Southwestern States Flood and Drought Summaries

MAJOR FLOODS AND DROUGHTS IN CALIFORNIA

This page is excerpted from Paulson, R.W., Chase, E.B., Roberts, R.S., and Moody, D.W., Compilers, **National Water Summary 1988-89-- Hydrologic Events and Floods and Droughts:** *U.S. Geological Survey Water-Supply Paper 2375, 591 p.*

Floods and droughts having major impact in terms of magnitude and areal extent are shown in **Figures 1 and 2**, respectively. Areas having flood recurrence intervals between 25 and 50 years and in excess of 50 years are identified in **Figure 1**. Areas having drought recurrence intervals between 10 and 25 years and in excess of 25 years are identified in **Figure 2**. Uncolored areas indicate recurrence intervals less than 25 years for floods and less than 10 years for droughts. Significant multiyear droughts and some of the State's most significant floods are identified chronologically in **Table 1**. Floods that resulted in the greatest loss of life or property were selected, but many significant floods are not included. Thus, for example, no floods are included for 1983, even though the volume of runoff for that year is the greatest on record for most of the State.

Streamflow records from more than 40 gaging stations were analyzed to determine the severity and areal extent of the floods and droughts. Streamflow data are collected, stored, and reopened by water year (a water year is the 12-month period from October 1 through September 30 and is identified by the calendar year in which it ends). The gaging stations were selected to represent the natural patterns of runoff over the entire State. The gaging stations generally are located in, or at least measure flows originating from, the mountainous areas that are the source of most runoff in the State. The arid Basin and Range and Southern California Desert provinces are represented only by gaging stations on their western fringe.

Table 1. Chronology of major and other memorable floods and droughts in California, 1827- 1989

Flood or Drought	Date	Area Affected	Recurrence Interval (in years)	Remarks
Droughts	1827-1916	Variable	Unknown	Multiyear: 1827- 29, 1843- 44, 1856- 57, 1863- 64(particularly extreme), 1887- 88, 1897- 1900, 1912- 13.
Flood	Dec. 1861-Jan. 1862	Statewide	Probably >100	Record stages on major rivers from Oregon to Mexico

Floods	1863-1936	Variable	Unknown	Major: Dec. 1867, Feb. 1884, Jan. 1895, Mar. 1906, Mar. 1907, Jan. 1909, Jan. 1916.
Drought	1917-21	Statewide except central Sierra Nevada and north coast.	10 to 40	Simultaneous in affected areas, 1919- 20. Most extreme in north.
Drought	1922-26	Statewide except central Sierra Nevada	20 to 40	Simultaneous in effect for entire State only during 1924, which was particularly severe.
Drought	1928-37	Statewide	>100	Simultaneously in effect for entire State, 1929- 34. Longest, most severe in State's history.
	Dec. 1937	Northern two-thirds of State.	5 to >100	Several peaks of record in northern and central Sierra Nevada. Damage $15 million.
Flood	Mar. 1938	Coastal basins from San Diego to San Luis Obispo, and parts of Mojave Desert.	50 to 90	Worst in 70 years. Deaths, 87; damage, $79 million.
Drought	1943-51	Statewide	20 to 80	Simultaneously in effect for entire State, 1947- 49. Most extreme in south.
Flood	Nov.-Dec. 1950	Kern River basin north to American River basin.	25 to 80	Deaths, 2; damage, $33 million.
Flood	Dec. 1955	Northern two-thirds of State.	10 to 100	Deaths, 76; widespread damage of $166 million.
Drought	1959-62	Statewide	10 to 75	Most extreme in Sierra Nevada and central coast.
Flood	Dec. 1964	Northern one-half of State	10 to >100	Greatest known in the history of northern California. Deaths, 24; damage, $239 million.
Flood	Dec. 1966	Kern, Tule, and Kaweah River basins.	>100	Deaths, 3; damage, $18 million.
Flood	Jan.-Feb. 1969	Southern and central coastal California, parts of Mojave desert.	30 to 50	Deaths, 60; damage, $400 million.
Drought	1976-77	Statewide, with the exception of southwestern deserts.	>100	Driest 2 years in State's history. Most severe in northern two-thirds of State.
Flood	Jan.-Feb. 1980	Central and southern coastal California.	10 to 50	Most severe in southern California. Deaths, 18; damage, $350 million.
Flood	Jan. 1982	San Francisco Bay area.	30	Severe, mudslides in mountains north of Santa Cruz. Deaths, 31; damage $75 million.

