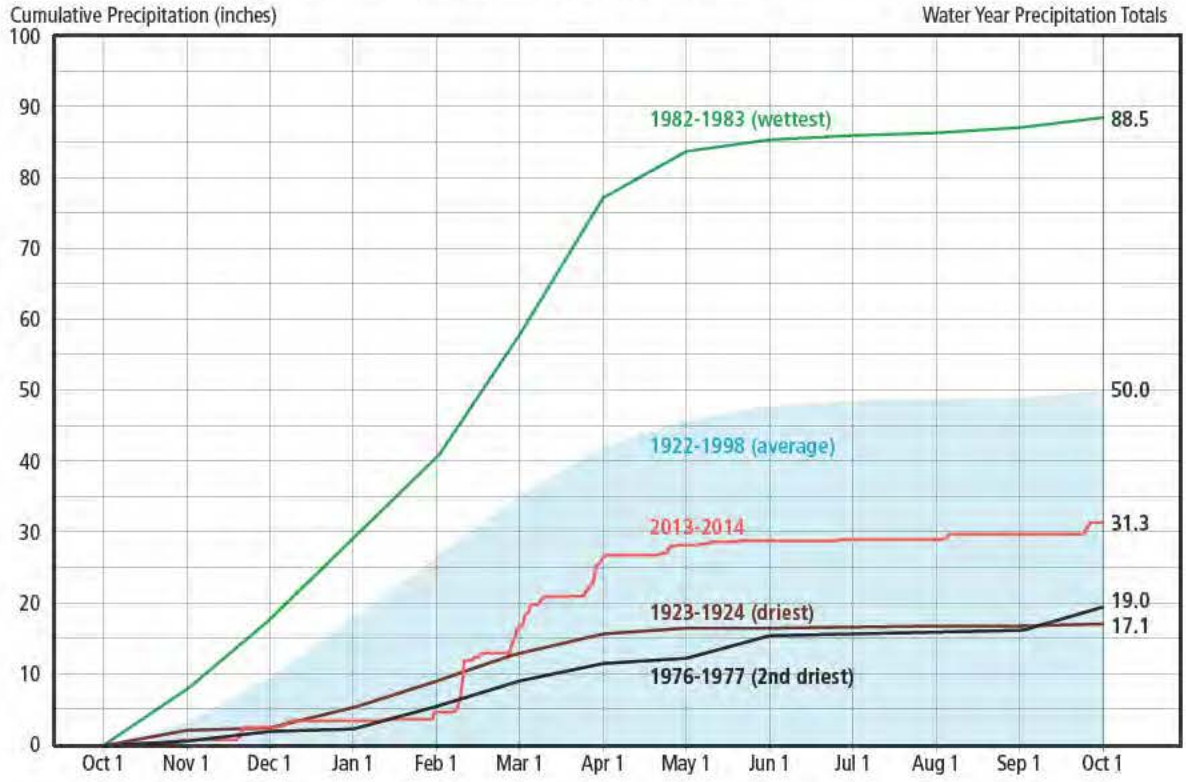
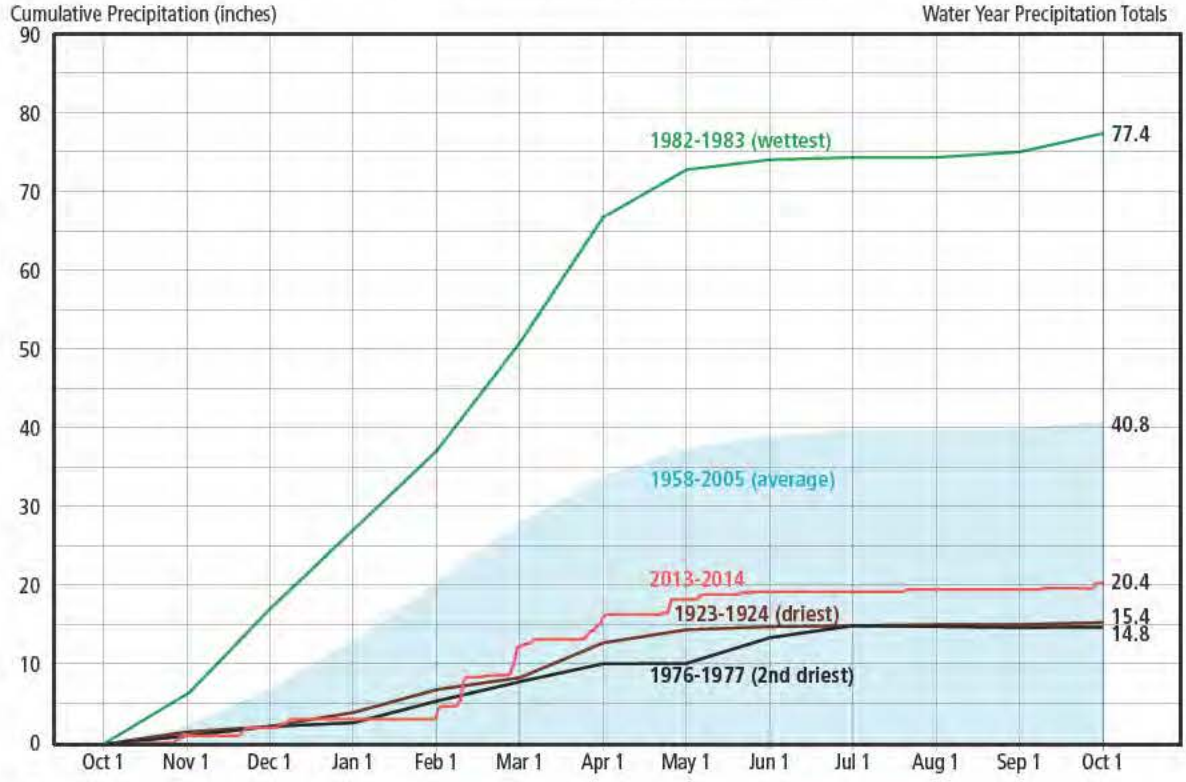


Figure 2.14: Southern Sierra 5-Station Precipitation Index for Selected Years



the expression of drought hydroclimate conditions in that it reflects not only precipitation but also temperature-related effects such as melting of snowpack. Streamflow registers effect of drought duration through depletion of soil moisture – all other things being equal, a given quantity of precipitation occurring at the beginning of dry conditions will result in more runoff than the same quantity of precipitation after multi-year dry conditions. Water year 1977 ranks as California's driest year in terms of statewide runoff, although it was only the third driest year in terms of statewide precipitation, due to the antecedent conditions of a very dry water year 1976.

Comparing streamflows during California's major historical droughts is problematic, due to changing levels of watershed development and changing regulatory requirements that affect flow. There are also different ways of expressing drought impacts on streamflow. A common approach used in hydrologic studies is to express streamflow at a specific point in terms of percent of average for some defined period of time (a day, a month, a year). This approach works well for major river basins where perennial flows are supported by upstream reservoirs. It can be less meaningful for resource managers in locations where drought may cause parts of the channel to go dry for extended periods, such as smaller watersheds that have little upstream storage, or ephemeral streams. Seasonal mean streamflows in small coastal watersheds, for example, may not be a useful metric for evaluating impacts on anadromous fish passage.

Reservoir storage, like streamflow, is another integrator of hydrologic drought impacts, although one that adds another layer of complexity – that of the institutional framework surrounding reservoir operations. End-of-season reservoir storage reflects multiple factors including hydrology, water rights, service area water demands, instream flow requirements, and other environmental regulatory requirements. Since the institutional framework for many California reservoirs has changed over time, comparisons of seasonal storage across historical droughts should be thought of as only relative indicators of water supply availability. Table 2.2 shows statewide reservoir storage at the end of selected dry water years.

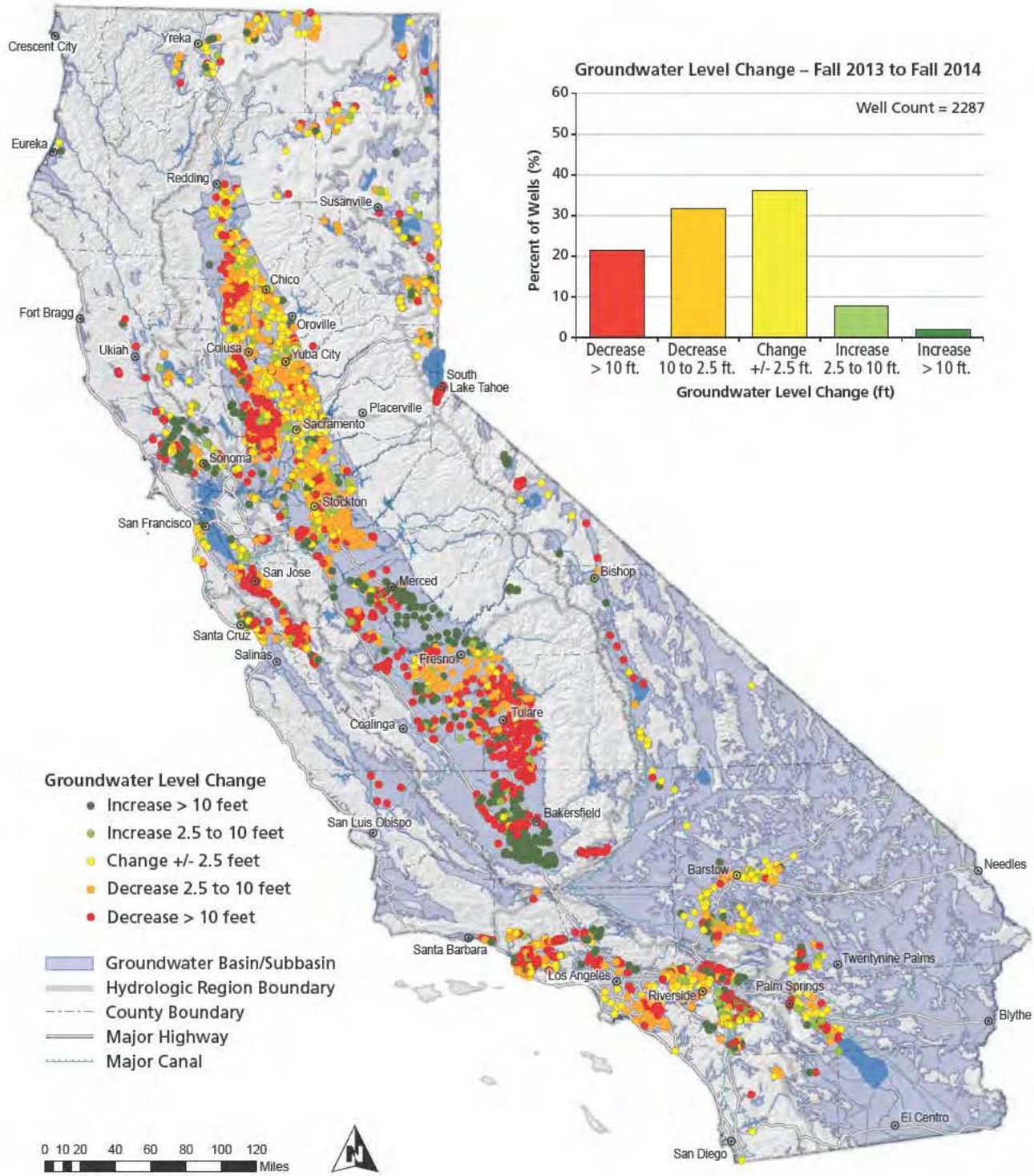
Like reservoir storage, water levels in alluvial groundwater basins integrate drought impacts. Unlike reservoir storage, however, groundwater basin storage can be only indirectly estimated through complex and data-intensive models; such information is available for a limited number of basins. Instead, groundwater level information is the key proxy used to represent storage; it is well suited to basins' subsurface heterogeneity and the local scale of groundwater management. State legislation enacted in 2009 mandated creation of a program for statewide groundwater level monitoring and public dissemination of the water level data, establishing an effort known as the California Statewide Groundwater Elevation Monitoring (CASGEM) program. CASGEM data are now beginning to permit statewide evaluation of drought impacts on groundwater (Figure 2.15).

There is limited availability of groundwater level data during historical (pre-CASGEM) drought periods,

Table 2.2: End of Water Year Statewide Reservoir Storage for Selected Dry Years
(percent of average at this time)

2014	56
2013	79
2012	97
2009	79
2008	72
1992	58
1991	63
1977	36

Figure 2.15: Recent Changes in Statewide Groundwater Elevations



Unimpaired Flow

Unimpaired flow in a river or stream (sometimes called natural flow) is a calculated value that reflects the amount of water that would have been present in a watercourse if there were no diversions or regulation of flow by reservoirs. Unimpaired flow is used as a metric for hydrologic conditions because it represents baseline conditions for streamflow. Measured (observed) flows typically change over time in response to development dependent on the watercourse. For example, storage provided by the Central Valley's major rim reservoirs supports downstream flows to meet water supply needs, water quality criteria, and fishery flow requirements, resulting in higher observed low flows during dry years than would have occurred in predevelopment conditions. The majority of California's rivers support some level of development that makes their observed flows not reflective of pre-development baseline conditions.

The Cosumnes River in 1977. Parts of the Cosumnes River typically go dry during drought, since there is no upstream storage to support streamflow during dry conditions.

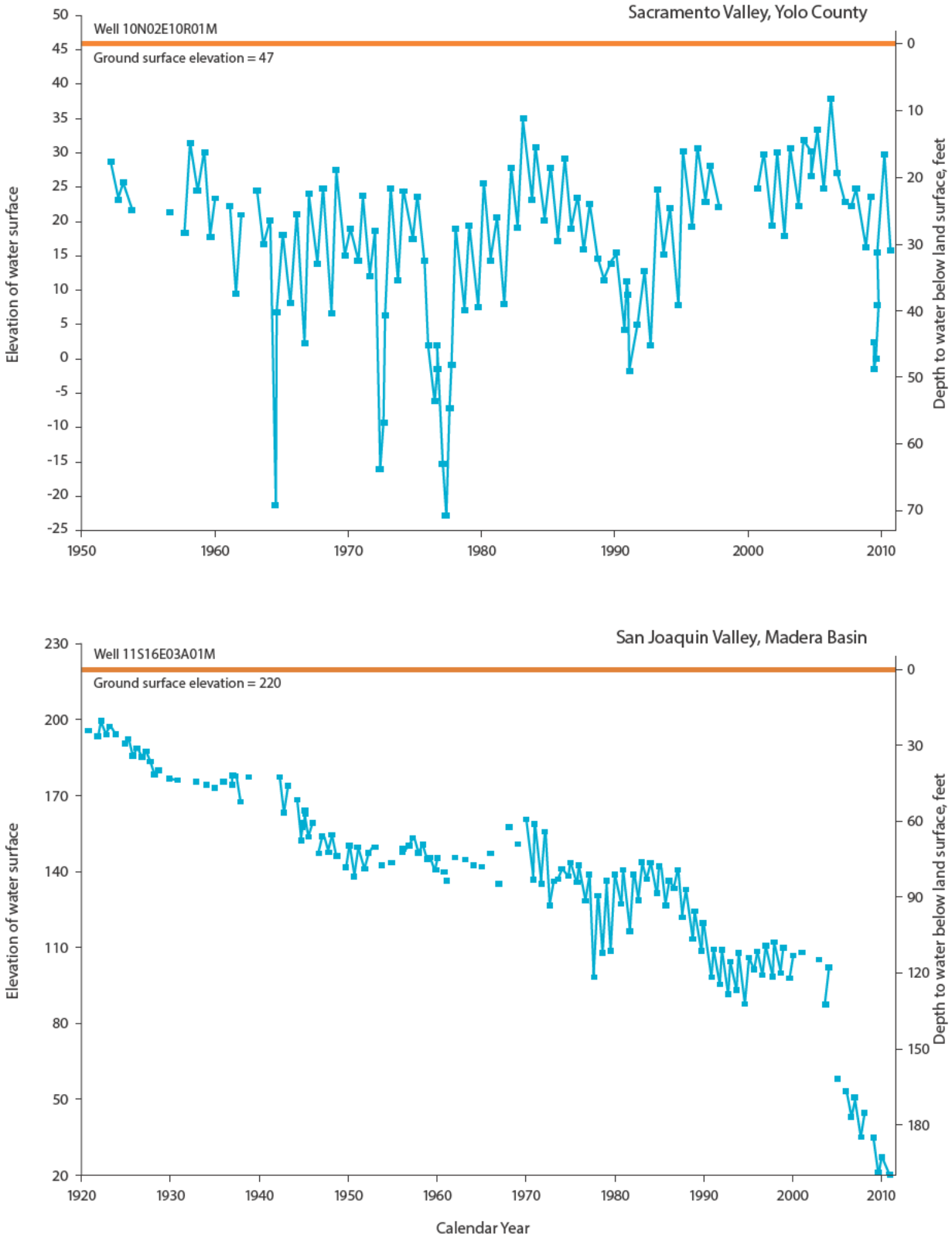
particularly for continuous long-term records that extend back to the 1920s-30s. Such long-term records – dating to early development of groundwater resources – are important for understanding a basin's response to development and sustainable levels of groundwater extraction. Reliance on groundwater increases during droughts when water users with reduced surface supplies turn to groundwater to help mitigate shortages; the increased groundwater use is typically reflected in declining groundwater levels. Figure 2.16 illustrates typical seasonal fluctuations in groundwater levels and longer-term trends associated with drought – a pattern of water level drawdown during dry conditions and recovery during wet conditions – for sample wells in the Sacramento and San Joaquin Valleys. The long-term overall decline in water levels for the San Joaquin Valley well shown is indicative of groundwater overdraft. Land subsidence (see sidebar) is one of the potential consequences of overdraft.

DWR prepared an April 2014 report on the status of groundwater levels and gaps in groundwater monitoring in response to a requirement in the January 2014 emergency proclamation (DWR, 2014), relying heavily on the availability of the data being provided by CASGEM. Among key findings of that report were that recent groundwater levels in many areas in the San Joaquin Valley were more than 100 feet below previous historical levels. In other parts of the state, such as the northern San Francisco Bay Area, and South Coast and South Lahontan areas, groundwater levels were more than 50 feet below previous historical lows.

LAND SUBSIDENCE

Land subsidence in California due to extraction of subsurface fluids (oil and gas or groundwater) has been recognized for about 80 years (USGS, 1999), and has been historically observed in diverse geographical areas including the southern San Francisco Bay area, coastal Los Angeles area, and Central Valley. The San Joaquin Valley has been an area of ongoing subsidence due to groundwater extraction. As USGS described in the 1970s (USGS, 1975), imported CVP and SWP water had almost recovered groundwater levels in much of the valley to predevelopment conditions, reducing the risk of continued subsidence. Increased subsidence was observed during the 1976-77 and 1987-92 droughts when pumping increased in response to surface water cutbacks, a phenomenon also observed in 2007-09. With imported CVP and SWP supplies becoming increasingly unreliable from about 1990 onward, growers turned to groundwater to make up surface water deficiencies and to irrigate new plantings of permanent crops, resulting in further subsidence in some areas. Adverse effects of subsidence include infrastructure damage, loss of capacity in water delivery canals and flood control channels, and loss of groundwater basin storage capacity.

Figure 2.16: Sample Hydrographs of Wells in the Sacramento and San Joaquin Valleys



3
Highlights of Past Droughts

This chapter summarizes highlights from historical droughts, focusing on water management conditions and actions taken, and drought impacts. While the hydrology of historical droughts can readily be compared from one event to another, the same cannot be said of their impacts, due to changes in California's institutional setting and level of development.

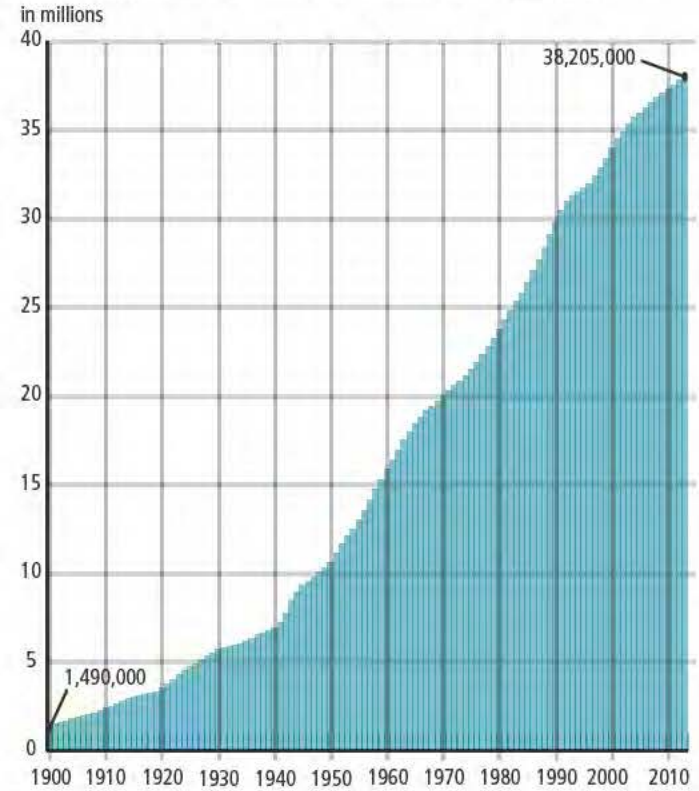
California experienced massive changes over the course of the twentieth century, evidenced by dramatic population increases and land use conversion. Figure 3.1 shows the state's population over time, illustrating the notably smaller size of California's population during the 1929-34 or 1976-77 droughts. Figure 3.2 shows the historical extent of California irrigated acreage which, after peaking in about 1980, has since declined slightly due to urbanization of agricultural lands. A timeline of some key dates shown in the sidebar gives a frame of reference for the discussion of the drought events that follows.

1929-34

Occurring some 80 years ago, this drought is difficult to place in context with modern conditions. California's population was estimated at only 5.7 million in 1930, making it then the nation's sixth most populous state. Irrigated acreage was small in comparison to modern levels. Most major water infrastructure had not been constructed; work on initial facilities of the CVP and on the Colorado River Aqueduct was just beginning. Figure 3.3 shows the geographic distribution of the state's population in 1930.

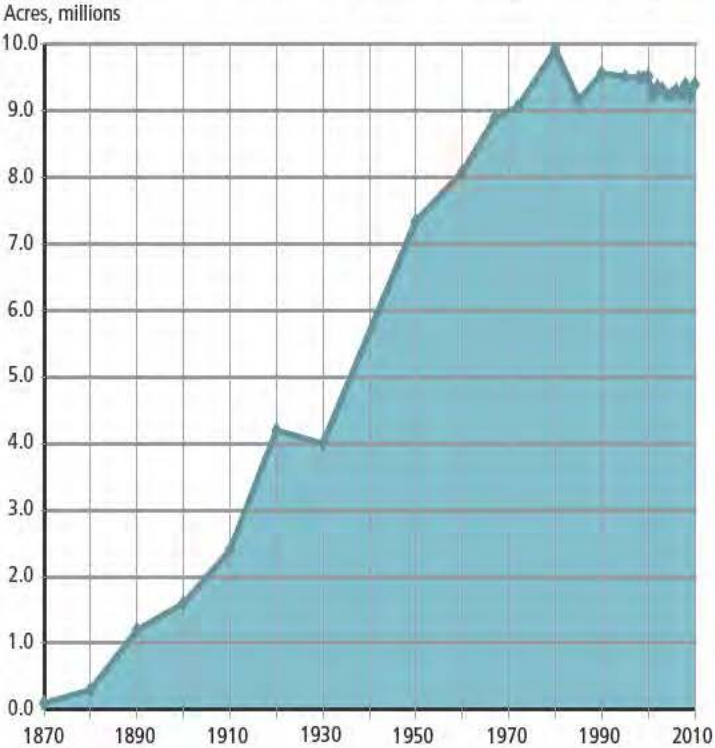
However, the drought was severe from a hydrologic perspective, especially in the context of its occurrence within a longer period of dry conditions. This longer-term dry sequence in the observed record stands out as being on a par with events of similar length in the paleoclimate record. In terms of calculated statewide runoff through 2013, water year 1931 ranks as second-driest in 113 years, second only to 1977. Within the 11-year period of water years 1924-1934, there were four extremely dry years, including 1924 – holder of many site-specific records in California. The relative severity of dry conditions during this time is illustrated by Table 3.1, which shows the ten driest three-year periods of statewide precipitation, based on 119 years of record. Table 3.2 shows single driest years of computed statewide runoff, based on 114 years of record.

Figure 3.1: Historical California Estimated Population



Data: Department of Finance

Figure 3.2: Historical California Estimated Irrigated Acreage



TIMELINE OF SELECTED EVENTS

1850	California admitted to the Union
1871	First reported construction of a dam on Lake Tahoe
1887	Legislature enacts the Wright Irrigation District Act, allowing creation of special districts
1902	Congress enacts the Reclamation Act, authorizing federal construction of water projects
1913	First barrel of Los Angeles Aqueduct completed
1922	Colorado River Compact signed
1929	Mokelumne River Aqueduct of East Bay Municipal Utility District is completed
1931	Legislature enacts the Water Conservation Act of 1931, spurring formation of many new special districts
1934	San Francisco's Hetch Hetchy Aqueduct completed
1940	All-American Canal completed
1941	Colorado River Aqueduct completed
1945	Shasta Dam completed
1968	Oroville Dam completed
1968	Congress enacts National Wild and Scenic Rivers Act
1971	Don Pedro Dam completed (largest local agency-owned dam in California)
1972	Legislature enacts California Wild and Scenic Rivers Act
1973	Congress enacts Endangered Species Act
1978	SWRCB adopts Water Rights Decision 1485 regarding CVP/SWP water operations criteria for the Delta
1984	Legislature enacts California Endangered Species Act
1992	Congress enacts Central Valley Project Improvement Act
1999	SWRCB adopts Water Rights Decision 1641 regarding CVP/SWP water operations criteria for the Delta
2003	Colorado River Quantification Settlement Agreement signed

Table 3.1: Driest Three Consecutive Water Years, Based on Statewide Precipitation

Years	Total Statewide Precipitation, inches
2012-14	44.5
1922-24	45.1
1918-20	46.1
1924-26	46.5
1929-31	46.7
1923-25	46.9
2007-09	48.2
1917-19	49.6
1975-77	49.8
1931-33	50.1

Data: Western Regional Climate Center

Table 3.2: Single Driest Years Based on Statewide Runoff

1. 1977	114th	7. 1990	108th
2. 1931	113th	8. 2001	107th
3. 1924	112th	9. 1934	106th
4. 2014	111th	10. 1992	105th
5. 1991	110th	11. 1976	104th
6. 1994	109th	12. 1929	103rd

Data: USGS

The 1935 barley harvest at the Mouren Farm in the Huron area, near the location of today's joint state-federal San Luis Canal. Prior to construction of the CVP to bring imported surface water to the San Joaquin Valley's west side, dry-farmed grain crops were a staple in the area. Photo courtesy of Coalinga Huron Library District.

