THE TOP TEN NORTHERN CALIFORNIA FLOODS OF THE 20TH CENTURY

by

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ABSTRACT

The purpose of this paper is to summarize the big northern California floods of the 20th century. These were all winter season general floods covering a large area. They are caused by a strong flow of moist subtropical air from the southwesterly direction. When the moist winds hit the mountain ranges, air is lifted, with copious amounts of rain extending to high elevations. The primary cause of high river runoff is simply too much rain, but melting of a prestorm snowpack can add to the runoff, perhaps up to 15 percent on major Sierra Nevada west slope rivers.

The history of large floods show that these occur at sporadic intervals. The one in 1907 became the impetus and guide for building the Sacramento River flood control project with its bypass overflow system. Flood control storage behind large multipurpose dams in the foothills added to flood protection. The system design was taxed by the enormous New Years flood of 1997 which set many new records for flood peaks, flood volumes, and in areal extent. There seems to be a trend for increasing flood size in the latter half of the 20th century.

INTRODUCTION

Floods in California can originate from three different causes:

- Winter general floods, which cover a large area
- Spring and early summer snowmelt floods unique to the higher elevation central and southern Sierra Nevada, which occur about once in 10 years on average.
- Local floods from strong thunderstorms, with intense rain over a relatively small area. Often these local storms occur in moist or subtropical air when remnants of eastern Pacific hurricanes get carried into the state. Intense cells also sometimes develop in the warm sector of major winter storms.

The most feared flooding comes from the general winter storms. These storms are slow moving, with a long southwesterly fetch extending toward Hawaii, the so-called "pineapple connection" (Figure 1). Often there is a near balance between a high-pressure area to the south of California and a strong low-pressure area off the northern California or Oregon coast. The greater the pressure difference, the stronger the southwesterly winds, which can reach speeds of 100 km/hr or more at 3000 meters over the San Francisco Bay area. The line of strongest air mass contrast, the frontal zone, can ripple back and forth several hundred kilometers but produces almost continuous rain to fairly high elevations over a

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broad zone in northern or central California (and less commonly in southern California). This warm southwesterly flow pattern is evident in practically all of our large general floods.

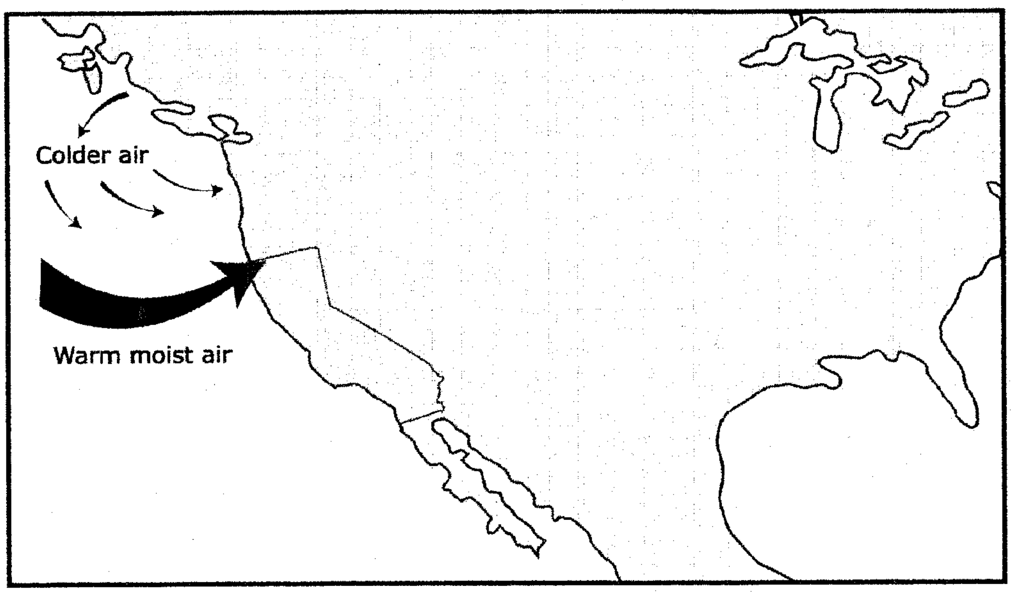


Figure 1. Warm Storm System

An important factor is the mountain barriers. As moisture-laden air is blown over mountains such as the Sierra Nevada, the air is lifted and cooled with additional rain and snow (Figure 2). Typically the orographic precipitation is three to four times the amount in the lowlands. For example, the 1600-meter elevation Blue Canyon weather station, northeast of Sacramento, averages around 1600 millimeters of precipitation per year, about 3.5 times the 450-mm expected at Sacramento, in the middle of the Central Valley. The multiplier ratio on some of the steeper ocean-facing mountain fronts of southern California can be even greater.