Flood	Feb. 1986	Northern one-half of State.	20 to 100	Peak discharge of record in Napa River and upper Feather River basins. Deaths, 14; damage, $379 million.
Drought	1987-printing	Statewide	10 to 40	Moderate, continuing through 1989. Most extreme in northern Sierra Nevada.

FLOODS

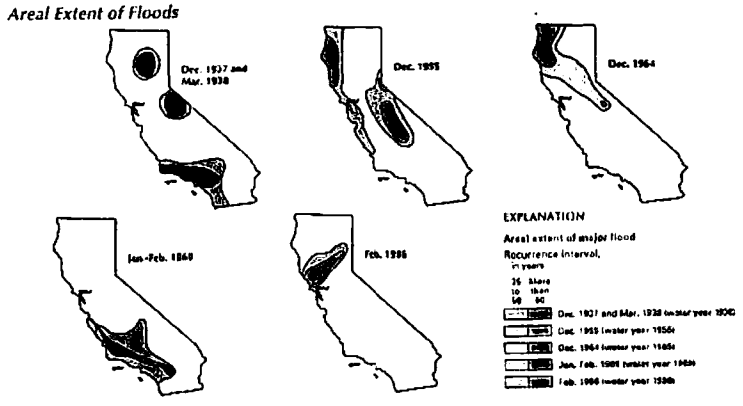

Figure 1. Areal Extent of Floods in California. Click to view a larger image.

In the winter of 1937-38, parts of California were flooded twice. The first floods, in the northern part of the State, were followed less than 3 months later by more flooding in the south. During December 9-12. 1937 (water year 1938). a single, intense storm moved rapidly from the north Pacific Ocean across California and caused flooding. The State Engineer estimated the resulting damage to be $15 million (McGlashan and Briggs, 1939). The storm was warm, and precipitation in the Sierra Nevada fell primarily as rain instead of snow. The most extreme flood-peak discharges were in parts of the northern and central Sierra Nevada.

The December 1937 storm began a period of almost-normal rainfall in southern California. In late January 1938, however, a pattern of almost-continuous and frequently intense rainfall developed in southern California and culminated in a series of storms that affected an area much farther south than usual (Troxell and others, 1942). On March 2,1938, with the southern California terrain saturated, a massive, slow-moving warm front collided with the west-trending mountains of the Transverse Range and resulted in near-record rainfall. Rainfall in this mountain area from February 27 to March 4 averaged 22.5 inches. The greatest rainfall recorded was 32.2 inches at an altitude of 8,300 feet.

Floods occurred from San Luis Obispo to San Diego and inland as far as the Mojave Desert. Runoff was greatest in the Santa Ana, San Gabriel, and Los Angeles River basins and parts of the Santa Clara River basin. Peak flows in much of the area probably were the greatest since the 1861-62 floods. Eighty-seven lives were lost, and the U.S. Army Corps of Engineers estimated the damage at about $79 million (Troxell and others, 1942).

The floods of December 1955 (water year 1956) were memorable not only for the magnitude of peak discharge, but also for the duration of rain and the extent of area affected. Rain fell in coastal areas on 39 of the 44 days between December 15 and January 28 as several storms crossed the northern two-thirds of the State (Hofmann and Rantz, 1963). In most areas, the storm of December 21-24, 1955, caused the most

damage. Warm, moist air from the southwest released rains that drenched the mountains and melted much of the snow that had accumulated in the Sierra Nevada. During December 15-27, extremes of 40 inches of rain fell at several locations, and quantities greater than 20 inches were common in the coastal mountains and the Sierra Nevada.