Figure 3.3: Distribution of California's Population in 1930

Data: Department of Finance

Water Infrastructure Development

Despite California's dry conditions, the latter 1920s and 1930s were a time of accomplishment with respect to water supplies. Although only a few large-scale water projects were then extant or recently finished, others were in the development. The first barrel of the Los Angeles Aqueduct was completed well before the drought; construction of the Mokelumne River Aqueduct serving the East Bay was just completed at the drought's beginning. San Francisco had purchased the privately held Spring Valley Water Company in 1930 and subsequently completed construction of the Hetch Hetchy Aqueduct in 1934. The new supply of imported Tuolumne River water was needed on the Peninsula, where local supplies were stretched thin. The Santa Cruz Evening News carried a short article on December 20, 1930, regarding San Francisco seeking a writ of possession for a 16-mile pipeline right-of

Construction of MWD's Colorado River Aqueduct in the 1930s, tunneling through the San Jacinto Mountains. Photo courtesy of Banning Library District.

way between Newark and San Lorenzo for an emergency water line, because Spring Valley Lake (now known as Crystal Springs Reservoir) held only enough water for the first 100 days of 1931.

In 1930, State Engineer Edward Hyatt had completed the State Water Plan, which called for construction of a major public works project to develop the state's water resources. The plan was adopted by the Legislature in 1931; then-Governor James Rolph issued a 1931 proclamation appointing a California Water Resources Commission and charging it with addressing the "real emergency" of "California's water problem" (California Department of Public Works, 1931). Implementation of elements of the plan was enabled through California's Central Valley Project Act of 1933, which placed a bond measure before the voters to finance initial project facilities. The voters approved this $170 million measure at the height of the Great Depression but the state was unable to sell bonds then and turned to the federal government to build the project. The state's focus on addressing water development needs also spurred 1931 legislation establishing new authority for formation of special districts, resulting in creation of many new local agencies.

Progress also had been occurring on the Colorado River. The Boulder Canyon Project Act of 1928 authorized construction of Hoover Dam; the Seven-Party Agreement of 1931, ratified by the Legislature, divided California's interstate apportionment of the river among the local contracting agencies. Metropolitan Water District (MWD) was formed in 1931 to contract for Colorado River water; it began construction of the Colorado River Aqueduct in 1932 and advanced funding to USBR to begin construction of Parker Dam in 1934. USBR also began construction of the All-American Canal in 1934. Construction of these facilities, together with those of the CVP, provided sorely-needed public works jobs during the Great Depression.

Impacts

Accounts of impacts of the 1929-34 drought differ noticeably from those of more recent droughts in California. In part this represents the difference in the level of development between then and now. Impacts of the Great Depression – and of the extreme drought occurring in the Great Plains states at the heart of the Dustbowl – overshadowed the dispersed and localized drought impacts occurring in California. Descriptions of drought in California during this period typically

Dorothea Lange photo of Dustbowl migrants at a camp in the Imperial Valley. Photo courtesy of The History Place.

focus on the influx of migrants from the Dustbowl states who came to California seeking farm jobs and often populated shanty towns or Hoovervilles in areas such as the San Joaquin Valley or Imperial Valley. John Steinbeck's *Grapes of Wrath* immortalized this era, in which California was characterized as an Eden (a theme featured in a Woody Guthrie folk song of the time) in comparison to the Dustbowl states. Demographers estimate that more than a million people moved to California during the 1930s from drought-affected states such as Oklahoma and Arkansas, a large increase in the state's population in percentage terms and one that, combined with economic conditions and labor market stresses, focused public attention on issues other than local water supply impacts.

Information about California impacts during the 1929-34 drought is scattered and often anecdotal, reflecting the highly localized nature of impacts and relatively low level of statewide development. Reported statistics, notably agricultural crop production values, are difficult to compare to modern times due the great difference in the scale of irrigated agriculture and in crop market conditions. Much has been written about agricultural production and policies during the Dustbowl drought, but this material is largely focused on conditions in the affected Midwestern and Southeastern states and on commodity crops. Impacts on livestock production (reducing herds, selling cattle early) is the subject most frequently mentioned in California accounts of the time, and one of the impacts most similar to modern conditions. Then as now, livestock producers relying on seasonal grazing on non-irrigated rangeland were at the mercy of annual precipitation conditions. Responding both to drought in the Dustbowl states and to the Depression's economic conditions, USDA-administered emergency drought relief programs designed to provide an outlet for producers to sell cattle whose meat would be canned and distributed through emergency food relief programs.

Low water levels at the City of San Diego's Morena Lake in 1930. Prior to construction of the San Diego Aqueduct to link the region to MWD's Colorado River Aqueduct, local drinking water supplies were almost exclusively dependent on reservoirs in the small watersheds of the Peninsular Ranges. Photo courtesy of San Diego History Center.

With respect to impacts from this time period directly linked to water project operations, the so-

Trying to End the Drought

Big Bear Lake in the San Bernardino Mountains was constructed to supply irrigation water for citrus and other crops in the Redlands area. Runoff to the lake is limited by the small size of the watershed. Newspaper articles from the spring and summer of 1931 report that the famous rainmaker Charles Hatfield, who used a secret mixture of chemicals that he would burn from the top of a tower, was hired by water users to make it rain to raise the lake by amounts variously reported as ten to 29 feet. Hatfield had employed his technology at a number of locations, initially becoming famous for a flood he was said to have caused at San Diego's Morena Dam in 1916. Precipitation records in the San Bernardino area show an unusually wet late April in 1931, but the timing of Hatfield's work relative to those storms is unknown.

Figure 3.4: Maximum Delta salinity intrusion 1921-1943

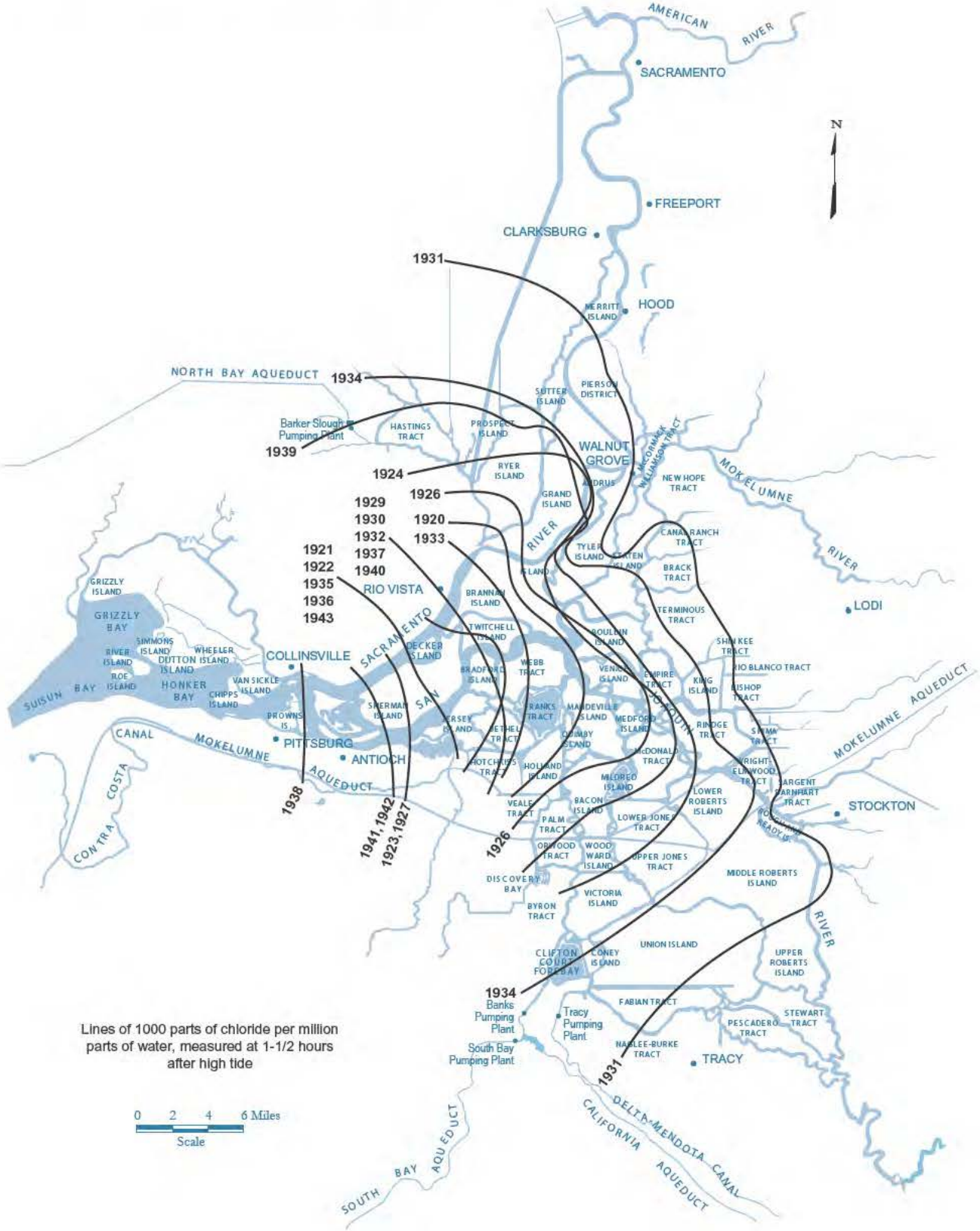


Figure 3.5: Maximum Delta salinity intrusion 1944-1990

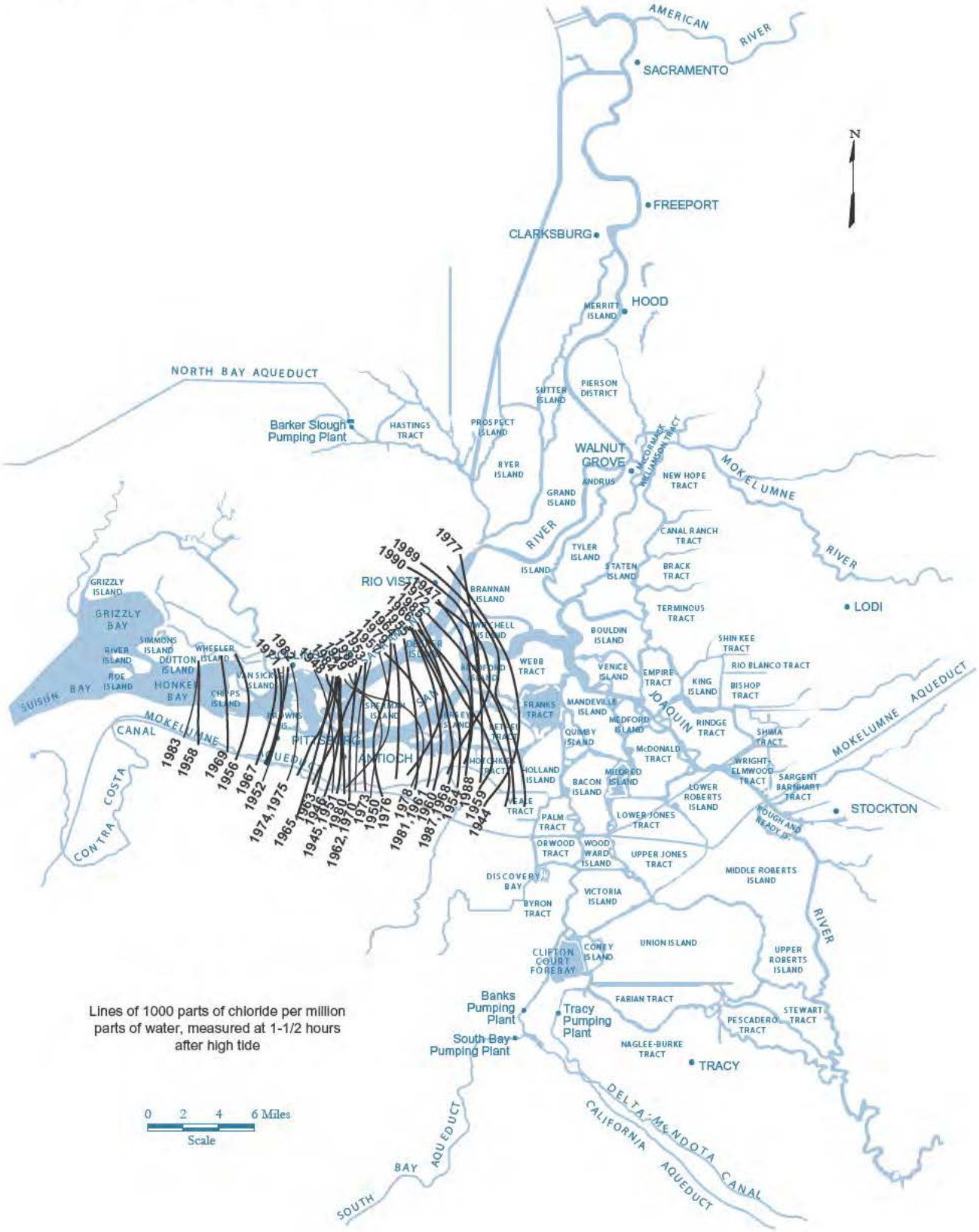
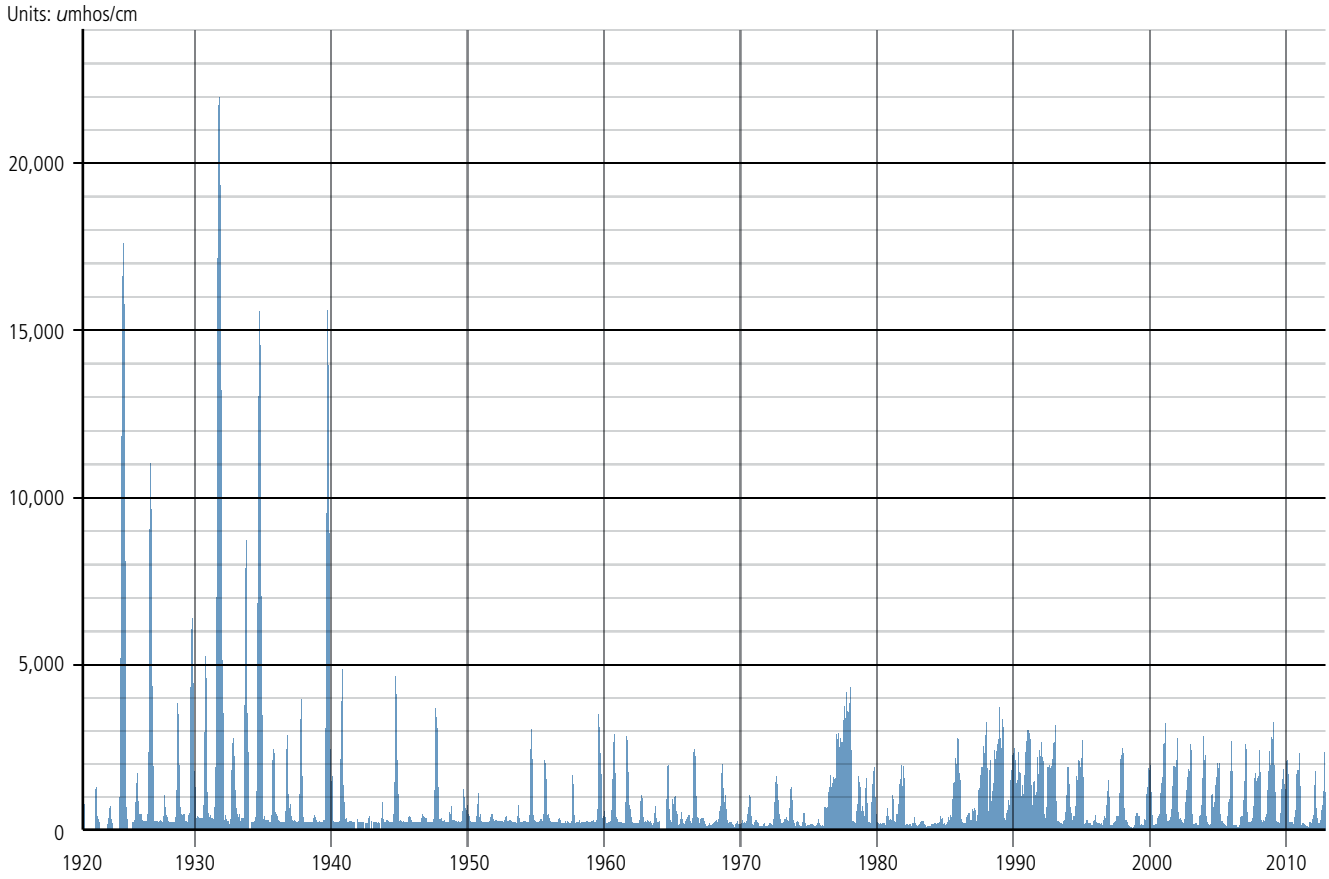


Figure 3.6: Historical Salinity (Modeled and Observed) at Jersey Point



Social conditions were the focus of attention for many during the Depression. This 1932 San Francisco scene shows jobless people living in pipes. Photo courtesy of San Francisco Public Library, San Francisco History Center.

Low flow conditions are shown in this December 1932 photo of construction of the H Street Bridge over the American River in Sacramento. Photo courtesy of Center for Sacramento History.

called water wars at Lake Tahoe may have been the most well-publicized, as lakeshore property owners (dominantly on the California side), took issue with downstream users of water in Nevada (see sidebar). Conversely, the lack of water management infrastructure to regulate streamflow during dry conditions also caused impacts, notably in terms of salinity intrusion in the Delta. Delta salinity levels fluctuated widely in response to hydrologic conditions prior to construction of the CVP and SWP. The projects now are required to meet salinity targets at specified Delta locations for protection of beneficial uses of water (e.g., in-Delta agricultural diversions or fishery needs), and variability in salinity levels has been greatly reduced. Figures 3.4 and 3.5, reproduced from DWR's Delta Atlas (DWR, 1993), show the contrast in upstream salinity intrusion under pre-project and post-project conditions. Figure 3.6 shows a long-term record of salinity measured at a single point in the western Delta to illustrate the range of numerical values observed.

Ending the Drought

The dry cycle of 1929-34 was followed by a water year that was near-average in terms of computed statewide runoff. The three-year period of water years 1935-37 was also in the near-average range in terms of statewide runoff. Subsequently, water year 1939 was one of the wettest in the measured record.

Conflict at Lake Tahoe

The upper portion of Lake Tahoe — more than 744 thousand acre-feet (TAF) of storage — is controlled by a small dam on the lake's natural outlet, constructed as part of USBR's Newlands Project to supply Nevada farms. During the dry conditions of the 1920s-30s, the lake dropped below its natural rim in the water years of 1924, and 1929–1935. Severely reduced flows for downstream irrigators (and for the private power company whose hydropower plants relied on the Truckee River to generate power for the Reno-Sparks area) led to conflicts between the downstream water users and lakeshore property owners. In 1924, a group of Truckee Meadows farmers threatened to dynamite the lake's natural rim to release more water into the Truckee River. In 1930, a group of Nevada interests sent a steam shovel with a Reno police guard to the power company's property adjacent to the dam to start digging a diversion trench to the rim, and it was feared by lakeshore property owners that they would try to dynamite the dam itself. The local sheriff's representatives formed a posse and sought to stop the digging. A court injunction was ultimately obtained by landowner interests and the diversion trench was backfilled. Arrangements were reached between landowner interests and downstream water users to allow lake water to be pumped over the natural rim in 1924, 1929-30, and 1934; amounts pumped were in the range of 25-34 TAF annually.

Lake Tahoe periodically falls below its natural rim during drought conditions, leaving USBR's dam on the lake's outlet to the Truckee River high and dry.

1976-77

The setting for the 1976-77 drought differed significantly from the dry times of the 1920s-30s. Although only a two-year event, its hydrology was severe. Based on 114 years of computed statewide runoff, 1977 occupies rank 114 (driest year) and 1976 is in rank 104. The drought was notable for the impacts experienced by water agencies that were unprepared for such conditions. One reason for the lack of preparedness was the perception of relatively ample water supplies in most areas of the state. The SWP's California Aqueduct had been completed less than ten years before, bringing a new source of water to parts of the San Joaquin Valley and Southern California. Likewise the state-federal joint-use facilities of the San Luis Canal brought new irrigation supplies for CVP contractors on the west side of the San Joaquin Valley. The imported water took some pressure off overdrafted groundwater basins in parts of the valley; growers and irrigation districts took many of their wells out of service with the advent of the new supplies. California was receiving more than its basic interstate apportionment of Colorado River water thanks to supplies unused by Nevada and Arizona and to hydrologic surpluses. There had not been major droughts in the recent past. (Although there had been multi-year dry periods of statewide scope in 1947-50 and 1959-61, the hydrology of these events was far less severe than that of the 1920s-30s.) The 1976-77 drought was a wake-up call for many water agencies.

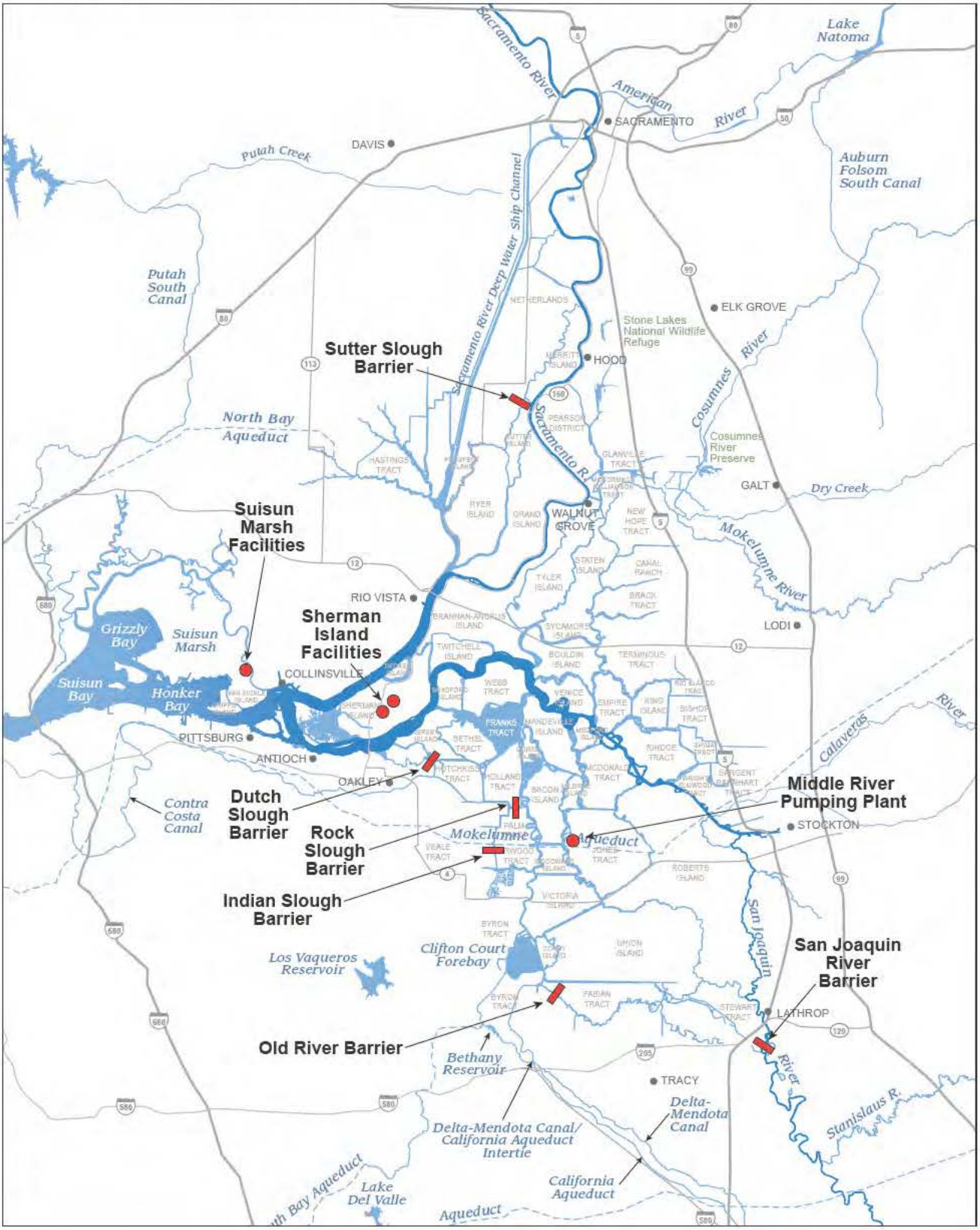
California's population in 1977 was about 22 million, not quite 60 percent of present levels. Irrigated acreage was essentially at present levels. Most of the state's major water infrastructure projects had now been constructed; the last major CVP reservoir (New Melones Lake) was under construction. There were no fish species listed pursuant to the ESA either migrating through or residing in the Delta; the striped bass index was being used by the then-Department of Fish and Game as a metric of Delta fishery conditions.

Water Supplies and Water Project Operations

The impacts of dry hydrology in 1976 were mitigated by reservoir storage and groundwater availability. The immediate succession of an even drier 1977, however, set the stage for widespread impacts. In 1977 CVP agricultural water contractors received 25 percent of their allocations, municipal contractors 25 to 50 percent, and the water rights or exchange contractors 75 percent. SWP agricultural contractors received 40 percent of their allocations and urban contractors 90 percent. Thanks to the availability of Colorado River water in excess of the state's basic interstate apportionment, MWD was able to reduce its use of SWP water, making more water from that source available for other project contractors.

Managing Delta salinity was a major challenge for the SWP, given the competing needs to preserve critical carry-over storage and to release water from storage to meet Bay-Delta water quality standards. (At this time the present-day Coordinated Operation Agreement between DWR and USBR was not in effect and USBR was not operating the CVP to protect Delta salinity.) In February 1977 SWRCB adopted an interim water quality control plan to modify Delta standards to allow the SWP to conserve storage in Lake Oroville. As extremely dry conditions continued that spring, SWRCB subsequently adopted an emergency regulation superseding its interim water quality control plan, temporarily eliminating most water quality standards and forbidding the SWP to export stored water. As a further measure to conserve reservoir storage, DWR constructed temporary facilities in the Delta to help manage salinity with physical, rather than hydraulic, approaches (Figure 3.7). These facilities included:

Figure 3.7: Temporary Salinity Management Facilities Installed in 1976-77



» a rock barrier at Sutter Slough to help meet water quality criteria and enable increased SWP pumping.