The direction of orographic wind flow is important. The greatest amount of water is extracted when the wind flow is at right angles to the mountain barrier, or from the southwest for the Sierra Nevada. A southerly wind direction does not produce such large amounts in the Sierra, but often concentrates precipitation at the north end of the Sacramento Valley, and even the normally rain-shadowed eastern slopes of the northern Coast Ranges if there is a small easterly component. Of course, many storms start out with a more southerly flow during the early phases and shift into a southwesterly and eventually westerly direction as the storm progresses. A west or northwest direction means the flood threat is passing for two reasons: cooler air has less moisture content; and cooler temperatures mean snow at lower elevations, which curtails direct runoff.

A lot of people think snowmelt is the cause of the flooding during the big southwesterly winter storms, but melting snow is a small portion of runoff during these events, perhaps 15 percent on Sierra west slope rivers. Most of the flow is direct rain runoff from intense rain falling to high elevations.

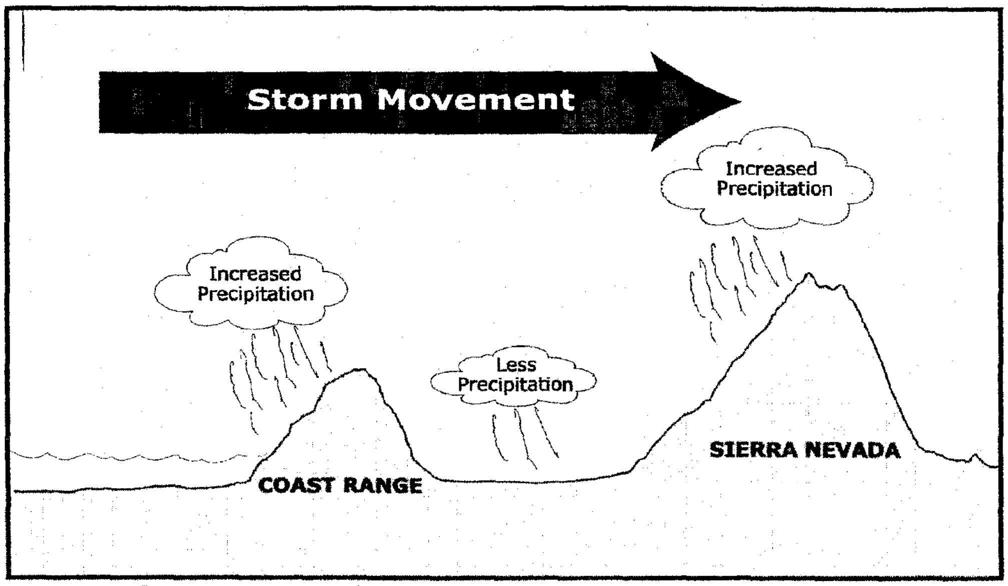


Figure 2. Orographic Precipitation

Another factor is necessary to produce large floods in northern California – wet ground, which requires antecedent precipitation. The most striking example is the Columbus Day storm of October 1962. This storm produced rainfall comparable to "standard project flood" amounts (on the order of a 1 in 200-year event), yet runoff was less than a 10-year annual flood event because the rain fell on dry ground. It produced only a moderate flood, unusually early in the season, but not big enough to make the list of top ten floods.

Folks have generally underestimated the size of the flood threat in our rivers. An exception was John Sutter, who built his Sacramento fort on high ground in 1839 after ascertaining from the Indians how high the water could get. The early pioneers mostly came from the humid east and just simply couldn't grasp that a river could expand 100 to 1000 times its low-flow discharge. They just didn't recognize the risk; some say we still don't.