The floods of December 1955 produced peak discharges in much of the area that were in excess of any previously recorded. Flooding was particularly notable on the Klamath River on the north coast, the San Lorenzo River at Santa Cruz, the Feather River near Yuba City, the Kaweah River at Visalia, Alameda Creek in the San Francisco Bay area, and the Carson River east of the Sierra Nevada. Peak discharges at these widely separated rivers were generally 1 1/2 to 2 times the discharge of the previously recorded peak flows. The peak discharge of the Merced River at Happy Isles Bridge, near Yosemite, had a recurrence interval that exceeded 100 years. On many streams, the floods ranked among the greatest since 1861 -62.

On December 24, 1955, a levee failure on the Feather River flooded more than 3,000 homes in Yuba City and forced the evacuation of 12,000 people. Thirty-eight people died, and 95 percent of the city was inundated with floodwater as much as 12-feet deep. For the entire Sacramento River basin, about 382,000 acres were flooded.

The San Joaquin River basin and the closed basins at the southern end of the Central Valley also were flooded as a result of the December 1955 storms. About 393,000 acres were inundated; the largest damage was in the Kaweah River basin. In the entire State, the floods resulted in 67 deaths and total damage estimated at $166 million by the U.S. Army Corps of Engineers (Hofmann and Rantz, 1963).

The floods of December 1964 (water year 1965) resulted from meteorological conditions similar to those of the December 1955 floods. An arctic airmass moved into northern California on December 14, 1964, and precipitation on December 18-20 produced large quantities of snow (Waananen and others, 1971). Beginning on December 20, a storm track 500 miles wide extended from Hawaii to Oregon and northern California. Warm, moist air collided with the arctic air and resulted in turbulent storms that produced unprecedented rainfall on northern California and melted much of the snow from the previous storms. In the Mattole River basin, nearly 50 inches of rain was reported during December 19-23, with 15 inches observed in 24 hours. In most of the coastal mountains and many locations in the northern Sierra Nevada, the December 19-23 rainfall totals were 20-25 inches.

The December 1964 floods did not extend as far south as those of December 1955, and peak discharges in the San Joaquin River basin were substantially less than during 1955. In the Sacramento River basin, many streams, such as Deer Creek, had peak discharges that were greater than during December 1955. In both basins, flood-control operations generally were able to confine downstream flows within flood-control channels. As a result, loss of life was avoided, and damage was less than one-half that caused by the 1955 flooding.

Exceptionally large flood peaks were recorded on rivers in north-coastal California. On December 23, 1964, peak discharges of the Eel River at Scotia, the Klamath River at Klamath, and the Smith River near Crescent City were 30-40 percent greater than the 1955 peaks and exceeded flood stages of the 1861-62 floods. The peak discharge of the Salmon River at Somes Bar had a recurrence interval that exceeded 100 years. Botanic and geomorphic evidence indicates that floods exceeding the magnitude of the December 1964 floods may not have occurred since about 1600 (Helley and LaMarche,1973). Bridges on every major stream were destroyed. Along the Eel River, flood levels were 10 to 14 feet higher than during the previous peak discharge of record in December 1955. Several towns along the Eel and Klamath Rivers were totally

destroyed. Twenty-four lives were lost in north-coastal California, and flood damage was about $195 million 1.5 times the loss in the same region caused by the December 1955 floods. Total damage for the State was estimated by the U.S. Army Corps of Engineers (1965 a,b) at $239 million.

The flood peak discharges produced by the storms of January and February 1969 were the largest in 30 years in central and southern California and in many places equaled or exceeded those of the March 1938 floods. In the Santa Clara, Santa Ynez, and Salinas River basins, flood levels may have approached those of 1861-62 (Waananen, 1969).