» a rock barrier at the head of Old River for improving fishery conditions (this barrier had been installed annually to improve conditions for migrating salmon; its use was not specific to drought years).

» rock barriers at Indian Slough and Rock Slough, along with a pumping plant on Middle River and temporary pipeline interconnection to one barrel of East Bay Municipal Utility District's Mokelumne Aqueduct, to move fresher water to the Contra Costa Canal intake.

» new diversions for Sherman Island agricultural water users.

» facilities to provide better water quality for duck clubs in the Suisun Marsh.

» rock barriers in Old River east of Clifton Court and in the San Joaquin River at Mossdale to protect South Delta agricultural water quality.

» a rock barrier on Dutch Slough in the West Delta to provide additional protection against salinity intrusion.

Special tidal cycle monitoring conducted by DWR found reverse flows due to tidal action occurring as far upstream on the Sacramento River as the mouth of the American River, an illustration of greatly reduced river inflows.

SWP and CVP contractors used water exchanges to respond to drought; one of the largest exchanges involved 435 TAF of SWP entitlement made available by MWD and three other SWP Southern California water contractors for use by San Joaquin Valley irrigators and urban agencies in the San Francisco Bay area. The MWD entitlement supplied water to Marin Municipal Water District via an emergency pipeline laid across the San Rafael Bridge and a complicated series of exchanges under which DWR delivered the water to the Bay Area via the South Bay Aqueduct. Public Law 95-18, the Emergency Drought Act of 1977, authorized USBR to purchase water from willing sellers on behalf of its contractors; USBR purchased about 46 TAF of water from sources including groundwater substitution and the SWP. USBR's ability to operate the program was facilitated by CVP water rights that broadly identified the project's service area as the place of use, allowing transfers within the place of use. Institutional constraints and water rights laws limited the transfer/exchange market at this time, and transfer activity outside of those exchanges arranged by DWR and the USBR's drought water bank was relatively small-scale.

An iconic image from the 1976-77 drought was the temporary emergency pipeline constructed across the San Rafael Bridge to bring imported water into southern Marin County.

Cloud Seeding Activities

Both DWR and USBR had active programs in 1977-78 in what was then termed "cloud seeding." DWR awarded a $127,000 contract in July 1977 for an aircraft-based summer seeding program in parts of the Sierra Nevada, intended to improve soil moisture conditions and to reduce wildfire risk. In December 1977, USBR awarded a contract for $289,000 for winter seeding in parts of the Cascade Range and northern Sierra Nevada, using both ground-based propane generators and aircraft. Three additional small contracts also were issued for monitoring and research or analysis associated with the winter seeding program. The winter seeding was terminated in February 1978 due to heavy precipitation. DWR was to again conduct a weather modification program during the 1987-92 drought, with a 1989 aerial seeding operation in the Feather River watershed and a demonstration ground-based propane generator project in the Middle Fork Feather River watershed in 1991.

Impacts

Depletion of reservoir storage was a major impact. Statewide storage in California's major reservoirs was 57 percent of average on October 1, 1976, and had dropped to 37 percent of average one year later. (Storage in the North Coast hydrologic region was only 15 percent of average at this time.) There was a major state-level policy drive for urban water conservation, beginning in the latter part of 1976. Widespread urban water conservation and mandatory rationing were hallmarks of the drought. Many communities achieved substantial savings, especially those where chronic water shortages (typically smaller communities outside major urban centers) led to cutbacks in water use of 50 percent or more. North and Central Coast communities had some of the highest conservation savings, due to local water shortages.

Marin County was the large urbanized area most affected by the drought, with most communities in the southern part of the county being limited to basic health and safety consumption levels. The area has limited groundwater resources and at the time had only local surface water sources. (Completion of Warm Springs Dam/Lake Sonoma in the Russian River watershed in the early 1980s subsequently provided a source of imported water.) Emergency response measures included the temporary pipeline to convey water exchanged from MWD's SWP entitlement, as well as state assistance with temporary storage tanks and connections for small water systems.

Outside of the Marin County problem, public water systems facing critical drinking water shortages were primarily small water systems in rural areas. State assistance was provided via loans or emergency response actions to support new wells, temporary storage tanks, temporary pipelines, interconnections, pumps and generators, and mobile treatment units. Some small systems were able to arrange temporary interconnections to other systems or to industrial users (e.g., timber mills). Water haulage was reported for small systems or for private residences on wells, especially throughout Northern California foothill areas and on the North Coast.

Reports at the time (U.S. Government Accountability Office, 1977) describe most of the drought's economic impacts as being associated with the agricultural and forestry sectors. Idling of irrigated cropland due to water shortage was reported as 125,000 acres in 1977 (DWR, 1978), with most of the idled acreage located in Fresno and Kern counties. The majority of the agricultural losses were ascribed to livestock production, with a geographic extent that covered most of the state. Agricultural production losses in 1977 were estimated at $566.5 million, composed of $414.5 million in livestock, $112 million in field crops, and

The city of Santa Barbara's Gibralter Reservoir on the Santa Ynez River during the 1976-77 drought. Reservoirs on the small Central Coast watersheds typically drop to low levels during droughts.

$40 million in fruit and nut crops. Timber production losses due to wildfire and insect damage were estimated at $517.5 million (DWR, 1978).

Institutional Actions

California was not alone in experiencing drought in 1976-77; dry conditions affected many western states. The Western Governors' Conference named a western regional drought action task force in 1977 and used that forum to coordinate state requests for federal assistance. Multi-state drought impacts led to increased appropriations for traditional federal financial assistance programs (e.g., USDA assistance programs for agricultural producers), and two drought-specific pieces of federal legislation. The Emergency Drought Act of 1977 authorized the Department of the Interior to take temporary emergency drought mitigation actions and appropriated $100 million for activities to assist irrigated agriculture, including USBR's water transfers programs. The Community Emergency Drought Relief Act of 1977 authorized $225 million for the Economic Development Agency's drought program, of which $175 million was appropriated ($109 million for loans and $66 million for grants) to assist communities with populations of 10,000 or more, tribes, and special districts with urban water supply actions. Projects in California received 41 percent of the funding appropriated pursuant to this act.

Within California, the Governor signed an executive order naming a drought emergency task force in 1977. Numerous legislative proposals regarding drought were introduced, about one-third of which became law. These measures included:

» authorization of a loan program for emergency water supply facilities

» authorization of funds for temporary emergency barriers in the Delta (the barriers were ultimately funded by the federal Emergency Drought Act instead)

» prohibition of public agencies' use of potable water to irrigate greenbelt areas if SWRCB found that recycled water was available

» authorization for water retailers to adopt conservation plans

» addition of drought to the definition of emergency in the California Emergency Services Act.

In contrast to the present-day approach of using state general obligation bond measures to provide grants to local agencies, state-financed local assistance programs of this time period were primarily based on loans. Two bond-funded programs related to water supply were in effect at this time – the Davis-Grunsky Act of 1960, which provided loans for local water supply projects, and a 1976 measure to provide loans for compliance with Safe Drinking Water Act requirements. Neither of these measures was drought-related, but they represented a potential source of assistance for local agency projects.

Water management issues highlighted by drought conditions – such as constraints on water transfers, potential forfeiture of water rights associated with conservation programs, or impacts resulting from over-extraction of groundwater — led to the Governor's appointment of a Commission to Review California Water Rights Law in 1977. The Commission released its final report to the Governor in 1978, identifying many statutory changes that could be made and recommending proposed legislative language. (Some of these recommendations were later addressed during the 1987-92 drought, particularly those related to water transfers and to conservation programs.)

The SWRCB was actively engaged in water rights administration during the drought, notifying diverters in Central Valley and Delta locations in 1977 that junior appropriators would be required to cease diverting as of specified dates, and that natural streamflows would be unavailable for riparian rights and pre-1914 appropriators in some areas after specified dates. SWRCB conducted field inspections of Sacramento Valley diversions in 1977 to monitor compliance with its curtailment orders, with assistance from DWR staff. DWR carried out Sacramento Valley land- and water-use studies in 1976-77 to quantify how the extremely dry conditions affected water use and diversion patterns. One finding of this effort was that for the first time in 30 years of DWR water-use studies, the Sacramento River appeared to have a net loss of water to the groundwater basin.

Ending the Drought

The record dry water year 1977 was followed by a year ranked in the top quarter of the record for statewide runoff.

1987-92

The six-year event of 1987-92 was California's first extended dry period since the 1920s-1930s, and the closest analog to extended drought conditions under a modern level of development. All six years were dry, with four of them ranking in the top ten percent in terms of driest statewide runoff. Water year 1991 was the driest year of this drought, ranking in fifth place in the statewide runoff record, behind 1977, 1931, 1924 and 2014.

USBR's 240 TAF Twitchell Reservoir on the Cuyama River in San Luis Obispo County in 1990. The reservoir provides supplemental irrigation supplies for Santa Maria Valley.

California's population in 1990 was about 30 million, close to 80 percent of present levels. Irrigated acreage was essentially at present levels. Delta regulatory constraints affecting CVP and SWP operations were based on SWRCB water right decision D-1485, which had taken effect in 1978 immediately following the 1976-77 drought. In 1992, NMFS issued its first Biological Opinion for the Sacramento River winter-run Chinook salmon, which had been listed as threatened pursuant to the ESA in 1989. The Central Valley Project Improvement Act of 1992 (CVPIA) was enacted just at the end of the drought, so provisions reallocating project yield for environmental purposes were not in effect for 1992 water operations. California was continuing to receive more than its basic interstate apportionment of Colorado River water thanks to the unused apportionment of Nevada and Arizona and to hydrologic surpluses. Access to Colorado River water above the basic apportionment helped mitigate impacts of SWP cutbacks in MWD's urban Southern California service area.

Water Supplies and Water Project Operations

Water users served by most of the state's larger suppliers did not begin to experience shortages until the third or fourth years of the drought due to deliveries from reservoir storage. Statewide reservoir storage was down to about 40 percent of average by the third year of the drought, and did not return to average conditions until 1994, thanks to a wet 1993.

The CVP and SWP met delivery requests during the first four years of the drought, but were then forced by declining reservoir storage to cut back deliveries substantially. In 1991 the SWP terminated deliveries to agricultural contractors and provided 30 percent of requested urban deliveries. The CVP delivered 25 percent to agricultural contractors and 25 to 50 percent to urban contractors.

In addition to D-1485 requirements on SWP and CVP operations in the Delta, other operational constraints included temperature standards imposed by the SWRCB through Orders WR 90-5 and 91-01 for portions of the Sacramento and Trinity Rivers. On the Sacramento River below Keswick Dam, these orders included a daily average water temperature objective of 56° F during periods when high temperatures could be detrimental to survival of salmon eggs and pre-emergent fry. As part of managing salinity during the drought, DWR installed temporary barriers at two South Delta locations – Middle River and Old River near the Delta-Mendota Canal intake — to improve water levels and water quality/water circulation for agricultural diverters. (In contrast to the 1976-77 drought, the Coordinated Operation Agreement of 1982 was now in effect between DWR and USBR with respect to project operations to meet Delta regulatory requirements.)

In response to Executive Order W-3-91 in 1991, DWR developed a drought water bank that operated in 1991 and 1992. The bank bought water from willing sellers and made it available for purchase to agencies with critical water needs. Critical water needs were understood to be basic domestic use, health and safety, fire protection, and irrigation of permanent plantings. DWR purchased 821 TAF of water for the bank in 1991, from land fallowing (about 50 percent), groundwater substitution (30 percent), and reservoir storage (20 percent). The 821 TAF purchased yielded a net amount of 656 TAF after accounting for Delta carriage water and instream flow requirements; 307 TAF of this amount went to urban uses, 83 TAF went to agricultural uses, and DWR purchased the remaining 266 TAF for SWP carry-over storage when needs of other buyers were satisfied. Building on lessons learned from the 1991 bank, DWR purchased 193 TAF for the 1992 bank, obtained from groundwater substitution (80 percent) and reservoir storage (20 percent). Additionally, the Department of Fish and Game operated a purchasing program in parallel with the drought water bank, acquiring 75 TAF for fish and wildlife purposes (primarily for refuge water supply) with state emergency drought relief funding. DWR monitored impacts in areas of groundwater substitution transfers to respond to concerns expressed by local water users and residents regarding third-party impacts.

Just as the Marin County emergency pipeline over the San Rafael Bridge was an iconic image of the 1976-77 drought, Santa Barbara's temporary emergency desalination project was emblematic of the 1987-92 drought.

Impacts

Effects of long-term dry conditions on reservoir storage were a concern, just as they were in 1976-77. Among the state's largest urban areas, the City of San Francisco's system experienced the greatest impacts with only about 25 percent of total storage capacity remaining in 1991, a circumstance leading to

its construction of two turnouts on the California Aqueduct to provide access to water transfer. The small reservoirs of USBR's Central Coast projects were another area of impact. The Santa Barbara area experienced the largest water supply reductions of California's larger municipalities; its limited groundwater and local surface supply (USBR's Cachuma Project) were unable to support residents' needs. (Although Santa Barbara had earlier contracted for SWP water supply, it had not at the time proceeded with construction of facilities to take delivery of its allocation and thus did not have access to imported water.) The Governor declared a state of emergency in the City and County of Santa Barbara in 1990. The city was forced to adopt emergency measures that included a 14-month ban on lawn watering. Multi-agency water transfer and exchange agreements were used to make an emergency SWP water supply available to Southern Santa Barbara County via construction of a 16-inch pipeline between Ventura and Oxnard. Santa Barbara contracted for installation of a portable seawater desalination plant that was briefly operated in 1991.

This drought's extended duration resulted in widespread problems for small water systems in rural areas dependent on unreliable water supplies. Likewise, there were widespread reports of dry private residential wells. Some communities were able to construct temporary pipelines to new surface water sources (e.g., Markleeville, Willits). Water haulage was a common emergency response, particularly in Northern California's foothill areas, the North Coast, and the Russian River corridor. Areas relying on fractured rock groundwater sources or shallow coastal terrace groundwater basins (such as along the Central Coast) experienced many of the reported problems. In the town of Mendocino, for example, much of the water supply is provided by private residential wells. It was estimated that ten percent of the town's wells go dry every year, a proportion that increased to 40 percent during drought.

In the agricultural sector, estimated drought-idled acreage was on the order of 500,000 acres, representing about five percent of 1988-level harvested acreage. Some agricultural water districts experienced financial problems due to reduced revenues from water sales but ongoing fixed costs for water. Financial problems experienced by Kern County Water Agency's member districts, for example, together with concerns about SWP water allocation rules, were an impetus for subsequent negotiation of the Monterey Amendments between DWR and its SWP contractors. When executed in 1994 the Monterey amendments provided that an equal annual allocation would be made to urban and agricultural contractors. The prior provisions in effect during the 1987-92 drought called for agricultural contractors to take a greater reduction in their allocations during shortages than urban contractors, which had resulted in the zero allocation to the agricultural contractors in 1991. Statewide, estimated gross revenue loss to farms was about $220 million in 1990 and $250 million in 1991 (DWR, 1994). The hardest hit commodities were grains, non-irrigated hay, and beef cattle. Geographically, impacts were greatest on the west side of the San Joaquin Valley.

DWR interviewed more than 60 entities associated with urban water uses to identify drought impacts to commercial and industrial water users. In administering their voluntary and mandatory water conservation programs, local urban water suppliers generally minimized cuts to commercial and industrial users in the interests of avoiding potential job losses, shifting the burden of water use reductions to residential customers. DWR's survey found only one sector within commercial and industrial users that had been impacted, the lawn and landscaping industry (also known as the green industry).

Cutbacks in residential and institutional (e.g., parks, schools) landscaping and landscape maintenance were estimated to result in a loss of $460 million in gross revenues and 5,600 full-time jobs in the green industry in 1991 (DWR, 1994).

Widespread damage to timber resources was reported throughout the Sierra Nevada due to bark beetle infestation. The drought's prolonged duration set the stage for a pattern that would emerge in future extended dry periods – the linkage between severe drought conditions and risk of major wildfire damage in densely populated urban areas located at the wildland-urban interface. The October 1991 Oakland Hills fire was the then-largest dollar fire loss event in U.S. history; 25 lives were lost and more than 3,000 structures were destroyed (FEMA, 1991). Lessons learned from this fire led to formation of the California Water/Wastewater Agency Response Network to promote emergency preparedness, disaster response, and mutual assistance processes for water and wastewater utilities.

Institutional Actions

Governor's Executive Order W-3-91 established an Interagency Drought Action Team chaired by DWR to coordinate state response to the drought. Among other things, the order authorized DWR to implement the drought water bank. Facilitating water transfers and banking was a focus of state action during the 1987-92 drought, including in an extraordinary session of the Legislature held in 1991-92. Enacted legislation included:

» Technical and clarifying changes were made to Water Code provisions governing temporary and long-term water transfers, including explicit authorization of groundwater substitution transfers

Most homes were unrecognizable after the 1991 Oakland Hills fire, even if some evidence of the home remained after the blaze swept through the Oakland/Berkeley area. Photo: California Office of Emergency Services

and exemption of leases of water for up to five years from SWRCB jurisdiction.

» Use of potable water for specified non-potable purposes was declared to be a waste or unreasonable use of water if suitable, cost-effective reclaimed water supplies were available.

» DWR was directed to draft and adopt a model water efficient landscape ordinance by July 1992; local agencies not adopting their own ordinances by January 1993 were required to begin enforcement of the model ordinance.

» Water purveyors were required to meter new connections effective January 1992.

» A statewide goal of recycling 1 MAF of water by 2010 was set.

» Existing requirements for urban water management plans (UWMPs) were amended to require that water suppliers estimate available supplies at the end of one, two, and three years, and develop contingency plans for shortages of up to 50 percent.

Ending the Drought

Water year 1992 was followed by a wet 1993, a year ranking in the top 20 percent with respect to statewide runoff.

Urban water suppliers are increasingly focusing on reducing outdoor water use both to respond to drought and to achieve long-term cutbacks in per capita water use. Increased demand for low-water-use plants has spurred development of new cultivars for residential landscaping. Photos courtesy of Mountain States Wholesale Nursery.

4

Comparison of Recent Conditions to Past Droughts and Lessons Learned

This chapter briefly compares California's two most recent droughts – the 2007-09 drought and the 2012-14 period — with the state's largest historical droughts, and discusses changed conditions since the 1987-92 drought. The state's population of about 36.6 million in 2007 has increased to more than 38 million, in comparison to the roughly 30 million during the 1987-92 drought. Important aspects of the state's water management setting have changed fairly significantly in the two-plus decades since the state's last major statewide drought.

Lessons learned from, or commonalities of, experiences during the large historical droughts are reviewed to highlight gaps in information or tools for water-sector drought response and preparedness. The Appendix contains copies of state executive orders and statewide emergency proclamations from historical and recent droughts, to illustrate typical response actions.

DROUGHTS OF 2007-09 AND 2012-14

Water years 2007-2009 were the seventh driest three-year period in the measured record for statewide precipitation and the 15th driest three-year period for DWR's 8-station precipitation index, which is a rough indicator of potential water supply availability to the SWP and CVP. Water year 2007 was the driest single year of that drought; it fell within the top 20 percent of dry years based on computed statewide runoff. Water years 2007-09 marked a period of then-unprecedented restrictions in CVP and SWP diversions from the Delta to protect listed fish species, a regulatory circumstance that exacerbated the impacts of hydrologic drought. A dry 2008 combined with water project Delta export restrictions led to issuance of Executive Order S-06-08 and a state emergency proclamation for selected Central Valley counties in June 2008. A Biological Opinion for Delta smelt issued in December 2008 called for measures that would substantially reduce the water projects' Delta diversions, and the opinion combined with low January 2009 precipitation and statewide reservoir storage at about 65 percent of average led to a February 2009 proclamation of statewide emergency due to water shortage. The 2007-09 drought was the first for which a statewide proclamation of emergency was issued. It was also the first drought (excluding that of the Dustbowl period) during which locally significant impacts due to economic recession

and drought resulted in emergency response actions related to social services (food banks and unemployment assistance). The drought's greatest impacts were observed in the CVP service area on the west side of the San Joaquin Valley; Figure 4.1 shows the spatial extent of idled summer cropland.

Water years 2012-14 were the driest three-year period in the measured record of statewide precipitation but only the 12th driest three-year period for the 8-station precipitation index, reflecting the dominance of drier conditions in the southern part of the state. Low water project allocations for San Joaquin Valley agriculture led to issuance of Executive Order B-21-13 in 2013; subsequently, the record dry conditions in December 2013 - January 2014 triggered a statewide proclamation of emergency in January 2014 which was followed by a second proclamation in April. CVP and SWP allocations were at record lows in 2014, as illustrated in Table 4.1 which compares allocations during the recent droughts with those of the large historical events.

Changes in Institutional Setting

The institutional setting for water management has changed greatly since the 1987-92 drought. Some of the most obvious changes have affected management of the state's largest water projects, such as the CVP, SWP, Los Angeles Aqueduct, or Colorado River system, as described below. New listings and management of fish populations pursuant to the ESA have impacted operations of many of the state's water projects, including the large projects affected by listing of Central Valley fish species as well as smaller projects on coastal rivers where coho salmon populations have been listed. During the 2007-09 drought, for example, urban water users in the Russian River service area were ordered by SWRCB to plan for water conservation targets of 25 to 50 percent due to the combined impacts of drought and multi-agency regulatory requirements for fish protection.

Other changes include the substantial increase in state financial assistance made available since the mid-1990s to local agencies for a variety of water

Figure 4.1A: Landsat Image of the San Joaquin Valley in Summer 2006

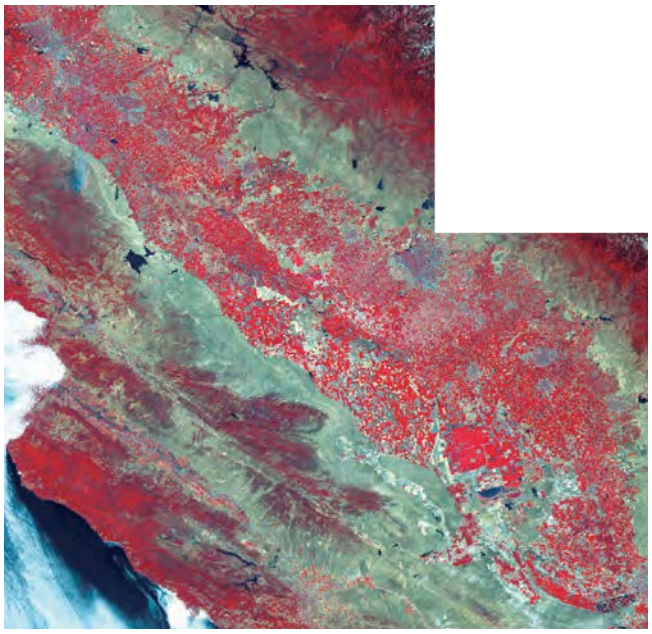
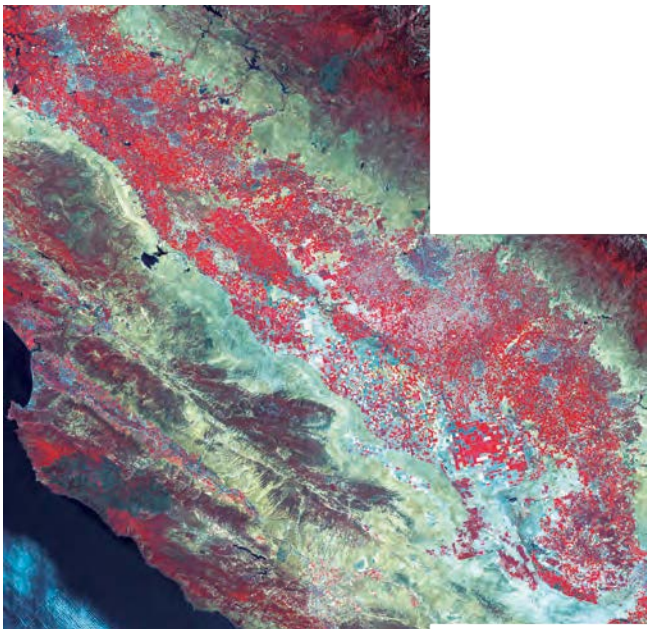


Figure 4.1B: Landsat Image of the San Joaquin Valley in Summer 2008



USGS Landsat Image. False-color infrared, irrigated areas in red.

Table 4.1: CVP and SWP Allocations in Selected Drought Years
(allocations in percent)

	1991	2009	2014
SWP	30/0*	40	5
SWP water rights contractors	50	100	100
CVP north of Delta agricultural contractors	25	40	0
CVP south of Delta agricultural contractors	25	10	0
CVP Friant Division, Class 1	100	100	0
CVP water rights settlement contractors	75	100	75
CVP San Joaquin exchange contractors	75	100	65

*30 percent to urban contractors and zero to agricultural contractors

management objectives, especially assistance in the form of grants rather than loans. Actions funded through some of these programs help improve water supply reliability during dry conditions.

Water Project Operations

The present regulatory framework for CVP and SWP operations is distinctly different from that of 1987-92. The first Biological Opinion for the then-threatened winter-run Chinook salmon was issued just at the end of the drought; in 1994 winter-run were reclassified as endangered. A significant provision of the initial 1992 Biological Opinion for winter-run salmon, and also of subsequent opinions, was a requirement to provide additional cold water in Sacramento River spawning areas downstream of Shasta Dam, resulting in increased late-season reservoir storage. Delta smelt were listed as threatened in 1993. Subsequently, other fish species listed pursuant to the federal ESA or the California ESA included the longfin smelt, Central Valley spring-run Chinook salmon, Central Valley steelhead, and green sturgeon.

The Biological Opinions for these species, together with changes in SWRCB Bay-Delta requirements, represent a major difference between 1987-92, when SWRCB's Water Rights Decision D-1485 governed the projects' Delta operations, and the present. SWRCB's Water Rights Decision D-1641 reduced water project exports in order to provide more water for Delta outflow. Requirements of the most recent USFWS and NMFS Biological Opinions for listed fish species modify D-1641 requirements, further reducing the water projects' delivery capabilities by imposing greater pumping curtailments and Delta outflow requirements. Additionally, the CVPIA mandate to reallocate 800 TAF of CVP yield for environmental purposes and to provide a base water supply for wildlife refuges was not in effect for 1987-92 water operations.