FLOOD HISTORY

With that background let us look at some of the historic floods. The first is the big one of March 1907. It was a monster flood, with huge outflows of water from the mountains – beyond what anyone had experienced except the few old folks who could remember the legendary inundations of 1862, 45 years earlier.

There had been a 50-year debate over what to do for flood control in the Sacramento Valley. A smaller flood (about half as big as 1907) in 1904 was a wake-up call and stimulated much flood control planning activity. In 1905, in cooperation with the U.S. Geological Survey, the State of California began to put in stream gages to measure flow in the Central Valley. In 1904, a commission of leading river engineers was appointed, headed by Major T. G. Dabney,

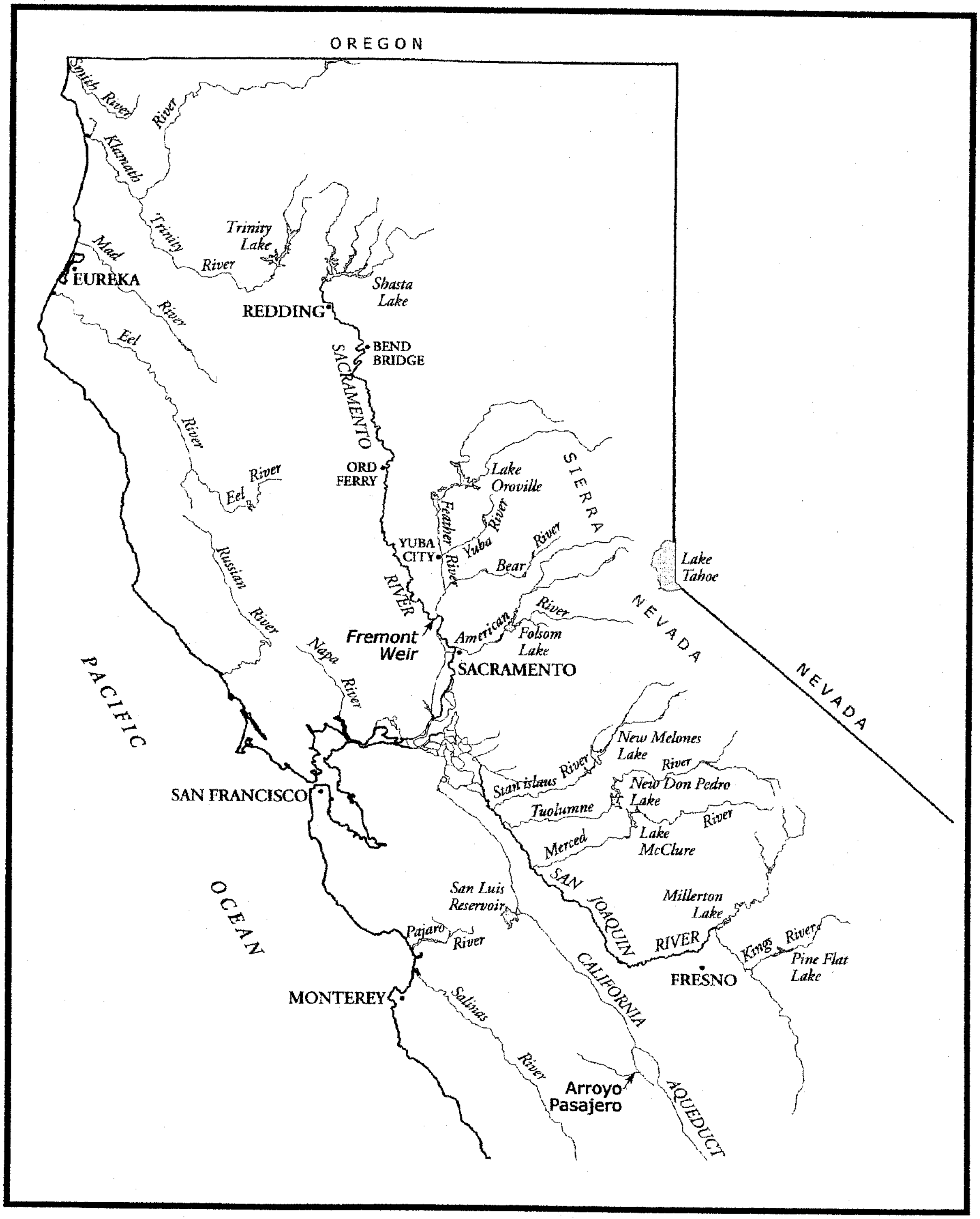


Figure 3. Major Rivers and Lakes in Northern and Central California

a distinguished U.S. Corps of Engineers engineer with 20 years experience in the lower Mississippi River. Relying on that experience, the Dabney Commission rejected the concept of bypasses and recommended that the Sacramento River be confined within levees (wider apart than the present ones) that would allow it to carry 7,000 $m^3/_{sec}$ (250,000 cubic feet per second). The main river channel would then scour, helping to restore river navigability which had been impaired by the hydraulic gold mining era of the 19th century. The report was published in 1905, and the "powers that be" set out to construct the plan as a joint local-state-federal project.

Then, in March 1907, the flood struck. The Feather River burst out of its banks a few miles south of Oroville to rush southwesterly, north of Sutter Buttes, and poured into the Sacramento River above and below the town of Colusa, overwhelming levees and inundating much of the land between the Sacramento and Feather rivers. In all, 120,000 hectares (300,000 acres) were flooded in the Sacramento Valley. By the time the Geological Survey got through analyzing its records, they found that about 17,000 $m^3/_{sec}$ (600,000 cfs) had poured out of the Sacramento River into Suisun Bay.