During January 18-27, 1969, a series of storms, drawing on a strong flow of warm, moist air from the southwest, moved across central and southern California. Massive quantities of precipitation fell on the coastal mountains from Monterey Bay to Los Angeles and in the southern Sierra Nevada. Precipitation for January 18-27 ranged from 10 to 15 inches in the lowlands in southern California and reached a maximum of 50.0 inches at a mountain community (altitude 7,700 feet) near San Bernardino. The peak discharge near the mouth of the Santa Clara River was 38 percent greater than the previous record discharge in March 1938. On the Santa Ynez River near Lompoc, the peak discharge was 78 percent greater than that during the floods of March 1938.

In late February 1969, a series of northwestern cold-front storms moved south along a low-pressure trough that had formed over the California coast. Precipitation for February 22-25 ranged from 5 to 15 inches in lowland areas of southern California; Lake Arrowhead (altitude 5,200 feet) recorded 23.9 inches. Almost the same areas were flooded in February as in January. Peak discharges in southern California were slightly less than in January, but the Salinas River at Spreckels on February 26 had a new peak discharge of record that exceeded the March 1938 peak by 11 percent. Sixty lives were lost in the January-February floods, and the estimated property damage was about $400 million (Nelson and Haley, 1970).

The most recent large floods in California were in February 1986. The storm pattern was similar to that of December 1955 and December 1964 and produced substantial rainfall and floods in the northern one-half of the State (California Department of Water Resources, 1988). A series of storms embedded in a flow of moist air from the southwest moved across the State. From February 11 to 22, precipitation was recorded in many areas of northern California for 12 consecutive days. The principal track of the storms passed northeastward over Santa Rosa, Sacramento, and Yuba City into the Feather, Yuba, and American River basins of the Sierra Nevada. The largest total rainfall for the period was 49.6 inches, recorded at Bucks Lake in the Feather River basin. Storm totals of 20-30 inches were common for many locations.

Peaks of record were measured on the Russian River at Guemeville and the Napa River near Napa. Flood damage to downtown Napa was extensive. In the upper Feather River basin, flood peaks were the highest of record. State Highway 70, which follows the North Fork Feather River, was closed for several months because of washouts, landslides, and damaged bridges.

Runoff in the Sacramento River from the February 1986 floods was generally well controlled by timely reservoir releases and by operation of bypass weirs and overflow channels. Levee failures, however, contributed to the 14 deaths, 69 injuries, and 50,000 evacuations caused by the floods. Damage to property was estimated by the State Office of Emergency Services to be $379 million (California Department of Water Resources, 1988). Considering that flood stages in the Sacramento River in the vicinity of Sacramento were the highest since at least 1909, it is fortunate that more levees did not fail.

DROUGHTS

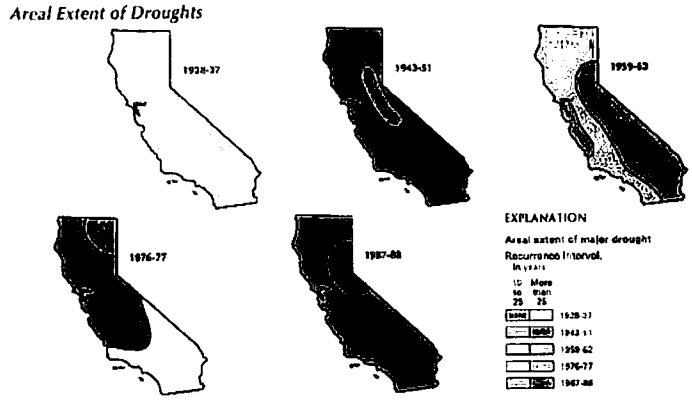

Figure 2. Areal Extent of Droughts in California. Click to view a larger image.