Figures 4.2 and 4.3 give a long-term perspective on CVP and SWP water supply availability; the projects' delivery capabilities over time are influenced by increases in service area demands and by regulatory requirements. Both projects have over time changed the manner in which they report allocation amounts; USBR has significantly expanded the number of categories it uses for making allocations. To simplify data presentation for the CVP figure, only allocations to project agricultural contractors, as USBR uses that term, are presented; USBR's south-of-Delta agricultural water contractors typically receive the smallest percentage allocation of the federal

Figure 4.2: Historical Central Valley Project Allocations to Agricultural Contractors

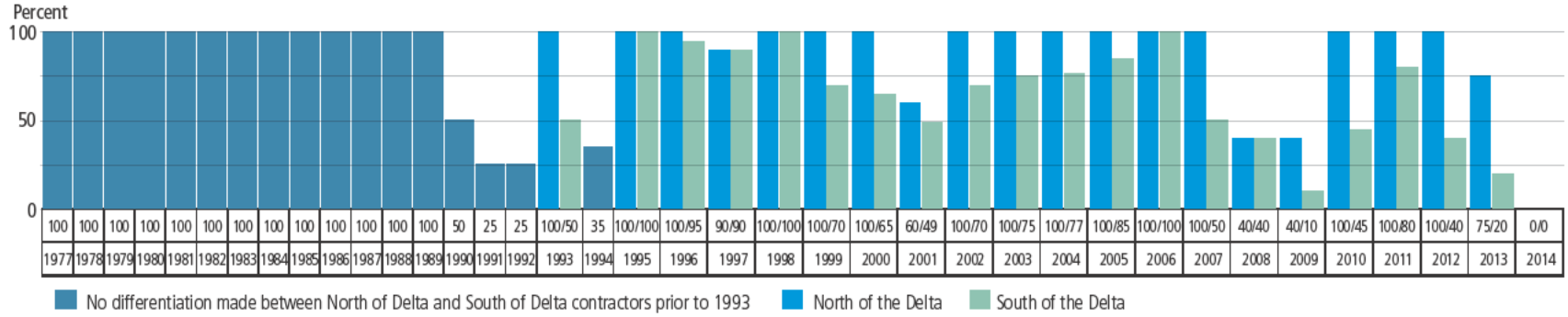
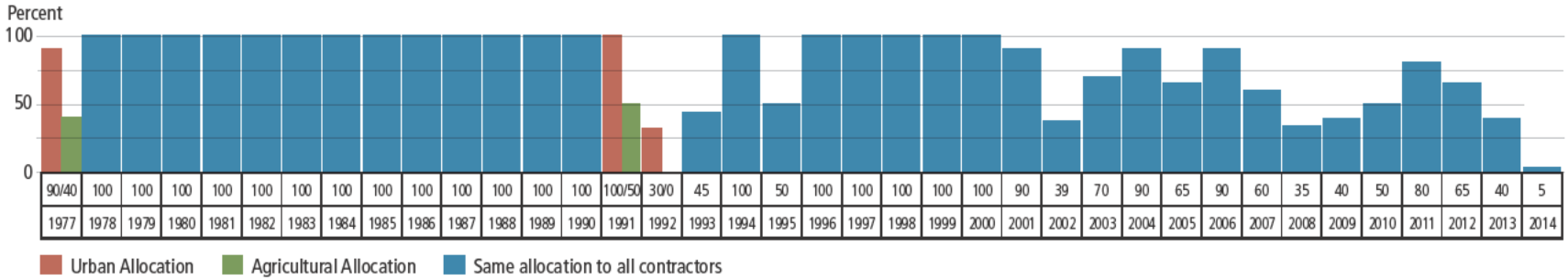


Figure 4.3: Historical State Water Project Allocations to Project Contractors



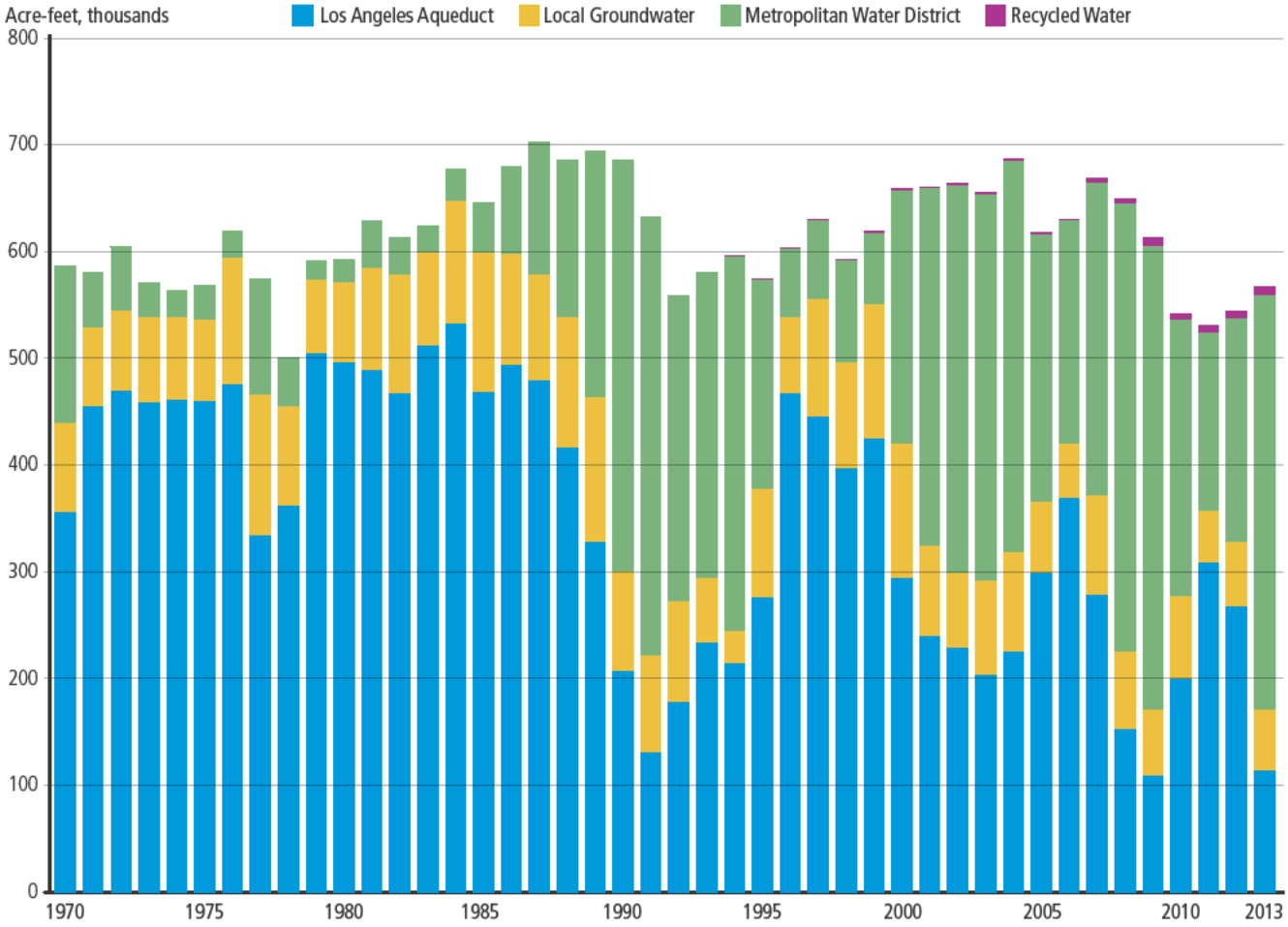
Prior to 1994, differential allocations could be made for urban and agricultural contractors. The few years for which separate allocations were made are highlighted in contrasting colors.

water recipients.

All three of the sources of imported water supply for Southern California have been affected by changing institutional conditions – SWP supplies as described previously, Los Angeles Aqueduct supplies by requirements such as dust control for Owens Lake, and Colorado River supplies by increased water use in Arizona and Nevada. Figure 4.4 shows the trend in supplies used by the City of Los Angeles, illustrating how the city has increased its purchases of water from MWD when its Los Angeles Aqueduct supplies were reduced.

During earlier droughts California was able to rely on water from the Colorado River in excess of the state's basic interstate apportionment — Lower Basin water that was either hydrologically surplus or unused apportionment of Nevada or Arizona. This additional supply helped protect the MWD service area against shortages and allowed MWD to participate in exchange agreements to assist other agencies experiencing critical shortages. Drought in the Colorado River Basin and increasing water usage by the other states brought this era of additional supplies to a close, and California was reduced to its basic interstate apportionment of 4.4 MAF annually of consumptive use in 2003, the year in which the Quantification Settlement Agreement was signed. Other long-term agreements put in place around this time covered the Imperial Irrigation District - San Diego County Water Authority water transfer and

Figure 4.4: Sources of City of Los Angeles Water Supply



Data courtesy of Los Angeles Department of Water and Power

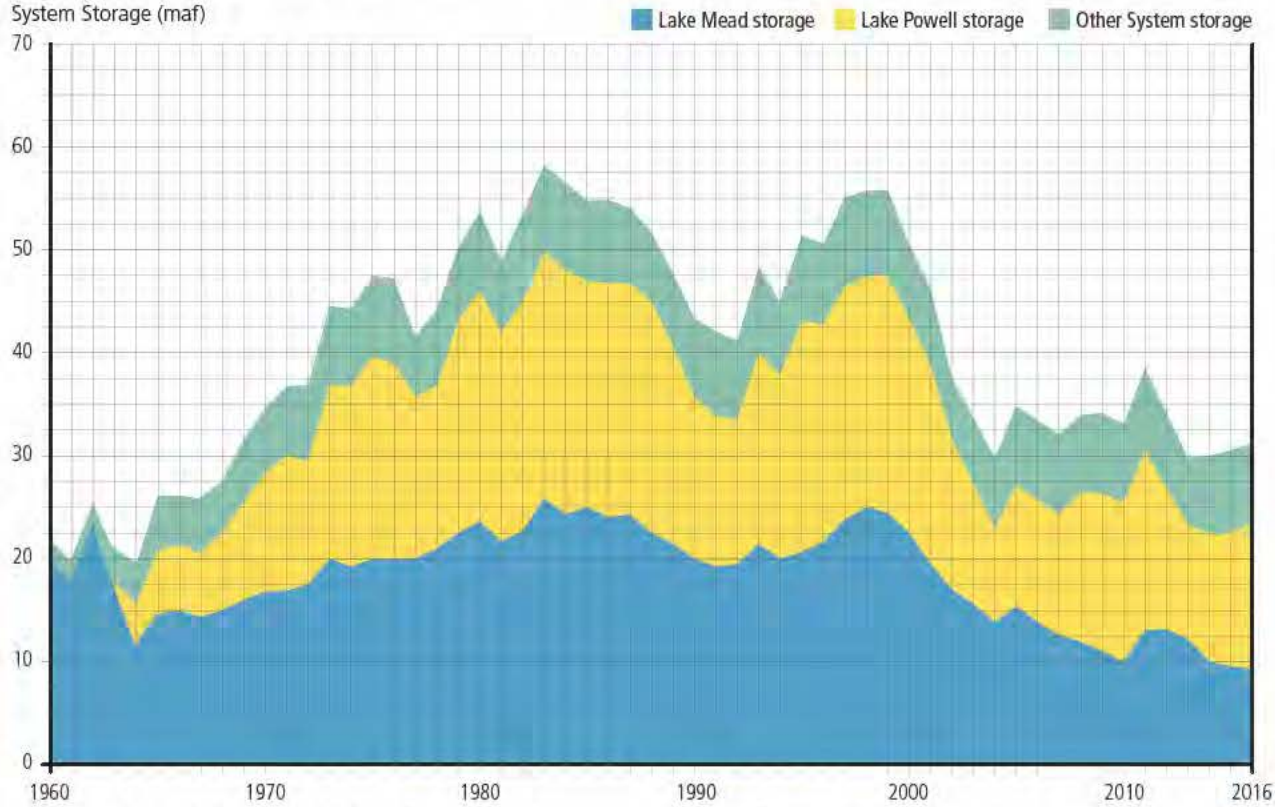
the 2004 Palo Verde Irrigation District – MWD land management/water supply program, both of which provided early water right priority supplies to urbanized coastal Southern California to help offset MWD's loss of the surplus water.

Ongoing dry conditions in the Colorado River Basin and declining reservoir storage (Figure 4.5) subsequently led USBR and the Basin States to examine measures to reduce the risk of future Lower Basin shortages. In 2007, USBR adopted interim guidelines for Lower Basin shortages and coordinated operations for Lake Mead and Lake Powell (USBR, 2007) that will remain in effect through 2025 for reservoir operations during 2026; implementation of the guidelines is expected to reduce the frequency and severity of potential future shortages. The guidelines define the circumstances under which USBR would reduce the annual amount of water available for consumptive use in the Lower Basin States below 7.5 MAF (i.e., define circumstances triggering shortage). As provided for in the guidelines, reductions in Lower Basin deliveries triggered by specified Lake Mead elevations occur first for Arizona and Nevada before California is affected. The guidelines also allow for storage and delivery of conserved Colorado River system water and non-system water in Lake Mead, to provide water contractors with tools to help manage shortage.

State Financial Support

After the 1987-92 drought, the state's voters approved major water bonds providing grant funding for actions such as improving water supply reliability, reducing flood risk, implementing conservation measures, or restoring fish and wildlife habitat. These bond measures were:

Figure 4.5: Colorado River Total System Storage



Storage data for WY 2015 and WY 2016 are based on projections from the October 2014 24-Month Study. Data courtesy of USBR.

Trees in avocado orchards in San Diego and Riverside counties were stumped or removed in response to the 2007-09 drought. This drought and the 2012-14 event highlighted the vulnerability of capital-intensive permanent plantings to unreliable or unaffordable water supplies.

- Proposition 204 in 1996 for $995 million
- Proposition 13 in 2000 for $2.1 billion
- Proposition 50 in 2002 for $3.44 billion
- Proposition 84 in 2006 for $5.388 billion
- Proposition 1E in 2006 for $4.09 billion
- Proposition 1 in 2014 for $7.12 billion

One feature of recent bond measures has been dedication of funding for local agency integrated regional management (IRWM) planning and plan implementation. IRWM planning encourages local agencies to develop multi-objective, multi-beneficiary projects that could, as an example, link regional projects for improved stormwater capture with goals to increase groundwater storage.

Expediting processing of bond-funded grants and targeting grants to provide drought response benefits were approaches used in both 2007-09 and 2012-14. Executive Order S-06-08 in 2008 directed DWR to expedite grant programs for new or ongoing water conservation and water use reduction programs, and for projects capable of timely implementation to ease drought conditions in 2008 or 2009. The March 2014 emergency drought relief legislation authorized $549 million from Proposition 84 and Proposition 1E IRWM funds for grants for projects already planned or partially completed to increase local reliability, including: recapturing storm water, expanding use of recycled water, enhancing groundwater management/storage, and strengthening water conservation. Table 4.2 shows awarded projects for this grant solicitation to illustrate types of projects proposed by local agencies.

Changes in Major Water Infrastructure

Two large water supply reservoirs were constructed since 1987-92 – MWD's 800 TAF Diamond Valley Lake and Contra Costa Water District's Los Vaqueros Reservoir (initially constructed at 100 TAF and later expanded to 160 TAF). Both reservoirs are offstream storage reservoirs with a common purpose of providing emergency water supplies in or near the agencies' service areas in an event that an earthquake or other disruption would make imported supplies unavailable. Half of the capacity of Diamond Valley is reserved for emergency purposes; the remainder can be used to buffer impacts of drought, as has occurred in 2012-2014.

Table 4.2: 2014 Grant Solicitations for Drought-Related Actions - Awarded Projects

Funding Area/IRWM Region/Project Name	Applicant Name/Implementing Agency of Project
Tulare-Kern	
Kern County	Buena Vista Water Storage District
Brackish Groundwater Recovery Project	Buena Vista Water Storage District
CVC Extension Lining Project (Phase 1-Pool No. 7)	Kern County Water Agency Imp. District No. 4
In-Lieu Program	Arvin-Edison WSD
Water Main Replacement and Meter Installation Project	Buttonwillow Improvement District
Kaweah River Basin	Kaweah Delta Water Conservation District
Visalia Water Conservation Program Project	CA Water Service Company
Well 15 Water Quality Protection Project	City of Lindsay
San Joaquin	
Merced	Merced Irrigation District
Cressey Recharge Basin Enlargement Project	Merced Irrigation District
Highlands Groundwater Conservation Project	Merced Irrigation District
Water Meter Conservation Project	Le Grand Community Services District
Mokelumne/Amador/Calaveras	Upper Mokelumne River Watershed Authority
Ione WTP Backwash Water Reuse Project	Amador Water Agency
Upper Amador Canal Untreated Pipeline Project	Amador Water Agency
Tuolumne-Stanislaus	Tuolumne Stanislaus Integrated Regional Water Management Authority
GCSD Water Filtration System	Groveland Community Services District
TCRCD Regional Water Conservation Program	Tuolumne County RCD
THCSD Shadybrook Well Project	Twain Harte Community Services District
TUD Matelot Reservoir	Tuolumne Utilities District
TUD Phoenix Lake Preservation and Restoration - Phase 3	Tuolumne Utilities District
Cosumnes American Bear Yuba[1]	Nevada Irrigation District
Grizzly Flats Drought Measures Infrastructure Project	Grizzly Flats Community Services District
Westside – San Joaquin	San Luis and Delta Mendota Water Authority
Agricultural Drainage Recirculation & Intertie Expansion	Patterson ID
Kaljian Pumping Plant and Conveyance System	San Luis Water District
Non-Potable Water System, Phase III	City of Patterson
North Valley Regional Recycled Program	City of Modesto
Turf Removal Project	City of Patterson
Central Coast	
San Luis Obispo	San Luis Obispo County Flood Control and Water Conservation District
Intertie between CSA 23 and Atascadero Mutual Water Company and Garden Farms CSD	San Luis Obispo County Public Works
Cambria Community Service District Emergency Water Supply	Cambria Community Services District
Heritage Ranch Community Services District Emergency Water Turnout	Heritage Ranch Community Services District
Nacimiento-Salinas-California Men's Colony Water Treatment Plant Emergency Intertie	San Luis Obispo County FC&WCD
San Simeon Community Services District Small Scale Recycled Water Project	San Simeon Community Services District
Pajaro River Watershed	Pajaro Valley Water Management Agency
Corralitos Creek Water Supply and Fisheries Enhancement	City of Watsonville
Delivered Water Enhancement and Drought Response Irrigation Program	Pajaro Valley Water Management Agency
Expanded Recycled Water Use Project	San Benito County FC&WCD
South County Recycled Water Improvements	Santa Clara Valley Water District
Santa Barbara Countywide	Santa Barbara County Water Agency
City of Santa Barbara Recycled Water Enhancement Project	City of Santa Barbara
Lake Cachuma Drought Pumping Facility Project	Cachuma Operation and Maintenance Board
Sacramento River	
Upper Sacramento-McCloud	City of Mt. Shasta
City of Mt. Shasta Supply Line Replacement	City of Mt. Shasta
City of Mt. Shasta Water Meter Installation	City of Mt. Shasta
American River Basin	Regional Water Authority
Project 1: Lower American River Pipeline	Carmichael Water District
Project 2: Hazel/50 Intertie Improvements	City of Folsom
Project 3: Well #2 Reactivation	City of Lincoln
Project 4: Nelson Well Improvements	City of Lincoln
American River Basin, continued	Regional Water Authority, continued
Project 5: PFE and Zone 4 Transfer Pump Stations	City of Roseville
Project 6: Phase 2B Well Rehabilitations	City of Sacramento
Project 7: Sacramento River Pump Station Modifications	City of Sacramento
Project 8: Lower American River Pump Station Modifications	City of Sacramento
Project 9: Main Ditch Piping	El Dorado Irrigation District
Project 10: Madison Well Construction	Fair Oaks Water District
Project 11: American River Pump Station Improvements	Placer County Water Agency
Project 12: Agricultural and Rural Residential Drought Response Incentives Program	Placer County Water Agency
Project 13: Regional Water Efficiency Drought Measures	Regional Water Authority
Project 14: Striker Well Upgrades	Sacramento County Water Agency
Project 15: Antelope Booster Pump Station Phase 2	Sacramento Suburban Water District
Project 16: Enterprise Intertie Improvements	Sacramento Suburban Water District
Project 17: Barton Road Intertie	San Juan Water District
Westside (Yolo, Solano, Napa, Lake, Colusa)	Yolo County Flood Control and Water Conservation District
Mt. Hannah Pipeline Water Loss Minimization Project	Lake County Special Districts
Paradise Valley Water System Intertie and Consolidation	Lake County Special Districts
Spring Valley Pipeline Water Loss Minimization Project	Lake County Special Districts
Woodland Recycled Water Project	City of Woodland
YCFCWCD-Regional Drought Preparedness Canal Modernization Project	Yolo County FC&WCD
Cosumnes American Bear Yuba[1]	Nevada Irrigation District
City of Placerville Waterline Replacement - Chamberlain/Sacramento Street Area	City of Placerville
El Dorado County Water Conservation Planning - Model Implementation and Education Programs	El Dorado County Water Agency
Georgetown Divide PUD Water Conservation, Supply Reliability and Environmental Protection Project	Georgetown Divide Public Utility District
Greeley Canal Drought Measures Optimization	Placer County Water Agency
Rock Creek Water Contingency Intertie	Nevada Irrigation District
Upper Pit River Watershed	North Cal-Neva Resource Conservation and Development Council, Inc.
Ash Valley Ranch Irrigation Infrastructure Efficiency Project	North Cal-Neva RC&CD, Inc.
Restoring Hydrologic Function on Ash Valley Ranch	North Cal-Neva RC&CD, Inc.
South Fork Irrigation District Infrastructure Upgrade	North Cal-Neva RC&CD, Inc.
North Sacramento Valley Group	Shasta County Department of Public Works
Anderson-Cottonwood Irrigation District Main Canal Lining Project	Anderson-Cottonwood Irrigation District
City of Shasta Lake Water Supply Enhancement Project	Shasta Lake City of
Rio Alto Water District Wastewater Treatment Improvements and Constructed Wetlands	Rio Alto Water District
Water Supply Reliability Well Project	City of Live Oak
North Coast	
North Coast	County of Humboldt
Agricultural Water Conservation and Water Supply Reliability Program - Russian/Navarro River Watersheds	Ca. Land Stewardship Institute
City of Crescent City, Elevated Water Tank Rehabilitation Project	Crescent City, City of
City of Fort Bragg, Summers Lane Reservoir Project	City of Fort Bragg
Lewiston Park Mutual Water Company, Meter Installation Project	Lewiston Park Mutual Water Company

Funding Area/IRWM Region/Project Name	Applicant Name/Implementing Agency of Project
North Coast, continued	County of Humboldt, continued
Rio Dell and Scotia Community Services District Emergency Water Intertie	Rio Dell City of
Sanctuary Forest Inc., Mattole Flow Program: Storage and Forbearance Program	Sanctuary Forest Inc.
Sonoma-Mendocino Immediate Drought Relief Project	Sonoma County Water Agency
The Flow Bank - Protecting Stream Flow in the Gualala River	Gualala River Watershed Council
Ukiah Valley-Redwood Valley Water Supply Reliability Intertie and Well Development Project	City of Ukiah
Westhaven Community Services District, Water Loss Reduction Project	Westhaven Community Services District
Yurok Tribe, Weitchpec Water Station	Yurok Tribe
San Francisco Bay	
San Francisco Bay Area	Association of Bay Area Governments
Project 1: Lower Cherry Aqueduct Emergency Rehabilitation Project	San Francisco Public Utilities Commission
Project 3: Zone 7 Water Supply Drought Preparedness Project	Zone 7 Water Agency
Project 4: Los Carneros Water District and Milliken-Sarco-Tulocay Recycled Water Pipelines	Napa Sanitation District
Project 5: Sunnyvale Continuous Recycled Water Production Facilities and Wolfe Road Pipeline	Santa Clara Valley Water District
Project 6: DERWA Phase 3 Recycled Water Expansion Project	DSRSD-EBMUD Recycled Water Authority
Project 7: Calistoga Recycled Water Storage Facility	Calistoga, City of
Project 8: Drought Relief for South Coast San Mateo County	San Mateo County RCD
Project 9: Stinson Beach Water Supply & Drought Preparedness Plan	Stinson Beach County Water District
Project 10: Bay Area Regional Drought Relief Conservation Program	StopWaste
Project 11: WaterSMART Irrigation with AMI/AMR	Marin Municipal Water District
San Diego	
Santa Ana Watershed Project Authority[1]	Santa Ana Watershed Project Authority
Interregional Landscape Water Demand Reduction Program	Santa Ana Watershed Project Authority
South Orange County Watershed Management Area	Orange, County of
MNWD Recycled Water System Extension Project	Moulton Niguel Water District
SCWD Recycled Water System Extension Project	South Coast Water District
SMWD Califia Recycled Water Project	Santa Margarita Water District
San Diego	San Diego County Water Authority
Carlsbad Recycled Water Plant and Distribution System Expansion	Carlsbad Municipal Water District
Fallbrook Plant Nurseries Recycled Water Distribution System Expansion	Fallbrook PUD
Regional Demand Management Program Expansion	San Diego County Water Authority
Regional Emergency Storage and Conveyance System Intertie Optimization	City of San Diego
Reynolds Groundwater Desalination Facility Expansion	Sweetwater Authority
Rincon Customer-Driven Demand Management Program	Rincon del Diablo Municipal Water District
San Diego Water Use Reduction Program	City of San Diego
Santa Ana	
Santa Ana Watershed Project Authority[1]	Santa Ana Watershed Project Authority
Interregional Landscape Water Demand Reduction Program	Santa Ana Watershed Project Authority
Los Angeles-Ventura	
Watersheds Coalition of Ventura County	County of Ventura
El Rio Retrofits for Groundwater Recharge	County of Ventura, Watershed Protection District
Watersheds Coalition of Ventura Cty, con't	County of Ventura, continued
Lake Casitas Aeration	Casitas Municipal Water District
Pleasant Valley Well	Camrosa Water District
Salinity Management Pipeline, Phase 2D	Calleguas Municipal Water District
San Antonio Creek Arundo Removal	Ojai Valley Land Conservancy
Ventura County Agricultural Water Use Efficiency Program	County of Ventura, Watershed Protection District
Greater Los Angeles County	Los Angeles County Flood Control District
Be a Water Saver Conservation Program Project	Burbank Water and Power
Goldsworthy Desalter Expansion	City of Torrance
Los Angeles-Burbank Groundwater System Interconnection	Los Angeles Department of Water and Power
Manhattan Wells Improvement	Los Angeles Department of Water and Power
Mission Wells Improvement	Los Angeles Department of Water and Power
On-Site Recycled Water Retrofits	West Basin Municipal Water District
Pomona Basin Regional Groundwater Project	Puente Basin Water Agency
Recycled Water Turnouts	Water Replenishment District of So. California
Rockhaven Well	Crescenta Valley Water District
TIWRP Advanced Water Purification Facility and Distribution System Expansion	Los Angeles Department of Water and Power
Upper San Gabriel Valley Municipal Water District Recycled Water Program Expansion	Upper San Gabriel Valley Municipal WD
Water Budget Based Rate Implementation	Las Virgenes Municipal Water District
Well No. 2 Rehabilitation	City of Inglewood
West Coast Basin Barrier Project Unit 12 Injection Observation Wells	Los Angeles County Flood Control District
Upper Santa Clara River	Castaic Lake Water Agency
Rosedale-Rio Bravo Water Storage District/ Castaic Lake Water Agency Banking Program	Castaic Lake Water Agency
Semitropic WSD Extraction and Conveyance Improvements for Return of Stored (Banked) Water to CLWA	Castaic Lake Water Agency
Valencia Water Reclamation Plant UV Disinfection System Facilities	Los Angeles County Sanitation Districts
Gateway Region	Gateway IRWM Authority
Cerritos/Forest Lawn Cypress Recycled Water System Extension	Gateway IRWM Authority
Miles Avenue Well Site Nitrate Blending Improvements	Gateway IRWM Authority
Signal Hill Advanced Groundwater Wellhead Treatment	Gateway IRWM Authority
Lahontan	
Mojave[1]	Mojave Water Agency
Hesperia Reclaimed Water Distribution System	City of Hesperia
Mojave Region Commercial, Industrial and Institutional (CII) Turf Removal Program	Mojave Water Agency
Antelope Valley	Los Angeles County Waterworks District No. 40
60th Street West Wellhead Arsenic Treatment Project	Los Angeles County Waterworks District No. 40
Colorado River	
Mojave[1]	Mojave Water Agency
Hi-Desert Capital Water Main Replacement Program	Hi-Desert Water District
Coachella Valley	Indio Water Authority
Disadvantaged Community Onsite Plumbing Retrofit Program	Coachella Valley Water District
Indio Water Authority Recycled Water Project	Indio Water Authority
Regional Turf Reduction Program	Indio Water Authority

[1] Proposals contained projects in two funding areas

Note: Applicants may reconfigure projects shown here based on amount of state funding available.