Two years later, in January 1909, another large flood reinforced this conclusion, with a comparable 3-day volume but not as high an instantaneous peak, at least on the Feather River. This record flood removed lingering doubts about the design flood for the Sacramento River Flood Control Project. It was fortunate that these floods happened before the Dabney Report's project could be constructed; it would have been mostly wasted money.

A gifted engineer, Thomas H. Jackson, from the Corps of Engineers, became a leading spirit in the California Debris Commission. Captain Jackson and the Debris Commission got right to work and produced a new plan in 1910, which included overflow weirs and bypasses. This plan has become the Sacramento River Flood Control Project (Figure 4). At the latitude of Sacramento, it can handle about 17,000 $m^3/_{sec}$ (600,000 cfs – 110,000 in the Sacramento River and 500,000 cfs in the Yolo Bypass), with the design based largely on a blend of the 1907 and 1909 flood events (see Figure 4). This design has served well, including the great 1986 and the huge 1997 floods. Remember, the initial plan did not include flood control reservoirs in the foothills – but was built to contain the largest expected flood – maybe about 50-year flood protection. The big flood control reservoirs were added later to further improve protection.

After 1909, no really big regional flood seems to have occurred until the 1950's. There was a moderate-sized flood in March 1928, another in December 1937, and again in late February 1940.

But we have to move to water year 1951, specifically November 1950, to see a resurgence of heavy southwesterly-origin downpours. This storm was especially heavy in the southern Sierra, with 2600 $m^3/_{sec}$ (91,000 cfs) peak flow on the Kings River east of Fresno, and was further impetus to complete the four major Tulare Lake Region flood control reservoirs from the Kings to Kern rivers: Pine Flat, Terminus (Lake Kaweah), Success, and Isabella reservoirs (and also Folsom Reservoir on the American River near Sacramento). The 1950 storm was not particularly impressive in the northern Sacramento Valley. Pine Flat and Isabella dams were completed in 1954; Folsom in 1956 (but the dam was ready for flood control in 1955), and Success and Terminus dams were completed in 1961 and 1962.