Unlike floods, droughts are not clearly defined. Identifying periods of drought in a statewide context is a matter of subjective interpretation, even in retrospect. The period of drought during the 1920's and 1930's in California, for example, has been variously identified as 1922-34 (Troxell, 1957). 1923-34 (Thomas and others, 1963), 1924-34 (Matthai. 1979). 1928-34 (California Department of Water Resources, 1987), 1929-34 (California Department of Water Resources, 1973), and 1928-37 (Earle and Fritts, 1986). Differences in the duration and severity of droughts from place to place account for much of the discrepancy. Even at a given location, however, it is a matter of judgment whether a period of greater than normal runoff represents the end of a drought or just a minor interruption.

In California, the total annual runoff generally is more important to the State's water supplies than the distribution of runoff within the year. Short periods of greater than normal runoff do not necessarily mark the end of a drought and are commonly included within identified droughts. In some instances, even an entire year of slightly greater than average flow is included in a drought. For example, three of the six representative gaging stations had greater than average flows during water year 1932, which by all accounts is considered to be part of a major statewide drought. In assessing the statewide significance of a period of drought, more importance is given to droughts in the northern part of the State than in the southern part because the northern part is the source of much of the State's developed water supply.

Streamflow records of the Sacramento River Basin Index were used to supplement the period of record for the drought analysis. The Sacramento River Basin Index, compiled by the DWR, is a widely used measure of northern California water supply. The index is adjusted to represent unimpaired runoff and is based on the combined flows from the upper Sacramento, Feather, Yuba, and American River basins. Two separate runoff records of the Sacramento River Basin Index were used in the drought analyses. The historical record is based on flows measured directly at gaging stations from 1906 to 1988 and on estimates of annual run-off made by the DWR by using historical data from 1872 to 1905. A separate record of annual runoff, referred to as the tree-ring reconstruction, has been estimated for 1560 to 1980 by Earle and Fritts (1986) from the analysis of tree rings. The accuracy of the tree-ring reconstruction is limited, and not all historic droughts are replicated in the reconstructed record.

The major drought of the 1920's and 1930's is identified here as lasting from 1928 to 1937, even though drought conditions were simultaneously in effect over the entire State only from 1929 to 1934. Less than normal flows did not begin until 1929 in the northern Coast Ranges and lasted only into 1934 or 1935 for most of the State (**Fig.2**); less than normal flows persisted into 1937 only in the northern one-quarter of the

State. The duration of the drought in different areas thus ranged from about 7 to 10 years. Owing in part to the extended duration, the drought of 1928-37 accumulated the largest deficiency in runoff of any drought in the State's history. It is arguably the State's most severe drought.

The drought of 1928-37 had a recurrence interval exceeding 80 years, based on the longest gaging-station records available. This drought is unequaled in the historical record of the Sacramento River Basin Index dating back to 1872; this indicates that the drought had a recurrence interval of more than 100 years. The streamflow record reconstructed from tree-ring data, moreover, indicates that the drought is unequaled for the entire period from 1560 to 1980; these data indicate a possible recurrence interval of more than 400 years.

For the drought of 1943-51 (**Fig. 2**), the durations at specific gaging stations differed widely. The drought was at its maximum extent (statewide) during 1947-49. In general, the drought lasted 3-4 years in the central and northern Sierra Nevada and 6-8 years in the rest of the State. Yearly departures of runoff were erratic in the northern part of the State; the general trend of the drought was interrupted by much greater than normal runoff early in water year 1946 and nearly normal runoff in water year 1948. This drought was most severe in central and southern coastal areas, where accumulated deficiencies in runoff approached, and in some instances exceeded, those of the drought of 1928-37.

Water year 1951 ranks as the driest of record at several gaging stations in southern coastal California. Recurrence intervals for the drought of 1943-51 were about 20 years in the central and northern Sierra Nevada, because of the short duration there, and about 20-80 years in the rest of the State, where this drought is exceeded in duration and severity only by the drought of 1928-37. The historical record of the Sacramento River Basin Index also indicates that the drought of 1943-51 (recurrence interval 55 years) ranks second only to the drought of 1928-37. The drought of 1943-51 is not well reflected in the streamflow record reconstructed from tree-ring data.