The capacity of large-scale managed groundwater storage projects also has increased. Some of the largest new projects becoming fully operational since 1987-92 include ones operated by Semitropic Water Storage District, Arvin-Edison Water Storage District, Kern Water Bank Authority, Kern County Water Agency, and Mojave Water Agency. These projects share a common feature of relying on recharge supplies exported from the Delta and are thus subject to the restrictions associated with these supplies. Water year 2014 presented an operational challenge for some San Joaquin Valley banking agreements, as the sometimes complicated system of water exchanges and wheeling used to put and take water from these projects by participating local agencies had not been developed with the concept that zero or very low allocations from the CVP or SWP would occur.

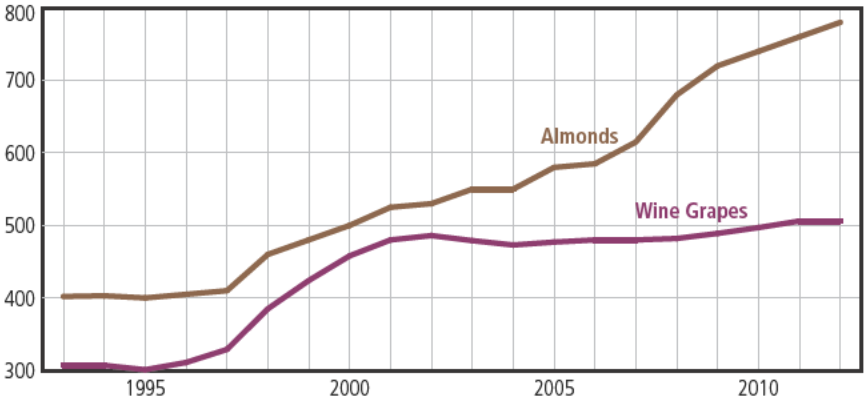
From a drought perspective one of the most significant large-scale conveyance facilities constructed since 1987-92 was the SWP's Coastal Aqueduct, which made imported water available to the previously hard-hit areas of San Luis Obispo and Santa Barbara Counties. Other major pipeline projects included enlargement and extension of the SWP's East Branch of the California Aqueduct to provide additional conveyance capacity into the Inland Empire area, and Mojave Water Agency's construction of two new pipelines to bring SWP water into parts of its service area previously dependent entirely on local groundwater.

Changes in Water Use Conditions

Long-term actions to reduce urban per capita water demand have been underway for some time, among them the federal Energy Policy Act of 1992, which set efficiency standards for plumbing fixtures manufactured after January 1994. Earlier, state legislation (the Environmental Water Act of 1989) had authorized a DWR grant program to provide funding to the City of Los Angeles for replacement water to compensate for water supplies lost due to the Mono Lake public trust court decision. This program was implemented to fund plumbing fixture retrofit projects in Los Angeles; plumbing fixture retrofit programs were broadly implemented statewide during the 1987-92 drought. Most recently the Water Conservation Act of 2009 (commonly referred to as the 20 percent by 2020 requirement) called for statewide reduction in urban per capita water use (and also required agricultural water suppliers to prepare and adopt agricultural water management plans). With significant progress having been made on urban indoor water reduction, water suppliers have been shifting their focus to

Figure 4.6: Example of Increased Acreage in Permanent Plantings

CDFA Harvested Acreage (1,000 Acres) 1993-2012



Statewide acreage data from California Department of Food and Agriculture

Table 4.3: Typical Multi-Year Drought Impacts

Unmanaged Systems	Health and Safety	Economic	Environmental
Risk of Catastrophic Wildfires	X	X	X
Non-Irrigated Agriculture (e.g. livestock grazing)	—	X	—
Fish and Wildlife (e.g. salmonids)	—	—	X
Managed Systems	**Health and Safety**	**Economic**	**Environmental**
Small Water Systems/Private Wells	X	—	—
Irrigated Agriculture	—	X	—
Green Industry (nursery and landscape)	—	X	—
Fish and Wildlife (e.g. salmonids, wildlife refuges)	—	—	X
Land Subsidence	X	X	X

outdoor (landscape) water use reduction. The Save Our Water conservation campaign, initially developed by DWR and the Association of California Water Agencies during the 2007-09 drought and continuing in the present drought, has emphasized messaging related to outdoor water use.

In the irrigated agriculture sector, increased acreage is being devoted to permanent plantings of orchard and vineyard crops that require reliable water supplies during dry conditions. One notable example is expansion of almond and pistachio acreage, including on the west side of the San Joaquin Valley where imported CVP and SWP supplies have become less reliable due to changed conditions described above. Figure 4.6 provides an example of the increase in acreage of almonds and wine grapes since the 1987-92 drought. The data shown is for harvested acres – actual planted acreage would be higher with the addition of acreage of

Table 4.4: Storage in Selected Reservoirs in Dry Water Years

End-of-water-year storage expressed as percent of capacity and percent of average at end of water year

	1976		1977		1990		1991		1992		2008		2009		2013		2014	
	% of capacity	% of average	% of capacity	% of average	% of capacity	% of average	% of capacity	% of average	% of capacity	% of average	% of capacity	% of average	% of capacity	% of average	% of capacity	% of average	% of capacity	% of average
Lake Shasta	28%	48%	14%	23%	36%	60%	29%	49%	37%	62%	30%	51%	39%	65%	42%	70%	25%	42%
Lake Oroville	52%	67%	26%	42%	33%	53%	40%	64%	37%	60%	31%	50%	38%	61%	46%	75%	30%	49%
Folsom Lake	43%	75%	15%	27%	18%	32%	52%	92%	18%	31%	28%	49%	42%	74%	37%	65%	35%	62%
Camanche Reservoir	43%	70%	13%	22%	41%	68%	27%	45%	27%	45%	35%	58%	77%	128%	61%	102%	32%	53%
Lake Berryessa	64%	84%	47%	63%	39%	52%	36%	47%	27%	36%	72%	95%	63%	83%	71%	94%	57%	75%
Lake Sonoma	–	–	–	–	38%	74%	47%	90%	56%	108%	53%	103%	51%	100%	50%	97%	39%	75%
Hetch Hechy Reservoir	34%	47%	31%	44%	38%	53%	65%	91%	53%	73%	77%	107%	81%	113%	73%	102%	77%	108%
New Melones Reservoir	–	–	–	–	16%	28%	12%	22%	3%	6%	46%	82%	46%	83%	44%	78%	22%	39%
Lake Don Pedro	33%	49%	15%	22%	49%	72%	47%	69%	38%	57%	52%	77%	71%	105%	53%	79%	38%	57%
Lake McClure	23%	52%	9%	19%	10%	23%	19%	42%	13%	29%	27%	60%	42%	93%	29%	65%	12%	26%
Millerton Lake	87%	215%	38%	94%	35%	87%	34%	83%	32%	78%	38%	95%	67%	167%	61%	151%	35%	88%
Pine Flat Lake	23%	68%	8%	24%	3%	9%	4%	13%	3%	9%	12%	36%	20%	59%	15%	46%	11%	34%
Isabella Lake	12%	37%	6%	19%	9%	26%	17%	53%	15%	45%	21%	65%	18%	55%	10%	30%	9%	27%
San Luis Reservoir	40%	84%	13%	29%	24%	51%	32%	68%	23%	50%	12%	25%	21%	44%	25%	53%	23%	49%
Lake Casitas	80%	96%	72%	86%	54%	65%	58%	69%	75%	90%	84%	100%	74%	89%	63%	76%	53%	64%
Lake Cachuma	75%	95%	57%	72%	18%	23%	32%	40%	82%	104%	91%	115%	75%	94%	48%	61%	32%	40%

Table 4.5: Estimated Wildfire Damages

Fire Season	CAL FIRE Fire Suppression Cost Estimate ($M)	Damage Cost Estimate ($M)	Structures Destroyed
2000	124	30	130
2001	109	87	389
2002	135	174	327
2003	253	974	5394
2004	166	127	1016
2005	105	49	102
2006	206	60	431
2007	298	254	3079
2008	460	899	1027
2009	256	34	121
2010	90	5.2	94
2011	140	7.2	137
2012	310	28.2	248
2013	240	29.8	495

Notes:
1. CAL FIRE fire suppression costs are reported on its seasonal basis, not by calendar year
2. Damage cost estimates and structure destroyed are only for CAL FIRE jurisdictional area (wildlands)
3. 2013 costs are preliminary and subject to revision

non-bearing trees and vines.

COMPARISON OF DROUGHT IMPACTS

This section briefly reviews some commonalities observed among the historical droughts. Table 4.3 provides examples of drought impacts associated with managed and unmanaged systems, breaking them down into the categories of public health and safety, economic, and environmental. Unmanaged systems refer to conditions associated solely with precipitation and streamflow, where no water infrastructure is used to control or influence the outcome of water shortage. Managed systems are those where actions such as releases from reservoirs or pumping groundwater can be used to mitigate impacts. Some impacts can be associated with both types of systems; for example, impacts to anadromous fish species can occur either in free-flowing streams or in rivers controlled by major reservoirs. As discussed in Chapter 1, impacts increase with drought duration. Table 4.4 illustrates how dry conditions have affected end-of-water-year storage in selected reservoirs. Persistent dry conditions reduce the water storage in reservoirs and groundwater basins used to mitigate drought impacts, and reduce the soil moisture that supports non-irrigated vegetation.

Defining small water systems

Pursuant to the Safe Drinking Water Act (SDWA), the U.S. Environmental Protection Agency (USEPA) defines a public water system as a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals. USEPA also classifies public water systems according to size:

» Very small water systems serve 25-500 people

» Small water systems serve 501-3,300 people

» Medium water systems serve 3,301-10,000 people

» Large water systems serve 10,001-100,000 people

» Very large water systems serve 100,001+ people

This report uses the term small water system in a loose sense to mean the systems that USEPA would define as very small to small, a size range that roughly represents the group of water suppliers not required to file UWMPs under California law. In practical terms, however, there is no hard and fast delineation between small and medium systems with respect to drought vulnerability; systems at the smaller end of USEPA's medium classification may share many of the same challenges as smaller systems.

Unmanaged Systems

The economic impacts associated with unmanaged systems have historically been greater than those

Figure 4.7: 2007 California Wildfires

Source: California Office of Emergency Services

associated with managed systems. Some of California's largest directly quantifiable economic impacts of drought were associated with loss of timber resources and wildfires. Risk of catastrophic wildfire also is a public health and safety threat, especially for densely populated urban areas located adjacent to wildlands. Just as the 1991 Oakland Hills fire was at the time described as the costliest fire disaster in U.S. history, the same became true for the 2003 Southern California wildfires (which followed a multi-year regional drought in Southern California) (U.S. House of Representatives, 2007); the October

2007 Southern California wildfires were of similar magnitude. Wildfires also pose a particular risk for facilities of small water systems, as these systems are often located in rural areas where wildfire risk exists. Table 4.5 shows costs in recent years associated with wildfires on lands under CAL FIRE's jurisdiction, while Figure 4.7 illustrates the broad spatial extent of the 2007 Southern California wildfires.

With respect to non-irrigated agriculture, losses related to livestock production – which typically relies heavily on non-irrigated rangeland grazing – were characterized as most significant in the large historical droughts. Unlike the impacts to irrigated agriculture which are concentrated in the Central Valley, impacts associated with livestock production are more geographically dispersed, affecting many rural and semi-rural counties. Prior to the recent revision in USDA's process for designating counties as eligible for drought disaster assistance, livestock-related impacts dominated the reasons for primary county designations in the big historical droughts.

Managed Systems

Public health and safety impacts associated with small water systems and private residential wells were common in past droughts. California's small water systems have historically experienced the bulk of reported health and safety impacts, as well as the majority of water shortage emergencies—regardless of water year type. Drought adds another stressor for small water systems, exacerbating the potential for problems in geographically vulnerable locations. Although small systems serve a low percentage of California's total population, they constitute the majority of the state's public water systems. Small systems tend to be located outside the state's major metropolitan areas, often in lightly-populated rural areas where opportunities for interconnections with another system or water transfers are limited. Small systems also have limited financial resources and

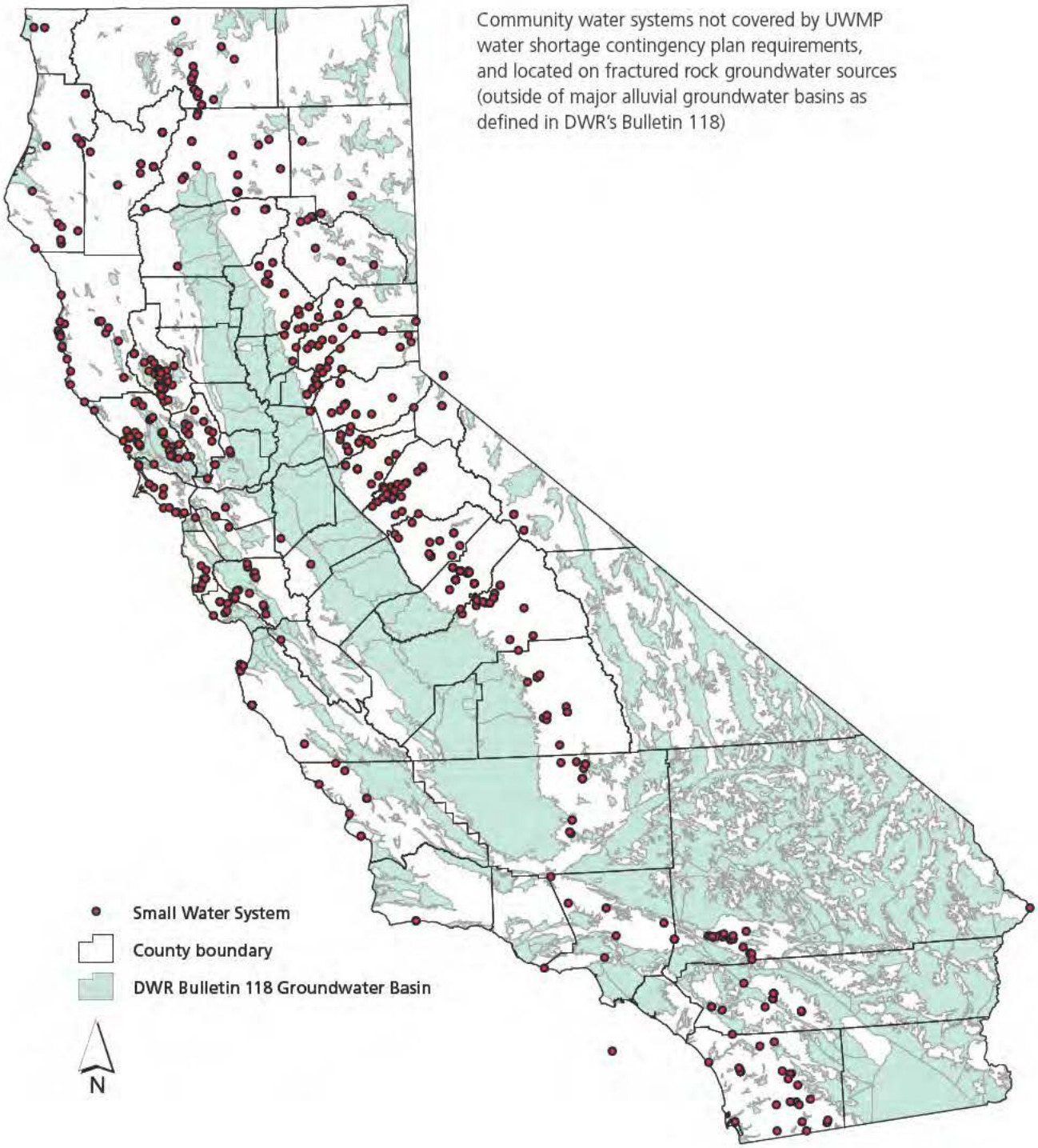
Reliance on fractured rock groundwater can be a predictor of vulnerability to drought. Private residential wells drilled in fractured bedrock often yield only a few gallons of water per minute. Source: Getty Images

rate bases that constrain their ability to undertake major capital improvements. Most small system drought problems stem from dependence on an unreliable water source, commonly groundwater in fractured rock systems or in small coastal terrace groundwater basins. Historically, particularly at-risk geographic areas have been foothills of the Sierra Nevada and Coast Range and inland Southern California, and the North and Central Coast regions (Figure 4.8).

Ongoing recurrence of drought-related water shortage problems in the same locations has been observed for both small water systems and some areas with high concentrations of private residential wells. DWR's August 1977 report on the status of the drought featured a section on critical areas/special problems which identified 39 (mostly small) communities or areas and noted that:

Large areas of California have been affected by the 1976-77 drought, and the effects will be intensified if the drought continues into 1978 with runoff conditions similar to those of 1977. Many cities and communities have had to resort to emergency measures, such as temporary importation of wells from other areas, drilling new wells, mandatory conservation measures and, in some cases, rationing to meet the

Figure 4.8: Example of Potentially At-Risk Small Water Systems



A $29 million intertie was completed in 2012 to link the SWP's California Aqueduct and the CVP's Delta-Mendota Canal, to enable increased flexibility in the projects' operations.

essential water needs.

Most of the more severely affected areas have developed, or are in the process of developing, contingency plans for 1978. There are, however, several cities and communities where local resources are inadequate to develop drought contingency plans or physical solutions. This is especially critical for small communities in the foothills and other areas where groundwater availabilty is limited.

Many of the same communities or areas named in the 1977 report have continued to experience water shortage problems during dry conditions. There have been areas that experienced water shortage problems in the 1976-77 drought, again in 1987-92, in 2007-09 and finally in 2014 as well. Even a single dry year can result in water haulage for vulnerable systems. Water year 2001, for example, fell in the top 5 percent of dry years in terms of statewide runoff, and records for then-low precipitation were set in many Southern California communities. The region's larger water suppliers, supported by imported surface water and local groundwater sources, were relatively unaffected by the one singularly dry year, but there was a sharp upswing in the number of small water systems on fractured rock groundwater experiencing supply problems in areas such as the Tehachapi Mountains, Inland Empire mountain and foothill areas, and eastern San Diego County. Local water suppliers in affected areas took actions such as imposing mandatory water use restrictions, limiting new connections, or hauling water.

Large urban water agencies have a high capacity to prepare for and respond to drought, and most have historically experienced drought primarily in the form of financial impacts that are ultimately passed on to ratepayers. Urban water suppliers, particularly those serving larger metropolitan areas, normally provide reliable supplies for their customers, as they have the resources and the revenue base to prepare for and respond to drought impacts. During past droughts, large urban water agencies often took actions to assure full water supplies for their commercial and industrial water customers, as these customers typically constitute a relatively small percentage of urban water demand but are seen as important contributors to local economies.

Lessons learned from prior droughts have spurred improved interconnections among urban water suppliers at both wholesale and retail levels. The capacity of California's larger urban areas to respond to drought is enhanced by the interconnectedness of much of California's water infrastructure, which facilitates actions such as water transfers as well as

Dead citrus trees in a San Joaquin Valley orchard during the 1929-34 drought, an image similar to that seen on the west side of the valley during the 2007-09 drought. This photograph comes from a booklet issued by Governor Rolph to the people of California calling for action on the state's urgent water development problems (Rolph, 1931). Photo courtesy Sacramento Public Library.

Figure 4.9A: Satellite Imagery of the Central Valley in Summer 2011

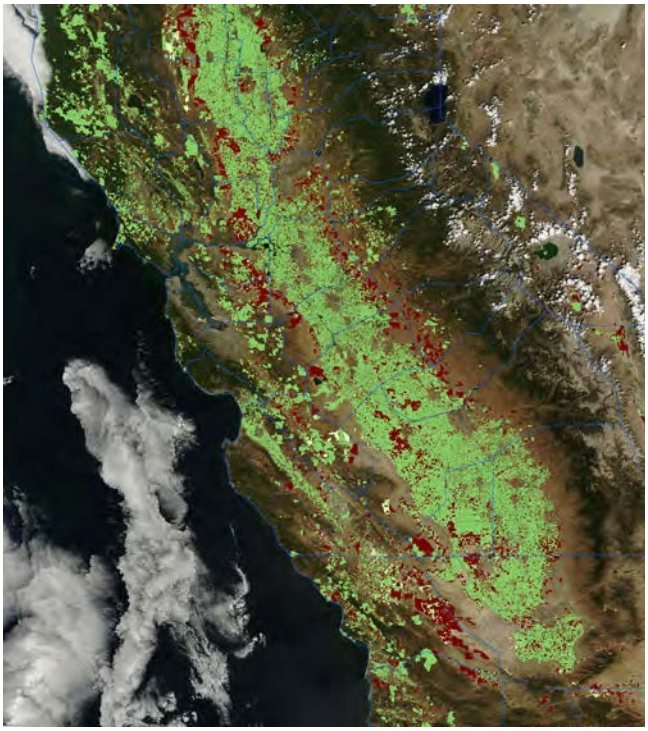
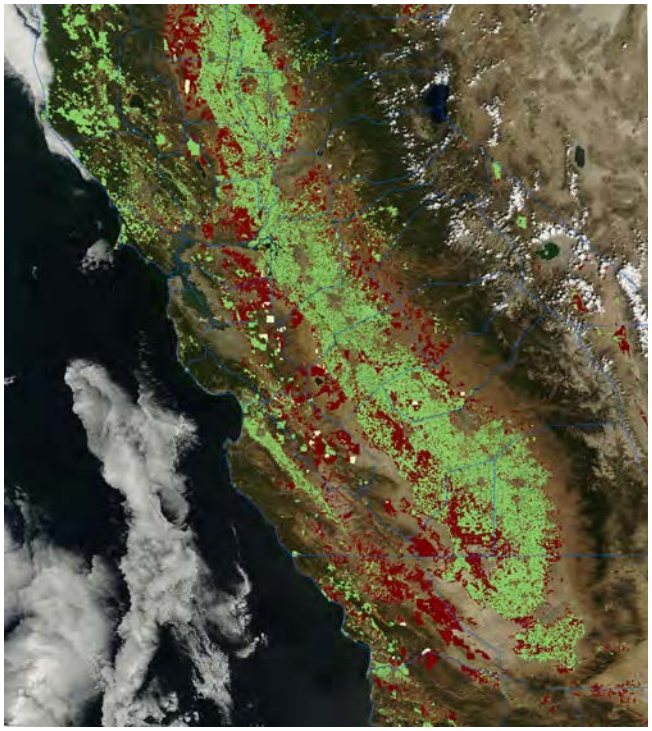


Figure 4.9B: Satellite Imagery of the Central Valley in Summer 2014



False color image. Estimated idled acreage shown in red.
Image courtesy of NASA

supporting improved emergency response to disasters such as wildfire or earthquake. California's major water infrastructure continues to become increasingly interconnected – for example, the Delta-Mendota Canal/California Aqueduct intertie (2012) or the East Bay Municipal Utility District-Contra Costa Water District intertie (2007).

In the irrigated agriculture sector, the largest at-risk area has been the west side of the San Joaquin Valley, particularly the area supplied by Central Valley Project south-of-Delta exports. The impacts of reduced supplies were evident in the 2007-09 drought, when growers abandoned permanent plantings such as orchards due to water shortages, a circumstance again observed in 2014. The extent of Central Valley idled agricultural land in summer 2014 is shown in Figure 4.9, obtained from National Aeronautics and Space Administration (NASA) imagery processed under a pilot project funded by NASA and NOAA for using satellite imagery to estimate idled acreage in near real-time during the growing season. A summer 2011 (wet year) image is provided for comparison purposes.

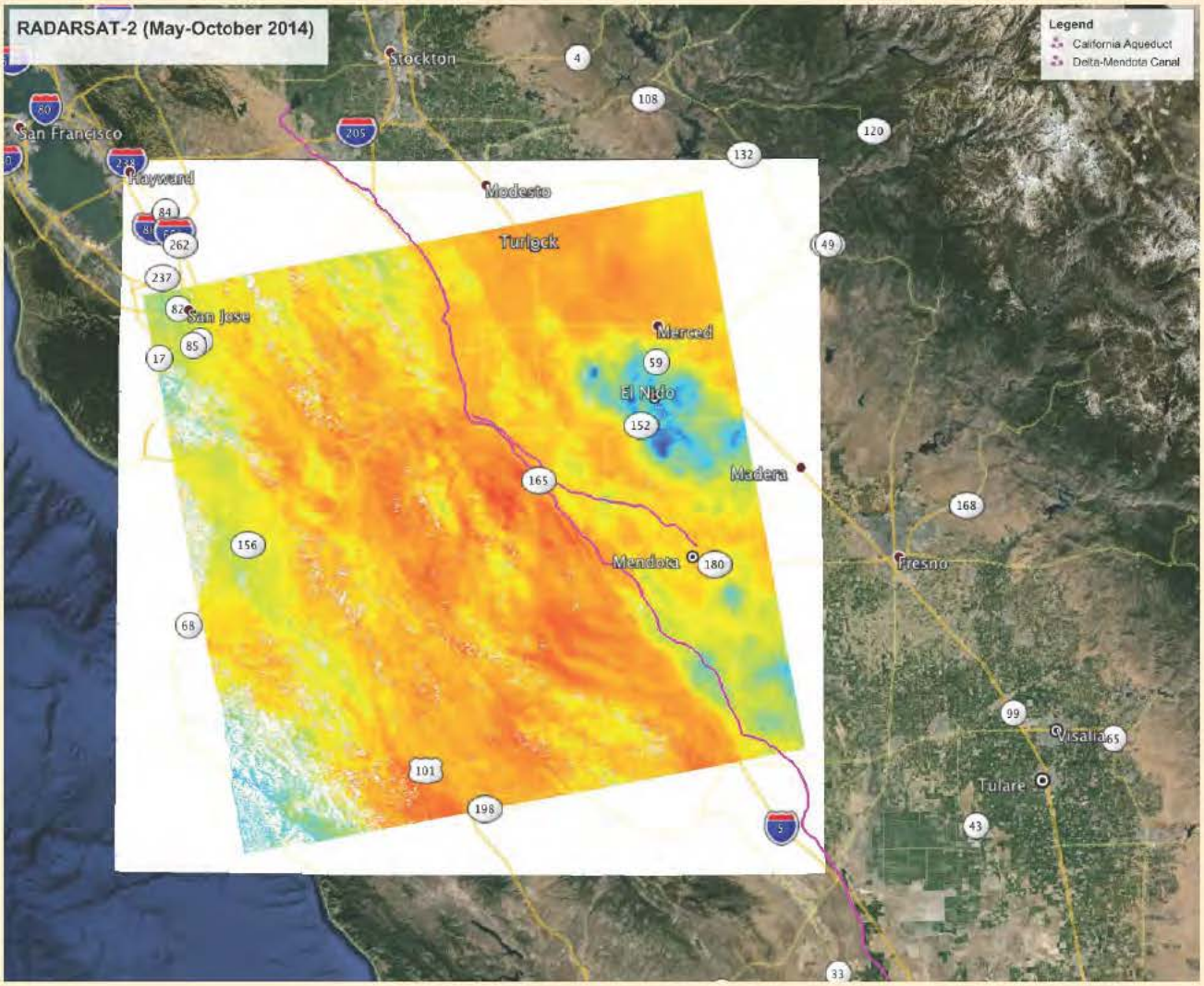
OTHER OBSERVATIONS FROM PAST DROUGHTS

Just as there were common themes among impacts observed in past droughts, there are also common observations that can be made about drought response and drought preparedness lessons learned. Three important gaps stand out in the historical experience: the ability to characterize statewide groundwater conditions, to predict if the next season will be wet or dry, and to improve drought preparedness for small water systems.

Monitoring Land Subsidence

Historical approaches for monitoring subsidence include use of conventional land surveying techniques and installation of borehole extensometers in conjunction with groundwater level monitoring. The availability of satellite-enabled global positioning systems (GPS) has offered another tool in recent years. Satellite-based interferometric synthetic aperture radar (InSAR), a technology used by geophysical researchers for purposes such as monitoring relative land surface displacement along fault zones, is an emerging tool for identifying subsidence due to its ability to provide rapid coverage over a large spatial scale (Figure 4.10). USGS used InSAR technology in an evaluation of subsidence in parts of the northern San Joaquin Valley in the early 2000s (USGS, 2013). The USGS work identified recent subsidence in an area outside of the historically at-risk region (see image below), prompting subsequent concerns about the effects of drought-related increased groundwater pumping and impacts of subsidence on SWP and CVP facilities and local flood control project infrastructure. DWR contracted with NASA in 2014 for mapping of recent subsidence in parts of the Central Valley where satellite-based InSAR imagery was available. The work, to be completed in 2015, is a drought response action and screening effort to identify areas of ongoing relative land surface displacement.

Figure 4.10: Example of Processed InSAR Image in the San Joaquin Valley
Image courtesy of NASA



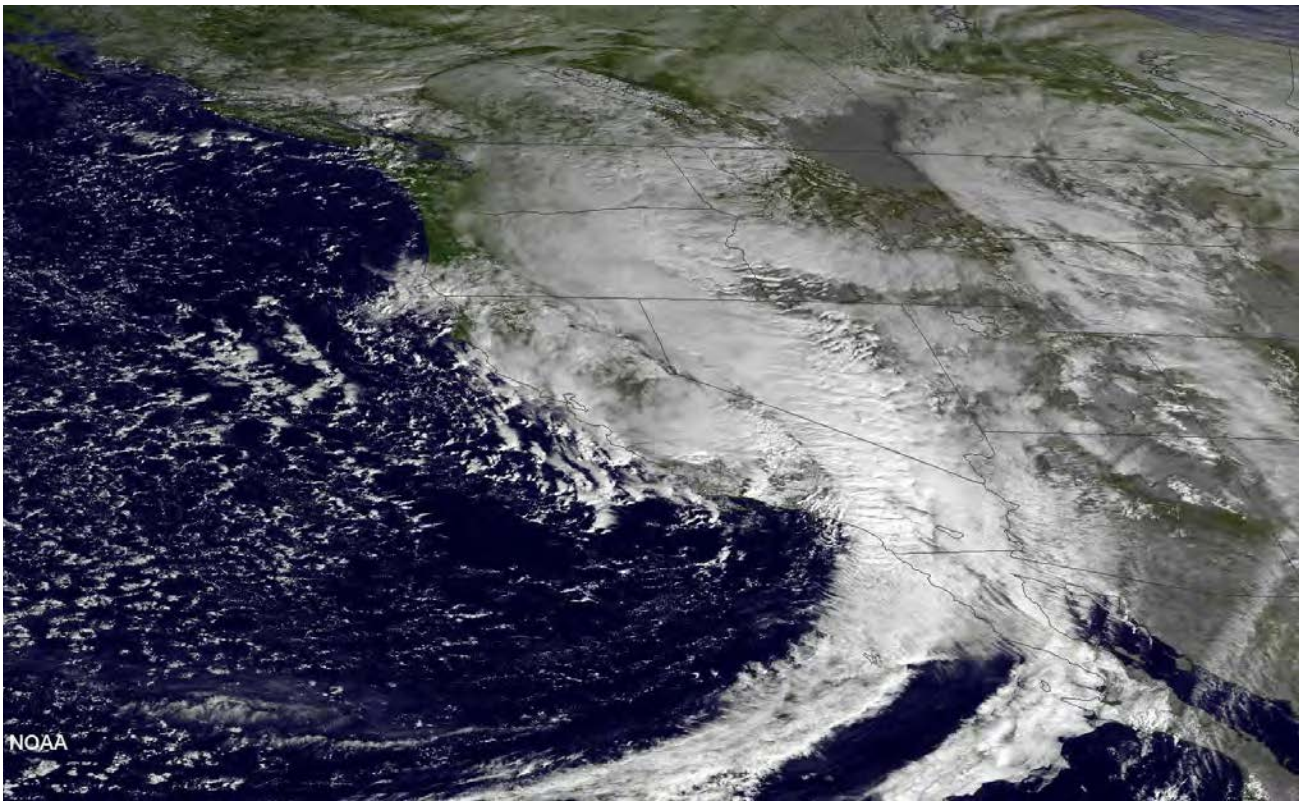
Evaluation of Statewide Groundwater Conditions

Reliance on groundwater substantially mitigates drought impacts for many urban and agricultural water users, and local water agencies have widely practiced conjunctive management of groundwater and surface water either formally or informally for many decades. Understanding groundwater conditions is a key aspect of monitoring drought impacts and taking response actions as needed. Timely assessment of statewide groundwater conditions was not historically possible during past California droughts, but enactment of the CASGEM legislation in 2009 greatly enhanced the information now available for drought preparedness and response. Continuing implementation of CASGEM and coverage of all the high- and medium-priority basins with water level monitoring data will fill a major information gap. Timely access to water level data allows early identification of, and response to, impacts such as land subsidence or seawater intrusion. Over time implementation of the California groundwater management legislation enacted in 2014 also will reduce the risk of drought impacts (see sidebar on monitoring land subsidence) in the state's major alluvial groundwater basins and will provide for more sustainable use of the resource.

Subseasonal and Seasonal Climate Forecasting

Skillful near-term climate forecasting would be extremely useful in informing drought preparedness and response; calls for improving forecasting in the context of drought date back to attempts to predict the end of dry conditions in the 1920s-30s. Weather models are run operationally out to two weeks ahead, but are most skillful for timeframes of less than five days. The present scientific capability for

NOAA image from GOES-West weather satellite. Although the accuracy of weather forecasts has improved considerably since the 1976-77 drought, skill in seasonal forecasting remains a challenge.



There was extensive news media coverage of widespread problems with dry private residential wells in the Tulare County community of East Porterville during 2014. Emergency supplies of bottled water and bulk water deliveries were part of the relief efforts. Photos (top) courtesy American Red Cross; (bottom) Chieko Hara, Porterville Recorder.

making skillful climate forecasts beyond the weather time domain, from a few months out (subseasonal) to the next water year (seasonal), is limited. Apart from simply predicting that historical climatology will recur, most of the present skill in making forecasts comes from ENSO conditions – if an ENSO signal is present and for a geographic region where ENSO may provide some predictive guidance.

Subseasonal forecasting, if skillful, would be useful for supporting reservoir operations planning and for evaluating potential water project allocations, particularly in the spring months. Improved seasonal forecasting has many potential applications. DWR noted in its discussion of this subject for the 1976-77 drought that what is needed for operation and management of a complex water supply project is a long-term projection, at least a year in advance, with a high degree of reliability (DWR, 1978). The primary source for monthly to seasonal forecasts is NOAA's Climate Prediction Center (CPC), which produces national-scale outlooks for temperature and precipitation (e.g., 30-day outlook, 90-day outlook, one-year outlook). CPC's outlooks only make a forecast for the geographic areas in which they have skill at the time of the forecast; there is often no forecast made for large areas of the United States.

While progress in improving skill of near-term climate forecasting at CPC's national scale is likely to remain slow (National Research Council, 2010), there are potential opportunities for improving skill at the spatial scale of California. DWR has been working with climate researchers to identify the most promising opportunities. A leading prospect is to improve the understanding of conditions favoring formation of atmospheric river storms that reach the West Coast, as the absence of these storms suggests a bias toward drier conditions. Improving prediction of these large storm events also is important for developing the ability to use forecast-informed reservoir operations in the longer-term as a tool for drought response and climate change adaptation.

Improving Small Water System Drought Preparedness

Water shortage problems with small systems on unreliable sources have been consistently observed in past droughts, and the requirements of shortage contingency planning associated with UWMPs are not applicable to smaller systems. Many small water system problems are associated with fractured rock groundwater sources, and improvements in alluvial

basin groundwater monitoring being brought about through CASGEM are not applicable to this situation. The high spatial variability of groundwater conditions in fractured rock settings typically makes regional-scale monitoring impractical.

Most state financial assistance for small systems has come through SDWA funding (administered through SWRCB as of July 2014) for achieving compliance with drinking water regulations. However, financial assistance alone, even if substantial new levels of support were available, would not itself be sufficient to address other technical and managerial challenges faced by the smallest systems (USEPA, 2011), and the relative geographical isolation of many systems often makes consolidation with larger systems difficult. Concerted effort over time will be needed to improve small system drought preparedness. In 2000, the Governor's Advisory Drought Planning Panel had recommended beginning a technical assistance and education program for rural homeowners on private wells and small water systems that would be implemented in coordination with county environmental health departments to improve awareness of drought risk mitigation (DWR, December 2000).

Basic steps that small systems can take to improve their drought preparedness include completing the emergency plans required for demonstration of capacity pursuant to SDWA regulations, regularly monitoring water levels in their wells, and implementing leak detection programs as needed. As funding has been available, DWR has historically partnered with the California Rural Water Association to provide assistance to small systems in these areas. Moving beyond the basic level could entail use of SDWA authorities and funding for actions such as promoting system consolidation where possible. Past droughts have identified areas of historical vulnerability that could be priority areas for seeking regional solutions.

Appendix

Acronyms

AMO	Atlantic Multidecadal Oscillation
AO	Arctic Oscillation
CASGEM	California Statewide Groundwater Elevation Monitoring
CPC	Climate Prediction Center
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DWR	Department of Water Resources
ENSO	El Niño – Southern Oscillation
ESA	Endangered Species Act
IRWM	Integrated Regional Water Management
MAF	Million Acre-Feet
MJO	Madden-Julian Oscillation
MWD	Metropolitan Water District
NAO	North Atlantic Oscillation
NASA	National Aeronautics and Space Administration
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
OES	Office of Emergency Services
PDO	Pacific Decadal Oscillation
SDWA	Safe Drinking Water Act
SWP	State Water Project
SWRCB	State Water Resources Control Board
TAF	Thousand Acre-Feet
USBR	U.S. Bureau of Reclamation
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UWMP	Urban Water Management Plan
WRCC	Western Regional Climate Center

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03/04/1977

Executive Order B-27-77

FILED
In the office of the Secretary of State of the State of California
MAR 4 - 1977
MARCH FONG EU, Secretary of State
By [illegible]
Deputy

Executive Department
State of California

EXECUTIVE ORDER NO. B-27-77

WHEREAS, it is necessary to provide for coordination of communications and directives to insure effective management and cooperative efforts by state agencies to combat the effects of the drought; and

WHEREAS, it is necessary to provide for coordination of communications between the state and other governmental agencies at the federal and local levels;

NOW, THEREFORE, I, Edmund G. Brown Jr., Governor of the State of California, by virtue of the power and authority vested in me by the Constitution and statutes of the State of California, do hereby initiate on an interim basis the following plan:

IT IS ORDERED that the Drought Emergency Task Force is hereby established. Said Task Force shall consist of representatives of the following state agencies and departments:

Agriculture and Services Agency
Business and Transportation Agency
Health and Welfare Agency
Resources Agency

Department of Finance
Department of Fish and Game
Department of Food and Agriculture
Department of General Services
Department of Health
Department of Housing and Community Development
Department of Navigation and Ocean Development
Department of Parks and Recreation
Department of Transportation (Caltrans)
Department of Water Resources
Division of Forestry
Employment Development Department
Military Department
Office of Emergency Services

The Task Force shall also consist of representatives of any of the following independent boards and commissions which are willing to participate and to voluntarily comply with this Executive Order:

California Coastal Commission
California Emergency Council
California Tahoe Regional Planning Agency
California Water Commission
Colorado River Board of California

Executive Order B-27-77, page 2 of 3

Executive Department
State of California

PAGE TWO

Commission on Housing and Community Development
Navigation and Ocean Development Commission
Public Utilities Commission
Regents of the University of California
San Francisco Bay Conservation and Development Commission
State Air Resources Board
State Board of Fire Services
State Board of Food and Agriculture
State Board of Forestry
State Energy Resources Conservation and Development Commission
State Park and Recreation Commission
State Personnel Board
State Reclamation Board
State Resource Conservation Commission
State Solid Waste Management Board
State Transportation Board
State Water Resources Control Board
Trustees of the California State University and Colleges

The Director of the Task Force shall be Major General Frank J. Schober, Commanding General of State Military Forces; and

IT IS FURTHER ORDERED that the head of each such agency and department and each participating board and commission shall immediately designate a duly authorized representative to the Drought Emergency Task Force; and

IT IS FURTHER ORDERED that the duties of the Drought Emergency Task Force shall include, but not be limited to, the direction and coordination of state efforts to combat the effects of the drought, and to provide public information regarding the nature and extent of the drought and efforts to combat the effects thereof; and

IT IS FURTHER ORDERED that said agencies, departments, boards, and commissions make available to Major General Frank J. Schober such resources, facilities and personnel as he may request; and

Executive Order B-27-77, page 3 of 3

Executive Department
State of California

PAGE THREE

IT IS FURTHER ORDERED that all state agencies, departments, and participating boards and commissions shall communicate with me through Major General Frank J. Schober, Director of the Drought Emergency Task Force, with respect to all matters pertaining to the drought.

IN WITNESS WHEREOF, I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this fourth day of March, nineteen hundred and seventy-seven

Governor of California

ATTEST

March Fong Eu
Secretary of State

by Megan R. Kirchberger
Deputy Secretary of State

02/01/91

Executive Order W-3-91

G275
E9
W-3-91

EXECUTIVE DEPARTMENT
STATE OF CALIFORNIA

FILED
in the office of the Secretary of State
of the State of California
FEB 01 1991
MARCH FONG EU, Secretary of State
By Michele Gilliam
Deputy

EXECUTIVE ORDER NO. W-3-91

WHEREAS, most regions of the State of California have experienced conditions of drought for the previous four years, and some regions in Central and Southern California have experienced drought conditions for the past seven years; and

WHEREAS, California has received less than 25 percent of its normal rainfall for this water year, and there only remains two and one-half months in which significant rainfall can be anticipated; and

WHEREAS, reservoir storage throughout California is substantially depleted; with most reservoirs at or near an all-time low; with many reservoirs dropping to near their minimum pool levels; and some reservoirs holding less than they did in the 1976-77 drought; and

WHEREAS, the State Water Resources Control Board has held special hearings on the need to take specific steps to mitigate the effects of the current and possible future drought conditions; and

WHEREAS, the Emergency Services Act confers extraordinary powers on the Governor to provide leadership in responding to emergencies which are beyond the control of any individual city or county or which require a coordinated statewide response; and

WHEREAS, it is now necessary for all agencies of the State of California to undertake steps to mitigate the effects of the current drought, and to develop the information necessary to enable the Governor to coordinate and direct remedial actions at all levels of government within the state to combat existing or threatened drought-caused conditions of disaster or peril to persons or property should it become necessary to proclaim a state of emergency under the Emergency Services Act; and

WHEREAS, many cities, counties, and water purveyors in California have already taken significant actions to deal with the drought; those which do not already have drought emergency plans should be encouraged to plan now for future actions necessary to mitigate the effects of the drought, and all counties should be encouraged to appoint a drought coordinator, so that State and local agencies can make a coordinated response to any future drought emergency; and

WHEREAS, impacts of the drought can reach virtually all of California's population, affect it's natural resources and its economy, and mitigating the drought's impact will require the cooperation of all of our citizens, elected officials, and public agencies;

NOW THEREFORE, I, Pete Wilson, Governor of the State of California, by virtue of the power and authority vested in me by the Constitution and statutes of the State of California, do hereby issue the following orders and directives to become effective immediately:

IT IS ORDERED that The Director of Water Resources is hereby appointed as the Governor's Drought Administrator who shall be the Governor's representative with respect to all matters related to implementing this Executive Order, and any subsequent orders or directives with respect to the drought; and

Executive Order W-3-91, page 2 of 3

6905 P.2

PAGE 2

IT IS FURTHER ORDERED that the Drought Action Team is hereby established. The Governor's Drought Administrator shall serve as its Chair. The Action Team shall consist of the following persons, together with the directors or executive officers of such other agencies as may be appointed upon the recommendation of the Administrator, where he finds that their department or agency has statutory responsibilities, expertise, or resources which would significantly contribute to mitigation of the effects of the drought:

Secretary of the Resources Agency
Director of the Department of Food and Agriculture
Director of the Office of Emergency Services
Director of the Department of Finance
Director of the Department of Fish and Game
Director of the Department of Forestry and Fire Protection
Director of the Department of Health Services
Director of the Office of Planning and Research
Adjutant General of the Military Department

The Governor's Drought Administrator shall also invite the participation of any independent boards and commissions and federal agencies which have jurisdiction, expertise and resources which would significantly contribute to the mitigation of the effects of the drought, including, but not limited to the following:

State Water Resources Control Board
Public Utilities Commission
United States Department of Agriculture
United States Department of the Interior
United States Army Corps of Engineers
Federal Emergency Management Agency

IT IS FURTHER ORDERED, that the general duties of the Drought Action Team include, but are not limited to, directing and coordinating state efforts to combat the effects of the drought, encouraging the preparation and implementation of local drought emergency plans, providing liaison and coordination between state and local efforts, and providing the Executive Department of the State of California with periodic reports on the status of the drought, together with recommendations for timely actions to remedy the effects of the drought. Specific duties of the Action Team shall include, but are not limited to, the following:

* The Action Team shall report regularly to the Governor on water supply conditions in California and the status of state and local efforts to combat the drought's effects. The Action Team shall recommend any additional measures which it deems necessary to combat the drought and protect the health, safety, and property of the people, while providing maximum feasible protection to the important environmental resources of the State. The first report shall emphasize water supply conditions and shall be made no later than February 15, 1991.

* The reports shall contain any information the Action Team finds to be of assistance to the Governor in determining whether and when to proclaim a state of emergency due to drought conditions and shall include an assessment of equitable issues and a rational framework for "sharing the pain" if extraordinary measures are recommended.

* The Action Team shall review and report on the availability and effectiveness of state and federal financial assistance programs for the relief of critical domestic water supply shortages, drought-induced water shortages which threaten the viability of environmental resources, including significant fish and wildlife populations, drought-induced adverse impacts to the economy, and any other adverse effects of the drought. The Action Team shall also recommend state and federal legislation, as appropriate, to provide emergency financial assistance.

Executive Order W-3-91, page 3 of 3

PAGE 3

IT IS FURTHER ORDERED, that the Department of Water Resources and the Office of Emergency Services shall provide staff to assist the Action Team in carrying out its responsibilities. The Governor's Drought Administrator may also call upon other departments for staff as needed; and

IT IS FURTHER ORDERED, that the Department of Water Resources shall do the following:

* The Department shall provide increased technical assistance and coordination to local water supply agencies on the development and implementation of water conservation measures.

* The Department shall develop a clearinghouse for facilitating water marketing transactions between willing sellers and buyers of water, consistent with the need to protect fish and wildlife resources.

* The Department shall review the effectiveness of water conservation measures ordered for all state agencies and departments pursuant to Executive Order D-85-90, and shall recommend any further actions necessary to effect the water savings directed in that Executive Order, together with such additional water savings as the Department believes to be reasonably attainable, in view of the severity of regional water shortages.

* The Department shall expand the Drought Center, which has been operating since 1986, as necessary to provide a focal point for drought activities, including providing information and assistance; and

IT IS FURTHER ORDERED, that the Department of Health Services shall evaluate and report to the Governor's Drought Administrator on the feasibility of temporary revisions of applicable water quality standards to make additional supplies of water available for beneficial uses, consistent with the protection of public health, including, but not limited to, expanded use of gray water, use of available ground water, and expanded use of reclaimed water; and

IT IS FURTHER ORDERED, that the State Water Resources Control Board is requested to hold further hearings on the drought, as appropriate, and coordinate its hearings with the Governor's Drought Administrator and the Drought Action Team; and

IT IS FURTHER ORDERED, that all state agencies and departments shall fully cooperate with the Governor's Drought Administrator, and communicate to the Executive Department of the State of California through the Administrator with respect to all matters pertaining to the drought and the actions to be taken pursuant to this Executive Order and all future orders and directives that may be issued to mitigate the effects of the drought.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 1st day of February 1991.