The drought of 1959-62 (**Fig. 2**) began simultaneously state-wide. In general, the drought lasted 4 years along the central and north coast and inland to the northern Sacramento River basin. In the rest of the State, it lasted 3 years. Despite the slightly longer duration in the northern part of the State, accumulated deficiencies in runoff generally increased from north to south.

In the southern one-half of the State, water year 1961 was the driest of the drought of 1959-62, ranking among the driest years of record at many sites. Recurrence intervals for this drought were greatest along the central coast, in the Sierra Nevada, and in the southern California desert (30-75 years). In the rest of the State, recurrence intervals were about 15-20 years. The historical record of the Sacramento River Basin Index indicates a recurrence interval for this drought of 23 years. The streamflow record reconstructed from tree-ring data that reflects reasonably the drought of 1959-62 indicates a recurrence interval of slightly more than 30 years.

The drought of 1976-77 was short and severe. The direct hydrologic effects of the drought were most severe in the northern three-quarters of the State (**Fig. 2**), but the impact of the drought was statewide because of the dependence of southern California on water transfers from the north. The duration of the drought in the areas most affected was about 2 years. Farther south, outside the area of extreme magnitude, the period of deficient runoff began in 1974; for sites in the Southern California Desert province, where the concept of drought has little meaning, the period of deficient runoff began as early as 1970.

Water year 1977 was the driest year of record at almost all gaging stations in the affected area. Water year

1976 ranks as the second driest at gaging stations in the central part of the Coast Ranges and among the five driest in the central and northern Sierra Nevada. The 2-year deficiency in runoff accumulated during the drought is unequaled at gaging stations in the affected area; this deficiency has a recurrence interval that exceeds 80 years. The 2-year deficiency in streamflow is also unequaled in severity for the historical record of the Sacramento River Basin Index. which indicates a recurrence interval of more than 100 years. Like the drought of 1943-51, the drought of 1976-77 is not well reflected in the streamflow record reconstructed from tree-ring data; the recurrence interval is considerably smaller than that derived from the historical record.

In terms of recurrence intervals, the droughts of 1928-37 and 1976-77 are similar; both are of unsurpassed severity among droughts of corresponding duration during the period of systematic record collection. Arguments can be made that either is the most severe drought in the history of the State. Because of the differences between the two droughts, however, direct comparisons‹beyond that provided by an evaluation of recurrence interval‹are difficult. The drought of 1928-37 was longer and accumulated a larger deficiency in runoff. The drought of 1976-77 was more intense and had greater annual deficiencies in runoff.

California's most recent drought began over most of the State in 1987 and is still in progress at the time of this writing (July 1989). In parts of southern California, less than normal runoff began in 1984, but with little statewide implication. The relative deficiencies in runoff accumulated during 1987-88 were greatest along the central coast and in the northern Sierra Nevada.

Water years 1987 and 1988 were approximately equivalent in severity, and neither year, by itself, was exceptionally dry. The drier of the two, which differs depending on the part of the State, ranks as only the fifth to tenth driest on record. The drought period 1987-88 was considerably less severe than the drought of 1976-77 and also less severe than parts of the drought of 1928-37. In different areas of the State, the drought in 1987 and 1988 also was less severe than 2-year periods within the droughts of 1922-26, 1943-51, and 1959- 62. For the years 1987-88, the current drought has a recurrence interval of about 15 years, except in the northern Sierra Nevada, where some gaging stations indicate that the drought had a recurrence interval as great as 35 years. The historical record of the Sacramento River Basin Index indicates a recurrence interval close to 40 years. The record of runoff reconstructed from tree-ring data extends only to 1980 and thus does not allow an analysis.

Plentiful rain and snow in the northern part of the State during March 1989 have averted a third seriously dry year. However, preliminary data indicate that runoff for water year 1989 remains less than normal in all parts of the State. The drought continues, especially along the central coast and in the southern Sierra Nevada.

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Back to Southwestern States Flood and Drought Summaries