Pete Wilson

Governor of California

ATTEST:

March Fong Eu

Secretary of State

06/04/2008

Executive Order S-06-08

WHEREAS Statewide rainfall has been below normal in 2007 and 2008, with many Southern California communities receiving only 20 percent of normal rainfall in 2007, and Northern California this year experiencing the driest spring on record with most communities receiving less than 20 percent of normal rainfall from March through May; and

WHEREAS California is experiencing critically dry water conditions in the Sacramento and San Joaquin River basins and the statewide runoff forecast for 2008 is estimated to be 41 percent below average; and

WHEREAS water storage in many of the state's major reservoirs is far below normal including Lake Oroville, which supplies the State Water Project, at 50 percent of capacity, Lake Shasta at 61 percent of capacity and Folsom Lake at 63 percent of capacity; and

WHEREAS the Colorado River Basin has just experienced a record eight-year drought resulting in current reservoir storage throughout the river system reduced to just over 50 percent of total storage capacity; and

WHEREAS climate change will increasingly impact California's hydrology and is expected to reduce snowpack, alter the timing of runoff and increase the intensity and frequency of droughts in the western United States; and

WHEREAS diversions from the Sacramento-San Joaquin River Delta for the State Water Project (SWP) and federal Central Valley Project (CVP) are being greatly restricted due to various factors including federal court actions to protect fish species, resulting in estimated SWP deliveries of only 35 percent, and CVP deliveries of only 40 percent, of local agencies' requested amounts for 2008; and

WHEREAS dry conditions have created a situation of extreme fire danger in California, and these conditions resulted in devastating fires last year, resulting in proclamations of emergency for the counties of El Dorado, Los Angeles, Orange, Ventura, Santa Barbara, Riverside, San Bernardino, Santa Clara, Santa Cruz and San Diego, with wildfires there causing millions of dollars in damages; and

WHEREAS on May 9, 2008, I signed an Executive Order directing various agencies and departments within my administration to respond to these dry conditions and prepare for another potentially severe wildfire season; and

WHEREAS the current drought conditions are harming urban and rural economies, and the state's overall economic prosperity; and

WHEREAS some communities are restricting new development and mandating water conservation and rationing, and some farmers have idled permanent crops and are not planting seasonal crops this year, because of unreliable or uncertain water supplies; and

WHEREAS recent supply reductions have jeopardized agricultural production in the San Joaquin Valley; and

WHEREAS it is not possible to predict the duration of present drought conditions; and**WHEREAS** while communities throughout the state have worked to significantly improve their drought preparedness, the readiness to cope with current and future drought conditions varies widely; and

WHEREAS immediate water conservation measures are needed this year to address current conditions and prepare for a dry 2009; and

WHEREAS the State of California is committed to enhancing drought response and drought preparedness and to protecting the state's economy and its environment

NOW, THEREFORE, I, ARNOLD SCHWARZENEGGER, Governor of the State of California, do hereby proclaim a condition of statewide drought, and in accordance with the authority vested in me by the Constitution and statutes of the State of California, do hereby issue the following orders to become effective immediately

IT IS HEREBY ORDERED that the Department of Water Resources (DWR) shall take immediate action to address the serious drought conditions and water delivery limitations that currently exist in California, and that are anticipated in the future, by taking the following actions:

1. Expedite existing grant programs for local water districts and agencies for new or ongoing water conservation and water use reduction programs and projects that are capable of timely implementation to ease drought conditions in 2008 or 2009.
2. Facilitate water transfers in 2008 to timely respond to potential emergency water shortages and water quality degradation, and prepare to operate a dry year water purchasing program in 2009.
3. In cooperation with local water agencies and other water-related organizations, conduct an aggressive water conservation and outreach campaign.
4. Immediately convene the Climate Variability Advisory Committee to prioritize and expedite drought-related climate research that will assist in responding to current drought conditions and help prepare for a potentially dry 2009.
5. Provide technical assistance for drought response to local water agencies and districts for improving landscape and agricultural irrigation efficiencies, leak detection and other measures as appropriate.
6. Review the water shortage contingency elements of Urban Water Management Plans and work cooperatively with water suppliers to implement improvements.
7. Coordinate and implement State Water Project operations and water exchanges to alleviate critical impacts to San Joaquin Valley agriculture.
8. Implement additional actions to facilitate drought response, preparedness and promote water conservation in 2008 and 2009, and which will contribute to achieving long term reductions in water use.

IT IS FURTHER ORDERED that DWR and the Department of Public Health (DPH) prioritize processing of loan and grant contracts for water suppliers and public water systems demonstrating drought-related hardships.

IT IS FURTHER ORDERED that DWR and DPH coordinate with the State Office of Emergency Services and local offices of emergency services to identify public water systems at risk of experiencing health and safety impacts due to drought conditions and water delivery limitations, and to mitigate such impacts.

IT IS FURTHER ORDERED that DWR and DPH work with local water districts to evaluate system interconnections among the state's large water purveyors, review the status or availability of mutual aid agreements among those large water purveyors, and work with the parties to those mutual aid agreements to correct any deficiencies that restrict the movement of water in an emergency situation

IT IS FURTHER ORDERED that DWR coordinate with the California Public Utilities Commission to identify investor-owned water utility systems at risk of experiencing health and safety impacts due to drought conditions and water delivery limitations, and to mitigate such impacts.

IT IS FURTHER ORDERED that DWR work with the Department of Food and Agriculture (CDFA), the United States Department of Agriculture and the United States Bureau of Reclamation to identify potential federal funding for local water

agencies and farmers to facilitate the rapid installation of best available irrigation management and conservation systems.

IT IS FURTHER ORDERED that the CDFA work with county Agricultural Commissioners and others as necessary to identify and gather data on crop losses and other adverse economic impacts caused by the drought and, when necessary, transmit that information to the appropriate federal and state agencies.

IT IS FURTHER STRONGLY ENCOURAGED that local water agencies and districts work cooperatively on the regional and state level to take aggressive, immediate action to reduce water consumption locally and regionally for the remainder of 2008 and prepare for potential worsening water conditions in 2009.

This Order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

I FURTHER DIRECT that as soon as hereafter possible, this Executive Order be filed in the Office of the Secretary of State and that widespread publicity and notice be given to this Executive Order.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 4th day of June 2008.

ARNOLD SCHWARZENEGGER, *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

06/12/2008

Emergency Proclamation Central Valley

STATE OF EMERGENCY – CENTRAL VALLEY REGION

PROCLAMATION
by the Governor of the State of California

WHEREAS on June 4, 2008, I issued an Executive Order proclaiming a statewide drought; and

WHEREAS in my June 4 Executive Order, I called on all Californians to conserve water, and I directed state agencies and departments to take immediate action to address the serious drought conditions and water delivery reductions that exist in California; and

WHEREAS in issuing my June 4 Executive Order, I said that I would proclaim a state of emergency in any county where emergency conditions exist due to the drought, in an effort to protect the people and property of California, including the businesses, workers and communities that depend on water deliveries for their livelihood and survival; and

WHEREAS since issuing my June 4 Executive Order, I have determined that emergency conditions exist in Central Valley counties caused by the continuing drought conditions in California and the reductions in water deliveries; and

WHEREAS statewide rainfall has been below normal in 2007 and 2008, with many Southern California communities receiving only 20 percent of normal rainfall in 2007, and Northern California this year experiencing the driest spring on record with most communities receiving less than 20 percent of normal rainfall from March through May; and

WHEREAS California is experiencing critically dry water conditions in the Sacramento and San Joaquin River basins and the statewide runoff forecast for 2008 is estimated to be 41 percent below average; and

WHEREAS water storage in many of the reservoirs serving the Central Valley are far below normal including San Luis reservoir which is at 53 percent of capacity, Lake Shasta at 61 percent of capacity and Lake Oroville at just 50 percent of capacity; and

WHEREAS diversions from the Sacramento-San Joaquin River Delta for the State Water Project (SWP) and federal Central Valley Project (CVP) are being greatly restricted due to various factors including federal court actions to protect fish species, resulting in estimated SWP deliveries of only 35 percent, and CVP deliveries of only 40 percent, of local agencies' requested amounts for 2008; and

WHEREAS the United States Bureau of Reclamation (USBR) recently announced an unexpected reduction in its water supply allocations to Central Valley Project (CVP) contractors within the San Luis Delta Mendota Water Agency Service Area from 45 percent to 40 percent; and

WHEREAS this unanticipated reduction will result in crop loss, increased unemployment and other direct and indirect economic impacts to Central Valley counties; and

WHEREAS water rationing has been ordered by the City of Long Beach, the City of Roseville, and the East Bay Municipal Utility District, which serves 1.3 million people in Alameda and Contra Costa counties; and

WHEREAS on June 10, 2008, the Metropolitan Water District of Southern California, which supplies water for 26 cities and water agencies serving 18 million people in six southern California counties, declared a water supply alert in an effort to sustain their water reserves; and

WHEREAS some communities are also restricting new residential and commercial development because of unreliable or uncertain water supplies, and this is causing harm to the economy; and

WHEREAS dry conditions have created a situation of extreme fire danger in California, and these conditions resulted in devastating fires last year, with wildfires causing millions of dollars in damages; and

WHEREAS San Joaquin Valley agriculture constitutes a $20 billion industry, and serves as an essential part of California's economy; and

WHEREAS the lack of water will cause devastating harm to the communities that rely on this important industry, as growers lack sufficient water to finish the growing season, are forced to abandon planted crops, and are forced to dismiss workers; and

WHEREAS the lack of water is causing agricultural workers in the Central Valley to lose their jobs, resulting in a loss of livelihood, an inability to provide for their families, and increased negative social and economic impacts on the communities that depend on them; and

WHEREAS San Joaquin Valley agricultural production and processing industries account for almost 40 percent of regional employment, and every dollar produced on the farm generates more than three dollars in the local and regional economies, and the loss of these dollars is devastating communities; and

WHEREAS almost 20 percent of San Joaquin Valley residents already live in poverty, and it consistently ranks as the top region in the nation in foreclosures; and

WHEREAS as workers lose their jobs because of the lack of water, they often move their families away from the communities, resulting in further harm to local economies, lower enrollments in local schools and reduced funding for schools; and

WHEREAS the city of Fresno received only 54 percent of normal rainfall in 2007 and 76 percent of normal in 2008, and had its fourth driest spring on record; and

WHEREAS on June 11, 2008, the Fresno County Board of Supervisors passed a resolution declaring a local state of emergency due to the severe drought conditions, stating among other things that the lack of water has resulted in water rationing by Fresno County water districts; that these reductions are causing abandonment of current planted seasonal crops and permanent crops; that the cumulative crop reductions will result in job losses in Fresno County communities; that the loss of revenue has negatively impacted Fresno County businesses and Fresno County government tax revenue; and that there will be a substantial negative economic impact to the community; and

WHEREAS the Fresno County Board of Supervisors also requested that I declare a state of emergency due to the drought conditions; and

WHEREAS the Central Valley cities of Bakersfield, Modesto, Stockton, and Sacramento experienced their driest spring on record in 2008, and additional Central Valley counties are

experiencing similar emergency conditions caused by drought and lack of water deliveries; and

WHEREAS to date, almost $65 million in losses have been reported by 19 counties due to reduced rangeland grasses that are used to graze livestock, and those reductions have been caused by drought; and

WHEREAS statewide and local conditions collectively have led to the rationing of water by affected water districts to their member farmers and these further reductions are resulting in abandonment of current planted seasonal crops and permanent crops; and

WHEREAS the crop losses will cause increased food prices, which will negatively impact families and economies throughout California and beyond our borders; and

WHEREAS the lack of water deliveries has forced local communities to draw water from their emergency water reserves, putting communities at risk of further catastrophe if emergency reserves are depleted or cut off; and

WHEREAS the circumstances of the severe drought conditions, by reason of their magnitude, are beyond the control of the services, personnel, equipment and facilities of any single county, city and county, or city and require the combined forces of a mutual aid region or regions to combat; and

WHEREAS under the provisions of section 8558(b) of the California Government Code, I find that conditions of extreme peril to the safety of persons and property exist within the counties of Sacramento, San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare and Kern, caused by the current and continuing severe drought conditions.

NOW, THEREFORE, I, ARNOLD SCHWARZENEGGER, Governor of the State of California, in accordance with the authority vested in me by the California Constitution and the California Emergency Services Act, and in particular, section 8625 of the California Government Code, HEREBY PROCLAIM A STATE OF EMERGENCY to exist within the counties of Sacramento, San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare and Kern.

IT IS HEREBY ORDERED that all agencies of the state government utilize and employ state personnel, equipment and facilities for the performance of any and all activities consistent with the direction of my Office of Emergency Services (OES) and the State Emergency Plan, and that OES provide local government assistance under the authority of the California Disaster Assistance Act, and that the emergency exemptions in sections 21080(b)(3) and 21172 of the Public Resources Code shall apply to all activities and projects ordered and directed under this proclamation, to the fullest extent allowed by law.

I FURTHER DIRECT THAT:

OES shall provide assistance under the authority of the California Disaster Assistance Act, by assisting public water agencies with drilling of groundwater wells or the improvement of existing wells and water delivery systems for human consumption, sanitation, and emergency protective measures, such as fire fighting.

The Department of Water Resources (DWR) shall transfer groundwater of appropriate quality through the use of the California Aqueduct to benefit farmers in the San Joaquin Valley

DWR and the State Water Resources Control Board (SWRCB) shall expedite the processing of water transfer requests.

DWR, in cooperation with USBR, shall make operational changes to State Water Project facilities, including the San Luis Reservoir and Southern California reservoirs, that will permit additional water deliveries to the San Joaquin Valley.

DWR shall prepare and file necessary water right urgency change petitions to facilitate surface water transfers and the use of joint point of diversion by the SWP and Central Valley Project.

SWRCB shall expedite the processing and consideration of water rights urgency change petitions filed by DWR and other

water agencies to facilitate water transfers to the San Joaquin Valley.

I FURTHER DIRECT that as soon as hereafter possible, this proclamation be filed in the Office of the Secretary of State and that widespread publicity and notice be given of this proclamation.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 12th day of June, 2008.

ARNOLD SCHWARZENEGGER, *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

2/27/2009

Emergency Proclamation Water Shortage

STATE OF EMERGENCY – WATER SHORTAGE

PROCLAMATION
by the Governor of the State of California

WHEREAS the State of California is now in its third consecutive year of drought; and

WHEREAS in each year of the current drought, annual rainfall and the water content in the Sierra snowpack have been significantly below the amounts needed to fill California's reservoir system; and

WHEREAS the rainfall and snowpack deficits in each year of the current drought have put California further and further behind in meeting its essential water needs; and

WHEREAS statewide, 2008 was the driest spring and summer on record, with rainfall 76 percent below average; and

WHEREAS the Sacramento and San Joaquin River systems, which provide much of the state's reservoir inflow, were classified as Critically Dry for the 2008 water year; and

WHEREAS in the second year of this continuous drought, on June 4, 2008, I issued an Executive Order proclaiming a statewide drought, and I ordered my administration to begin taking action to address the water shortage; and

WHEREAS because emergency conditions existed in the Central Valley in the second year of the drought, I issued an Emergency Proclamation on June 12, 2008, finding that conditions of extreme peril to the safety of persons and property existed in the counties of Sacramento, San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare, and Kern caused by severe drought conditions, and I ordered my administration to take emergency action to assist the Central Valley; and

WHEREAS the drought conditions and water delivery limitations identified in my prior Executive Order and Emergency Proclamation still exist, and have become worse in this third year of drought, creating emergency conditions not just in the Central Valley, but throughout the State of California, as the adverse environmental, economic, and social impacts of the drought cause widespread harm to people, businesses, property, communities, wildlife and recreation; and

WHEREAS despite the recent rain and snow, the three year cumulative water deficit is so large there is only a 15 percent chance that California will replenish its water supply this year; and

WHEREAS in the time since the state's last major drought in 1991, California added 9 million new residents, experienced a significant increase in the planting of permanent, high-value crops not subject to fallowing, and was subjected to new biological opinions that reduced the flexibility of water

operations throughout the year; and

WHEREAS because there is no way to know when the drought will end, further urgent action is needed to address the water shortage and protect the people and property in California; and

WHEREAS rainfall levels statewide for the 2008–2009 water year are 24 percent below average as of the February 1, 2009 measurement; and

WHEREAS the second snow pack survey of the 2009 winter season indicated that snow pack water content is 39 percent below normal; and

WHEREAS as of February 23, 2009, storage in the state's reservoir system is at a historic low, with Lake Oroville 70 percent below capacity, Shasta Lake 66 percent below capacity, Folsom Lake 72 percent below capacity, and San Luis Reservoir 64 percent below capacity; and

WHEREAS low water levels in the state's reservoir system have significantly reduced the ability to generate hydropower, including a 62 percent reduction in hydropower generation at Lake Oroville from October 1, 2008 to January 31, 2009; and

WHEREAS a biological opinion issued by the United States Fish and Wildlife Service on December 15, 2008, imposed a 30 percent restriction on water deliveries from the State Water Project and the Central Valley Project to protect Delta Smelt; and

WHEREAS State Water Project water allocations have now been reduced to 15 percent of requested deliveries, matching 1991 as the lowest water allocation year in State Water Project history, and Central Valley Project water allocations for agricultural users have now been reduced to zero; and

WHEREAS the lack of water has forced California farmers to abandon or leave unplanted more than 100,000 acres of agricultural land; and

WHEREAS California farmers provide nearly half of the fresh fruits, nuts and vegetables consumed by Americans, and the crop losses caused by the drought will increase food prices, which will further adversely impact families and economies throughout California and beyond our borders; and

WHEREAS agricultural revenue losses exceed $300 million to date and could exceed $2 billion in the coming season, with a total economic loss of nearly $3 billion in 2009; and

WHEREAS it is expected that State Water Project and Central Valley Project water delivery reductions will cause more than 80,000 lost jobs; and

WHEREAS the income and job losses will adversely impact entire communities and diverse sectors of the economy supported by those jobs and income, including the housing market and commercial business; and

WHEREAS these conditions are causing a loss of livelihood for many thousands of people, an inability to provide for families, and increased harm to the communities that depend on them; and

WHEREAS this loss of income and jobs will increase the number of defaults, foreclosures and bankruptcies, and will cause a loss of businesses and property at a time when Californians are already struggling with a nationwide and worldwide economic downturn; and

WHEREAS the Central Valley town of Mendota, as one example, already reports an unemployment rate of more than 40 percent and lines of a thousand or more for food distribution; and

WHEREAS when jobs, property and businesses are lost, some families will move away from their communities, causing further harm to local economies, lower enrollments in local schools and reduced funding for schools; and

WHEREAS at least 18 local water agencies throughout the state have already implemented mandatory water

conservation measures, and 57 agencies have implemented other water conservation programs or restrictions on water deliveries, with many agencies considering additional rationing and water supply reductions in 2009; and

WHEREAS the lack of water has forced local communities to draw water from their emergency water reserves, putting communities at risk of further catastrophe if emergency reserves are depleted or cut off; and

WHEREAS the state recently endured one of its worst wildfire seasons in history and the continuing drought conditions increase the risk of devastating fires and reduced water supplies for fire suppression; and

WHEREAS on February 26, 2009, the United States Department of Agriculture and the United States Department of Interior created a Federal Drought Action Team to assist California to minimize the social, economic, and environmental impacts of the current drought; and

WHEREAS the circumstances of the severe drought conditions, by reason of their magnitude, are beyond the control of the services, personnel, equipment and facilities of any single county, city and county, or city and require the combined forces of a mutual aid region or regions to combat; and

WHEREAS under the provisions of section 8558(b) of the California Government Code, I find that conditions of extreme peril to the safety of persons and property exist in California caused by the current and continuing severe drought conditions and water delivery restrictions.

NOW, THEREFORE, I, ARNOLD SCHWARZENEGGER, Governor of the State of California, in accordance with the authority vested in me by the California Constitution and the California Emergency Services Act, and in particular California Government Code sections 8625 and 8571, HEREBY PROCLAIM A STATE OF EMERGENCY to exist in California.

IT IS HEREBY ORDERED that all agencies of the state government utilize and employ state personnel, equipment and facilities for the performance of any and all activities consistent with the direction of the California Emergency Management Agency (CalEMA) and the State Emergency Plan.

I FURTHER DIRECT THAT:

1. The California Department of Water Resources (DWR) shall, in partnership with other appropriate agencies, launch a statewide water conservation campaign calling for all Californians to immediately decrease their water use.
2. DWR shall implement the relevant mitigation measures identified in the Environmental Water Account Environmental Impact Report, Environmental Impact Statement, Supplement, and Addendums for the water transfers made through the 2009 Drought Water Bank. In addition, the California Air Resources Board shall, in cooperation with DWR and other agencies, expedite permitting and development of mitigation measures related to air quality impacts which may result from groundwater substitution transfers.
3. DWR and the State Water Resources Control Board (SWRCB) shall expedite the processing of water transfers and related efforts by water users and suppliers that cannot participate in the 2009 Drought Water Bank, provided the water users and suppliers can demonstrate that the transfer will not injure other legal users of water or cause unreasonable effects on fish and wildlife.
4. The SWRCB shall expedite the processing and consideration of the request by DWR for approval of the consolidation of the places of use and points of diversion for the State Water Project and federal Central Valley Project to allow flexibility among the projects and to facilitate water transfers and exchanges.
5. DWR shall implement short-term efforts to protect water quality or water supply, such as the

installation of temporary barriers in the Delta or temporary water supply connections.

6. The SWRCB shall expedite the processing and consideration of requests by DWR to address water quality standards in the Delta to help preserve cold water pools in upstream reservoirs for salmon preservation and water supply.
7. To the extent allowed by applicable law, state agencies within my administration shall prioritize and streamline permitting and regulatory compliance actions for desalination, water conservation and recycling projects that provide drought relief.
8. The Department of General Services shall, in cooperation with other state agencies, immediately implement a water use reduction plan for all state agencies and facilities. The plan shall include immediate water conservation actions and retrofit programs for state facilities. A moratorium shall be placed on all new landscaping projects at state facilities and on state highways and roads except for those that use water efficient irrigation, drought tolerant plants or non-irrigated erosion control.
9. As a condition to receiving state drought financial assistance or water transfers provided in response to this emergency, urban water suppliers in the state shall be required to implement a water shortage contingency analysis, as required by California Water Code section 10632. DWR shall offer workshops and technical assistance to any agency that has not yet prepared or implemented the water shortage contingency analysis required by California law.
10. DWR shall offer technical assistance to agricultural water suppliers and agricultural water users, including information on managing water supplies to minimize economic impacts, implementing efficient water management practices, and using technology such as the California Irrigation Management Information System (CIMIS) to get the greatest benefit from available water supplies.
11. The Department of Public Health shall evaluate the adequacy of emergency interconnections among the state's public water systems, and provide technical assistance and continued financial assistance from existing resources to improve or add interconnections.
12. DWR shall continue to monitor the state's groundwater conditions, and shall collect groundwater-level data and other relevant information from water agencies, counties, and cities. It is requested that water agencies, counties and cities cooperate with DWR by providing the information needed to comply with this Proclamation.
13. DWR and the Department of Food and Agriculture shall recommend, within 30 days from the date of this Proclamation, measures to reduce the economic impacts of the drought, including but not limited to, water transfers, through-Delta emergency transfers, water conservation measures, efficient irrigation practices, and improvements to CIMIS.

14. The Department of Boating and Waterways shall recommend, within 30 days from the date of this Proclamation, and in cooperation with the Department of Parks and Recreation, measures to reduce the impacts of the drought conditions to water-based recreation, including but not limited to, the relocation or extension of boat ramps and assistance to marina owners.
15. The Labor and Workforce Development Agency shall recommend, within 30 days from the date of this Proclamation, measures to address the impact of the drought conditions on California's labor market, including but not limited to, identifying impacted areas, providing one-stop service, assisting employers and workers facing layoffs, and providing job training and financial assistance.
16. DWR and the Department of Food and Agriculture shall be the lead agencies in working with the Federal Drought Action Team to coordinate federal and state drought response activities.
17. The emergency exemptions in Public Resources Code sections 21080(b)(3), 21080(b)(4) and 21172, and in California Code of Regulations, title 14, section 15269(c), shall apply to all actions or efforts consistent with this Proclamation that are taken to mitigate or respond to this emergency. In addition, Water Code section 13247 is suspended to allow expedited responses to this emergency that are consistent with this Proclamation. The Secretary for the California Environmental Protection Agency and the Secretary for the California Natural Resources Agency shall determine which efforts fall within these exemptions and suspension, ensuring that these exemptions and suspension serve the purposes of this Proclamation while protecting the public and the environment. The Secretaries shall maintain on their web sites a list of the actions taken in reliance on these exemptions and suspension.
18. By March 30, 2009, DWR shall provide me with an updated report on the state's drought conditions and water availability. If the emergency conditions have not been sufficiently mitigated, I will consider issuing additional orders, which may include orders pertaining to the following:
    (a) institution of mandatory water rationing and mandatory reductions in water use;
    (b) reoperation of major reservoirs in the state to minimize impacts of the drought;
    (c) additional regulatory relief or permit streamlining as allowed under the Emergency Services Act; and
    (d) other actions necessary to prevent, remedy or mitigate the effects of the extreme drought conditions.

I FURTHER REQUEST THAT:

19. All urban water users immediately increase their water conservation activities in an effort to reduce their individual water use by 20 percent.
20. All agricultural water suppliers and agricultural water users continue to implement, and seek additional opportunities to immediately implement, appropriate efficient water management practices in order to minimize economic impacts to agriculture and make the best use of available water supplies.
21. Federal and local agencies also implement water use reduction plans for facilities within their control, including immediate water conservation efforts.

I FURTHER DIRECT that as soon as hereafter possible, this proclamation be filed in the Office of the Secretary of State and that widespread publicity and notice be given of this proclamation.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 27th day of February, 2009.

ARNOLD SCHWARZENEGGER, *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

06/19/2009

Executive Order S-11-09

WHEREAS on June 4, 2008, I issued an Executive Order proclaiming a statewide drought, and I ordered my administration to take immediate action to address the water shortage; and

WHEREAS on June 12, 2008, I proclaimed a state of emergency for nine Central Valley counties because the drought had caused conditions of extreme peril to the safety of persons and property; and

WHEREAS on February 27, 2009, I proclaimed a state of emergency for the entire state as the severe drought conditions continued and the impacts were well beyond the Central Valley; and

WHEREAS the February 27, 2009 state of emergency proclamation provided specific orders and directions to my Department of Water Resources, State Water Resources Control Board, Department of General Services, Department of Public Health, California Department of Food and Agriculture, and Labor and Workforce Development Agency to reduce and mitigate the human, environmental, and economic impact of the drought; and

WHEREAS I have supported state and local water managers' efforts to increase the availability of water, directed efforts to better integrate regional water management practices to balance water demand with water supply, directed expedited water transfers, ordered increased job training, and substantially increased statewide water conservation; and

WHEREAS I have requested and we have received United States Department of Agriculture disaster designations for 21 counties for drought; and

WHEREAS the drought conditions have exacerbated unemployment and the local emergency food banks are struggling to meet the demands of hungry families.

NOW, THEREFORE, I, ARNOLD SCHWARZENEGGER, Governor of the State of California, in accordance with the authority vested in me by the state Constitution and statutes, activate the California Disaster Assistance Act to provide temporary supplemental assistance to the local governments and non-profit organizations that provide food and other aid to those who are impacted by the drought statewide.

IT IS HEREBY ORDERED that my California Emergency Management Agency, Department of Social Services, Labor and Workforce Development Agency, and California Department of Food and Agricultural develop a comprehensive strategy by July 15, 2009, to provide adequate nutrition for those individuals who are temporarily unable to afford food as a result of the drought conditions.

IT IS FURTHER ORDERED THAT the provisions of California Unemployment Insurance Code section 1253 imposing a one-week waiting period for unemployment insurance applicants are suspended as to all applicants who are unemployed as a specific result of the drought conditions, who apply for unemployment insurance benefits during the time period beginning June 19, 2009, and ending on the close of business on November 1, 2009, and who are otherwise eligible for unemployment insurance benefits in California.

I FURTHER DIRECT that as soon as hereafter possible, this Order be filed in the Office of the Secretary of State and that widespread publicity and notice be given this Order.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 19th Day of June 2009.

ARNOLD SCHWARZENEGGER, *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

State of Emergency Fresno County

PROCLAMATION BY THE GOVERNOR OF THE STATE OF CALIFORNIA

WHEREAS on June 4, 2008, I issued an Executive Order proclaiming a statewide drought, and I ordered my administration to begin taking action to address the water shortage; and

WHEREAS on June 12, 2008, I proclaimed a state of emergency for nine Central Valley counties because the current and continuing severe drought had caused conditions of extreme peril to the safety of persons and property; and

WHEREAS on February 27, 2009, I proclaimed a state of emergency for the entire state as the severe drought conditions continued and the impacts were well beyond the Central Valley; and

WHEREAS on June 19, 2009, I issued an Executive Order that suspended the one-week waiting period for unemployment insurance applications and ordered the development of a comprehensive strategy to provide adequate nutrition for those individuals who are temporarily unable to afford food as a result of the severe drought conditions; and

WHEREAS severe drought conditions continue and over 28,000 people in Fresno County require emergency food assistance; and

WHEREAS local emergency food assistance organizations serving the Fresno County area cannot keep up with the demand for food; and

WHEREAS the circumstances of these continuing severe drought conditions, by reason of their magnitude, are or are likely to be beyond the control of the services, personnel, equipment, and facilities of any single county, city and county, or city and require the combined forces of a mutual aid region or regions to combat; and

WHEREAS under the provisions of section 8558(b) of the California Government Code, I find that conditions of extreme peril to the safety of persons and property continue to exist in Fresno County, caused by the current and continuing severe drought conditions.

NOW, THEREFORE, I, ARNOLD SCHWARZENEGGER, Governor of the State of California, in accordance with the authority vested in me by the state Constitution and statutes, including the California Emergency Services Act, and in particular, section 8625 of the California Government Code, HEREBY PROCLAIM A STATE OF EMERGENCY to exist within Fresno County.

IT IS HEREBY ORDERED that all agencies of the state government utilize and employ state personnel, equipment and facilities for the performance of any and all activities consistent with the direction of the California Emergency Management Agency (CalEMA) and the State Emergency Plan, and that CalEMA provide local government assistance under the authority of the California Disaster Assistance Act.

I FURTHER DIRECT that as soon as hereafter possible, this proclamation be filed in the Office of the Secretary of State and that widespread publicity and notice be given of this proclamation.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 21st Day of July 2009.

ARNOLD SCHWARZENEGGER, *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

05/20/2013

Executive Order B-21-13

WHEREAS much of California experienced record dry conditions in January through March 2013, registering historic lows on the Northern Sierra and the San Joaquin precipitation indices; and

WHEREAS record dry and warm conditions resulted in a snowpack substantially below average, with estimated May water content in the statewide snowpack being only 17 percent of average and with the spring snowmelt season now being well underway; and

WHEREAS the water year began with adequate rainfall, but restrictions to protect Delta smelt prevented pumping water from the Delta to store in the San Luis Reservoir have resulted in substantial losses to the State Water Project and to the Central Valley Project; and

WHEREAS only 35 percent of State Water Project contractors' and 20 percent of south-of-Delta Central Valley Project agricultural contractors' requested amounts have been allocated because of these conditions; and

WHEREAS reductions in surface water deliveries will likely force San Joaquin Valley agricultural water users to extract additional groundwater from already overused basins, potentially resulting in additional land subsidence; and

WHEREAS the supply reductions will jeopardize agricultural production in parts of the San Joaquin Valley; and

WHEREAS the supply reductions will also impact millions of municipal and industrial water users across California; and

WHEREAS the Legislature has, in Water Code section 109, declared that the State's established policy is to facilitate the voluntary transfer of water and water rights, and has directed the Department of Water Resources and State Water Resources Control Board to encourage voluntary transfers.

NOW, THEREFORE, I, EDMUND G. BROWN JR., Governor of the State of California, do hereby issue this Order to become effective immediately.

IT IS HEREBY ORDERED that the Department of Water Resources (DWR) and the State Water Resources Control Board (SWRCB) take immediate action to address the dry conditions and water delivery limitations, by doing the following:

1. Expedite processing of one-year water transfers for 2013 and assist water transfer proponents and suppliers as necessary, provided that the transfers will not harm other legal users of water and will not unreasonably affect fish, wildlife, or other in-stream beneficial uses.
2. The SWRCB shall expedite review and processing of water transfer petitions in accordance with applicable provisions of the Water Code.
3. The DWR shall expedite and facilitate water transfer proposals in accordance with applicable provisions of the Water Code.
4. The DWR shall coordinate State Water Project operations, in cooperation with Central Valley Project operations, to alleviate critical impacts to San Joaquin Valley agriculture.
5. The DWR shall continue to analyze trends in groundwater levels in the San Joaquin Valley, together with impacts of groundwater extraction on land subsidence.
6. The DWR and the SWRCB shall make all efforts to coordinate with relevant federal agencies, water districts, and water agencies to expedite the review and approval

of water transfers in California.

This order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

I FURTHER DIRECT that as soon as hereafter possible, this Executive Order be filed in the Office of the Secretary of State and that widespread publicity and notice be given to this Executive Order.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 20th day of May 2013.

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

11/17/2014

A Proclamation of a State of Emergency

WHEREAS the State of California is experiencing record dry conditions, with 2014 projected to become the driest year on record; and

WHEREAS the state's water supplies have dipped to alarming levels, indicated by: snowpack in California's mountains is approximately 20 percent of the normal average for this date; California's largest water reservoirs have very low water levels for this time of year; California's major river systems, including the Sacramento and San Joaquin rivers, have significantly reduced surface water flows; and groundwater levels throughout the state have dropped significantly; and

WHEREAS dry conditions and lack of precipitation present urgent problems: drinking water supplies are at risk in many California communities; fewer crops can be cultivated and farmers' long-term investments are put at risk; low-income communities heavily dependent on agricultural employment will suffer heightened unemployment and economic hardship; animals and plants that rely on California's rivers, including many species in danger of extinction, will be threatened; and the risk of wildfires across the state is greatly increased; and

WHEREAS extremely dry conditions have persisted since 2012 and may continue beyond this year and more regularly into the future, based on scientific projections regarding the impact of climate change on California's snowpack; and

WHEREAS the magnitude of the severe drought conditions presents threats beyond the control of the services, personnel, equipment and facilities of any single local government and require the combined forces of a mutual aid region or regions to combat; and

WHEREAS under the provisions of section 8558(b) of the California Government Code, I find that conditions of extreme peril to the safety of persons and property exist in California due to water shortage and drought conditions with which local authority is unable to cope.

NOW, THEREFORE, I, EDMUND G. BROWN JR., Governor of the State of California, in accordance with the authority vested in me by the state Constitution and statutes, including the California Emergency Services Act, and in particular, section 8625 of the California Government Code **HEREBY PROCLAIM A STATE OF EMERGENCY** to exist in the State of California due to current drought conditions.

IT IS HEREBY ORDERED THAT:

1. State agencies, led by the Department of Water Resources, will execute a statewide water conservation campaign to make all Californians aware of the drought and encourage personal actions to reduce water usage. This campaign will be built on the existing Save Our Water campaign (www.saveourh20.org) and will coordinate with local water agencies. This campaign will call on Californians to reduce their water usage by 20 percent.

2. Local urban water suppliers and municipalities are called upon to implement their local water shortage contingency plans immediately in order to avoid or forestall outright restrictions that could become necessary later in the drought season. Local water agencies should also update their legally required urban and agricultural water management plans, which help plan for extended drought conditions. The Department of Water Resources will make the status of these updates publicly available.

3. State agencies, led by the Department of General Services, will immediately implement water use reduction plans for all state facilities. These plans will include immediate water conservation actions, and a moratorium will be placed on new, non-essential landscaping projects at state facilities and on state highways and roads.

4. The Department of Water Resources and the State Water Resources Control Board (Water Board) will expedite the processing of water transfers, as called for in Executive Order B-21-13. Voluntary water transfers from one water right holder to another enables water to flow where it is needed most.

5. The Water Board will immediately consider petitions requesting consolidation of the places of use of the State Water Project and Federal Central Valley Project, which would streamline water transfers and exchanges between water users within the areas of these two major water projects.

6. The Department of Water Resources and the Water Board will accelerate funding for water supply enhancement projects that can break ground this year and will explore if any existing unspent funds can be repurposed to enable near-term water conservation projects.

7. The Water Board will put water right holders throughout the state on notice that they may be directed to cease or reduce water diversions based on water shortages.

8. The Water Board will consider modifying requirements for reservoir releases or diversion limitations, where existing requirements were established to implement a water quality control plan. These changes would enable water to be conserved upstream later in the year to protect cold water pools for salmon and steelhead, maintain water supply, and improve water quality.

9. The Department of Water Resources and the Water Board will take actions necessary to make water immediately available, and, for purposes of carrying out directives 5 and 8, Water Code section 13247 and Division 13 (commencing with section 21000) of the Public Resources Code and regulations adopted pursuant to that Division are suspended on the basis that strict compliance with them will prevent, hinder, or delay the mitigation of the effects of the emergency. Department of Water Resources and the Water Board shall maintain on their websites a list of the activities or approvals for which these provisions are suspended.

10. The state's Drinking Water Program will work with local agencies to identify communities that may run out of drinking water, and will provide technical and financial assistance to help these communities address drinking water shortages. It will also identify emergency interconnections that exist among the state's public water systems that can help these threatened communities.

11. The Department of Water Resources will evaluate changing groundwater levels, land subsidence, and agricultural land fallowing as the drought persists and will provide a public update by April 30 that identifies groundwater basins with water shortages and details gaps in groundwater monitoring.

12. The Department of Water Resources will work with counties to help ensure that well drillers submit required groundwater well logs for newly constructed and deepened wells in a timely manner and the Office of Emergency Services will work with local authorities to enable early notice of areas experiencing problems with residential groundwater sources.

13. The California Department of Food and Agriculture will launch a one-stop website (www.cdfa.ca.gov/drought) that provides timely updates on the drought and connects farmers to state and federal programs that they can access during the drought.

14. The Department of Fish and Wildlife will evaluate and manage the changing impacts of drought on threatened and endangered species and species of special concern, and develop contingency plans for state Wildlife Areas and Ecological Reserves to manage reduced water resources in the public interest.

15. The Department of Fish and Wildlife will work with the Fish and Game Commission, using the best available science, to determine whether restricting fishing in certain areas will become necessary and prudent as drought conditions persist.

16. The Department of Water Resources will take necessary actions to protect water quality and water supply in the Delta, including installation of temporary barriers or temporary water supply connections as needed, and will coordinate with the Department of Fish and Wildlife to minimize impacts to affected aquatic species.

17. The Department of Water Resources will refine its seasonal climate forecasting and drought prediction by advancing new methodologies piloted in 2013.

18. The California Department of Forestry and Fire Protection will hire additional seasonal firefighters to suppress wildfires and take other needed actions to protect public safety during this time of elevated fire risk.

19. The state's Drought Task Force will immediately develop a plan that can be executed as needed to provide emergency food supplies, financial assistance, and unemployment services in communities that suffer high levels of unemployment from the drought.

20. The Drought Task Force will monitor drought impacts on a daily basis and will advise me of subsequent actions that should be taken if drought conditions worsen.

I FURTHER DIRECT that as soon as hereafter possible, this Proclamation be filed in the Office of the Secretary of State and that widespread publicity and notice be given of this Proclamation.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 17th day of January, 2014.

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

04/25/2014

A Proclamation of a Continued State of Emergency

WHEREAS on January 17, 2014, I proclaimed a State of Emergency to exist in the State of California due to severe drought conditions; and

WHEREAS state government has taken expedited actions as directed in that Proclamation to minimize harm from the drought; and

WHEREAS California's water supplies continue to be severely depleted despite a limited amount of rain and snowfall since January, with very limited snowpack in the Sierra Nevada mountains, decreased water levels in California's reservoirs, and reduced flows in the state's rivers; and

WHEREAS drought conditions have persisted for the last three years and the duration of this drought is unknown; and

WHEREAS the severe drought conditions continue to present urgent challenges: water shortages in communities across the state, greatly increased wildfire activity, diminished water for agricultural production, degraded habitat for many fish and wildlife species, threat of saltwater contamination of large fresh water supplies conveyed through the Sacramento-San Joaquin Bay Delta, and additional water scarcity if drought conditions continue into 2015; and

WHEREAS additional expedited actions are needed to reduce the harmful impacts from the drought as the state heads into several months of typically dry conditions; and

WHEREAS the magnitude of the severe drought conditions continues to present threats beyond the control of the services, personnel, equipment, and facilities of any single local government and require the combined forces of a mutual aid region or regions to combat; and

WHEREAS under the provisions of section 8558(b) of the Government Code, I find that conditions of extreme peril to the safety of persons and property continue to exist in California due to water shortage and drought conditions with which local authority is unable to cope; and

WHEREAS under the provisions of section 8571 of the Government Code, I find that strict compliance with the various statutes and regulations specified in this proclamation would prevent, hinder, or delay the mitigation of the effects of the drought.

NOW, THEREFORE, I, EDMUND G. BROWN JR., Governor of the State of California, in accordance with the authority vested in me by the Constitution and statutes of the State of California, including the Emergency Services Act and in particular Government Code section 8567, do hereby issue this Executive Order, effective immediately, to mitigate the effects of the drought conditions upon the people and property within the State of California.

IT IS HEREBY ORDERED THAT:

1. The orders and provisions contained in Proclamation No. 1-17-2014, dated January 17, 2014, remain in full force and effect except as modified herein.

2. The Department of Water Resources and the State Water Resources Control Board (Water Board) will immediately and expeditiously process requests to move water to areas of need, including requests involving voluntary water transfers, forbearance agreements, water exchanges, or other means. If necessary, the Department will request that the Water Board consider changes to water right permits to enable such voluntary movements of water.

3. Recognizing the tremendous importance of conserving water during this drought, all California residents should refrain from wasting water:

   a. Avoid using water to clean sidewalks, driveways, parking lots and other hardscapes.

   b. Turn off fountains and other decorative water features unless recycled or grey water is available.

   c. Limit vehicle washing at home by patronizing local carwashes that use recycled water.

   d. Limit outdoor watering of lawns and landscaping to no more than two times a week.

   Recreational facilities, such as city parks and golf courses, and large institutional complexes, such as schools, business parks and campuses, should immediately implement water reduction plans to reduce the use of potable water for outdoor irrigation.

   Commercial establishments such as hotel and restaurants should take steps to reduce water usage and increase public awareness of the drought through measures such as offering drinking water only upon request and providing customers with options to avoid daily washing of towels or sheets.

   Professional sports facilities, such as basketball arenas, football, soccer, and baseball stadiums, and hockey rinks should reduce water usage and increase public awareness of the drought by reducing the use of potable water for outdoor irrigation and encouraging conservation by spectators.

   The Water Board shall direct urban water suppliers that are not already implementing drought response plans to limit outdoor irrigation and other wasteful water practices such as those identified in this Executive Order. The Water Board will request by June 15 an update from urban water agencies on their actions to reduce water usage and the effectiveness of these efforts. The Water Board is directed to adopt emergency regulations as it deems necessary, pursuant to Water Code section 1058.5, to implement this directive.

   Californians can learn more about conserving water from the Save Our Water campaign (SaveOurH2O.org).

4. Homeowners Associations (commonly known as HOAs) have reportedly fined or threatened to fine homeowners who comply with water conservation measures adopted by a public agency or private water company. To prevent this practice, pursuant to Government Code section 8567, I order that any provision of the governing document, architectural or landscaping guidelines, or policies of a common interest development will be void and unenforceable to the extent it has the effect of prohibiting compliance with the water-saving measures contained in this directive, or any conservation measure adopted by a public agency or private water company, any provision of Division 4, Part 5

(commencing with section 4000) of the Civil Code notwithstanding.

5. All state agencies that distribute funding for projects that impact water resources, including groundwater resources, will require recipients of future financial assistance to have appropriate conservation and efficiency programs in place.

6. The Department of Fish and Wildlife will immediately implement monitoring of winter-run Chinook salmon in the Sacramento River and its tributaries, as well as several runs of salmon and species of smelt in the Delta as described in the April 8, 2014 Drought Operations Plan.

7. The Department of Fish and Wildlife will implement projects that respond to drought conditions through habitat restoration and through water infrastructure projects on property owned or managed by the Department of Fish and Wildlife or the Department of Water Resources for the benefit of fish and wildlife impacted by the drought.

8. The Department of Fish and Wildlife will work with other state and federal agencies and with landowners in priority watersheds to protect threatened and endangered species and species of special concern and maximize the beneficial uses of scarce water supplies, including employment of voluntary agreements to secure instream flows, relocation of members of those species, or through other measures.

9. The Department of Water Resources will expedite the consideration and, where appropriate, the implementation, of pump-back delivery of water through the State Water Project on behalf of water districts.

10. The Water Board will adopt statewide general waste discharge requirements to facilitate the use of treated wastewater that meets standards set by the Department of Public Health, in order to reduce demand on potable water supplies.

11. The Department of Water Resources will conduct intensive outreach and provide technical assistance to local agencies in order to increase groundwater monitoring in areas where the drought has significant impacts, and develop updated contour maps where new data becomes available in order to more accurately capture changing groundwater levels. The Department will provide a public update by November 30 that identifies groundwater basins with water shortages, details remaining gaps in groundwater monitoring, and updates its monitoring of land subsidence and agricultural land fallowing.

12. The California Department of Public Health, the Office of Emergency Services, and the Office of Planning and Research will assist local agencies that the Department of Public Health has identified as vulnerable to acute drinking water shortages in implementing solutions to those water shortages.

13. The Department of Water Resources and the Water Board, in coordination with other state agencies, will provide appropriate assistance to public agencies or private water companies in establishing temporary water supply connections to mitigate effects of the drought.

14. For the protection of health, safety, and the environment, CAL FIRE, the Office of Emergency Services, the Department of Water Resources, and the Department of Public Health, where appropriate, may enter into contracts and arrangements for the procurement of materials, goods, and services necessary to quickly mitigate the effects of the drought.

15. Pursuant to the drought legislation I signed into law on March 1, 2014, by July 1, 2014, the California Department of Food and Agriculture, in consultation with the Department of Water Resources and Water Board, will establish and implement a program to provide financial incentives to agricultural operations to invest in water irrigation treatment and distribution systems that reduce water and energy use, augment supply, and increase water and energy efficiency in agricultural applications.

16. To assist landowners meet their responsibilities for removing dead, dying and diseased trees and to help landowners clear other trees and plants close to structures that increase fire danger, certain noticing requirements are suspended for these activities. Specifically, the requirement that any person who conducts timber operations pursuant to the exemptions in Title 14, California Code of Regulations sections 1038 (b) and (c) submit notices to CAL FIRE under the provisions of Title 14, California Code of Regulations, section 1038.2 is hereby suspended. Timber operations pursuant to sections 1038(b) and (c) may immediately commence operations upon submission of the required notice to CAL FIRE and without a copy of the Director's notice of acceptance at the operating site. All other provisions of these regulations will remain in effect.

17. The Water Board will adopt and implement emergency regulations pursuant to Water Code section 1058.5, as it deems necessary to prevent the waste, unreasonable use, unreasonable method of use, or unreasonable method of diversion of water, to promote water recycling or water conservation, and to require curtailment of diversions when water is not available under the diverter's priority of right.

18. In order to ensure that equipment and services necessary for drought response can be procured quickly, the provisions of the Government Code and the Public Contract Code applicable to state contracts, including, but not limited to, advertising and competitive bidding requirements, are hereby suspended for directives 7 and 14. Approval by the Department of Finance is required prior to the execution of any contract entered into pursuant to these directives.

19. For several actions called for in this proclamation, environmental review required by the California Environmental Quality Act is suspended to allow these actions to take place as quickly as possible. Specifically, for actions taken by state agencies pursuant to directives 2, 3, 6¬-10, 13, 15, and 17, for all actions taken pursuant to directive 12 when the Office of Planning and Research concurs that local action is required, and for all necessary permits needed to implement these respective actions, Division 13 (commencing with section 21000) of the Public Resources Code and regulations adopted pursuant to that Division are hereby suspended. The entities implementing these directives will maintain on their websites a list of the activities or approvals for which these provisions are suspended. This suspension and that provided in paragraph 9 of the January 17, 2014 Proclamation will expire on December 31, 2014, except that actions started prior to that date shall not be subject to Division 13 for the time required to complete them.

20. For several actions called for in this proclamation, certain regulatory requirements of the Water Code are suspended to allow these actions to take place as quickly as possible. Specifically, for actions taken pursuant to directive 2, section 13247 of the Water Code is suspended. The 30-day comment period

provided in section 1726(f) of the Water Code is also suspended for actions taken pursuant to directive 2, but the Water Board will provide for a 15-day comment period. For actions taken by state agencies pursuant to directives 6 and 7, Chapter 3 of Part 3 (commencing with section 85225) of the Water Code is suspended. The entities implementing these directives will maintain on their websites a list of the activities or approvals for which these provisions are suspended.

I FURTHER DIRECT that as soon as hereafter possible, this Proclamation shall be filed in the Office of the Secretary of State and that widespread publicity and notice be given to this Proclamation.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 25th day of April, 2014

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

09/19/2014

Executive Order B-26-14

WHEREAS on January 17, 2014, I proclaimed a State of Emergency to exist throughout the State of California due to severe drought conditions; and

WHEREAS on April 25, 2014, I proclaimed a Continued State of Emergency to exist throughout the State of California due to the ongoing drought; and

WHEREAS drought conditions have persisted for the last three years and the duration of this drought is unknown; and

WHEREAS many residents across the state who rely on domestic wells or very small water systems now live in homes that can no longer provide water for drinking or sanitation purposes due to declining groundwater supplies resulting from the drought; and

WHEREAS the shortage of water for drinking and sanitation purposes that many residents now face constitutes a threat to human health and safety; and

WHEREAS additional expedited actions are needed to reduce the harmful impacts from these water shortages and other impacts of the drought; and

WHEREAS the magnitude of the severe drought conditions continues to present threats beyond the control of the services, personnel, equipment, and facilities of any single local government and require the combined forces of a mutual aid region or regions to combat; and

WHEREAS under the provisions of section 8571 of the California Government Code, I find that strict compliance with various statutes and regulations specified in this order would prevent, hinder, or delay the mitigation of the effects of the drought.

NOW, THEREFORE, I, EDMUND G. BROWN JR., Governor of the State of California, in accordance with the authority vested in me by the Constitution and statutes of the State of California, in particular Government Code sections 8567 and 8571 of the California Government Code, do hereby issue this Executive Order, effective immediately.

IT IS HEREBY ORDERED THAT:

The Office of Emergency Services shall provide local government assistance as it deems appropriate for the purposes of providing temporary water supplies to households without water for drinking and/or sanitation purposes under the authority of the California Disaster Assistance Act, California Government Code section 8680 et seq. and California Code of Regulations, Title 19, section 2900 et seq.

The provisions of the Government Code and Public Contract Code applicable to state contracts and procurement, including but not limited to, advertising and competitive bidding requirements, are hereby waived for the sole purpose of allowing state agencies and departments to purchase water for the protection of health, safety, and the environment.

3. The provisions of California Penal Code section 396 prohibiting price gouging in times of emergency are hereby reinstated as of the date of this Order. The 30-day time period limitation under subsection (b) is hereby waived. For the purposes of calculating the price differential, the price of goods or services shall be compared to the price in effect as of the date of this Order.

4. The State Water Resources Control Board, the Department of Water Resources, the Office of Emergency Services, and the Office of Planning and Research will assist local agencies with the identification of acute drinking water shortages in domestic water supplies, and will work with local agencies in implementing solutions to those water shortages. For any actions the listed state agencies take pursuant to this directive, for any actions taken by a local agency where the Office of Planning and Research concurs that local action is required, and for any necessary permits to carry out those actions, Division 13 (commencing with section 21000) of the Public Resources Code and regulations adopted pursuant to that Division are hereby suspended. This suspension will expire on December 31, 2014, except that actions started prior to that date shall not be subject to Division 13 for the time required to complete them.

This Executive Order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

I FURTHER DIRECT that as soon as hereafter possible, this Order be filed in the Office of the Secretary of State and that widespread publicity and notice be given to this Order.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 18th day of September 2014.

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

12/22/2014

Executive Order B-28-14

WHEREAS on January 17, 2014, I proclaimed a State of Emergency to exist throughout the State of California due to severe drought conditions; and

WHEREAS on April 25, 2014, I proclaimed a Continued State of Emergency to exist throughout the State of California due to the ongoing drought; and

WHEREAS the rainfall the State has recently experienced, while significant, is insufficient to end the historic drought that continues to impact the State, and it is unknown how much rain will fall over the next few months; and

WHEREAS additional expedited actions are needed to reduce the harmful impacts from water shortages and other impacts of the drought; and

WHEREAS the magnitude of the severe drought conditions continues to present threats beyond the control of the services, personnel, equipment, and facilities of any single local government and require the combined forces of a mutual aid region or regions to combat; and

WHEREAS under the provisions of section 8571 of the California Government Code, I find that strict compliance with various statutes and regulations specified in this order would prevent, hinder, or delay the mitigation of the effects of the drought.

NOW, THEREFORE, I, EDMUND G. BROWN JR., Governor of the State of California, in accordance with the authority vested in me by the Constitution and statutes of the State of California, in particular Government Code sections 8567 and 8571 of the California Government Code, do hereby issue this Executive Order, effective immediately.

IT IS HEREBY ORDERED THAT:

The waiver of the California Environmental Quality Act and Water Code section 13247 in paragraph 9 of the January 17, 2014 Proclamation, and paragraph 19 of the April 25, 2014 Proclamation, is extended through May 31, 2016. This waiver shall also apply to the adoption of water reclamation requirements by the State Water Board that serve the purpose of paragraph 10 of the April 25, 2014 Proclamation. Drought relief actions taken pursuant to these paragraphs that are started prior to May 31, 2016, but not completed, shall not be subject to Division 13 (commencing with section 21000) of the Public Resources Code or Water Code section 13247 for the time required to complete them.

This Executive Order is not intended to, and does not, create any rights or benefits, substantive or procedural, enforceable at law or in equity, against the State of California, its agencies, departments, entities, officers, employees, or any other person.

I FURTHER DIRECT that as soon as hereafter possible, this Order be filed in the Office of the Secretary of State and that widespread publicity and notice be given to this Order.

IN WITNESS WHEREOF I have hereunto set my hand and caused the Great Seal of the State of California to be affixed this 22nd day of December 2014.

EDMUND G. BROWN JR., *Governor of California*

ATTEST:

DEBRA BOWEN, *Secretary of State*

California Department of Water Resources
1416 Ninth Street, Sacramento, CA 95814
www.water.ca.gov/drought