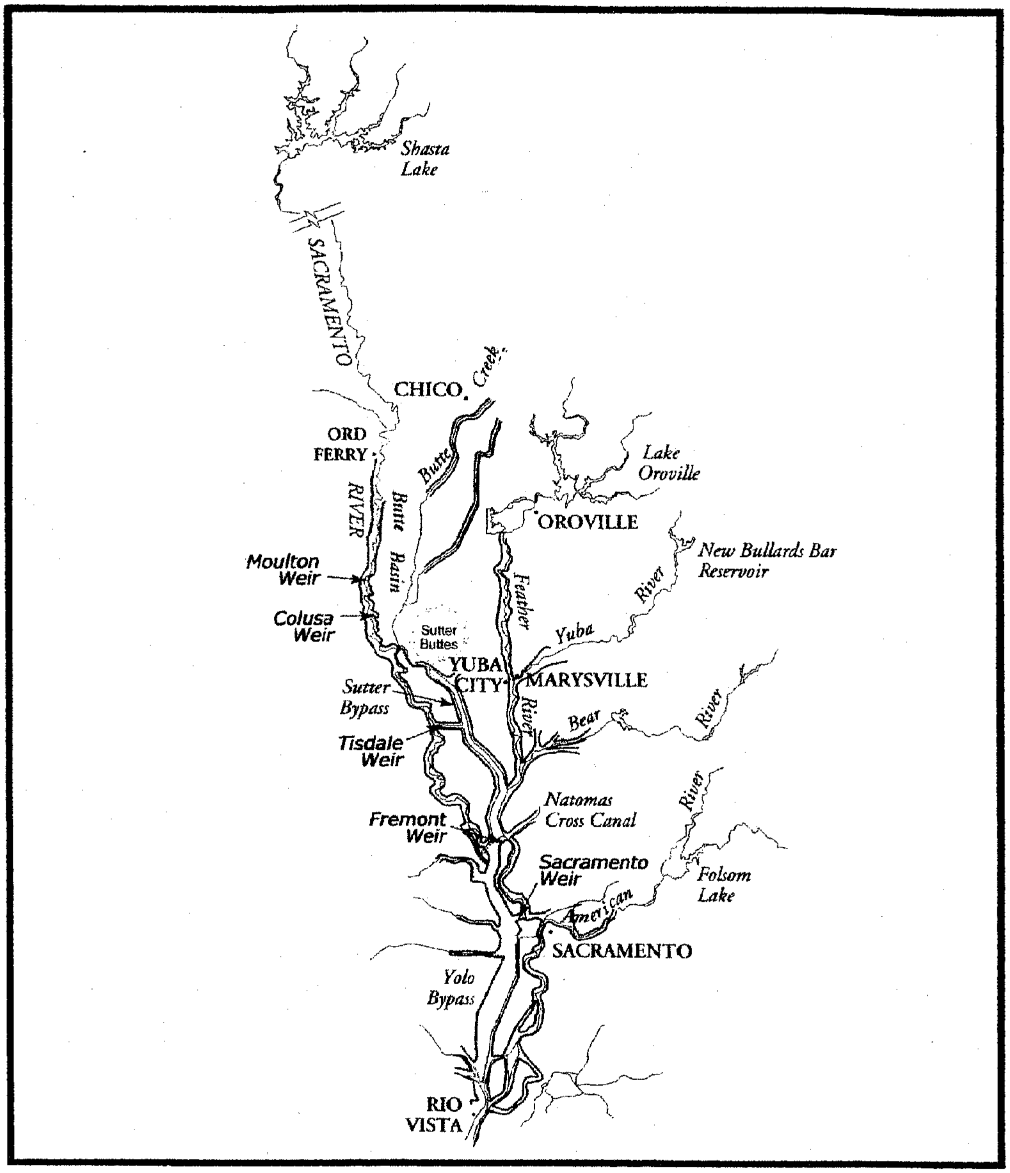


Figure 4. Sacramento River Flood Control System

As several of these new flood control projects became operational, an even larger flood was unleashed a few days before Christmas 1955. The storm ranged over most of the central and northern part of California from Bakersfield to the Oregon border. It was larger than the 1907 flood on the upper Sacramento and American rivers, but not quite as big on the Feather River. The North Coast was hit heavily, with the greatest flow of record (to that time), 15,000 m^3/sec (541,000 cfs), on the Eel River. A break in the Feather River levee at Yuba City caused 38 deaths.

Nine years later, in December 1964, a still bigger flood struck. Again a large area was affected, from about Fresno northward into western Oregon. The runoff of the North Coast rivers was enormous, with a peak flow shooting past the 1955 record to around 21,200 m^3/sec (750,000 cfs) on the Eel River at Scotia. The area was devastated. Three-day runoff on the Feather River exceeded the 1907 peak and the nearly comparable 1955 peak, with a 3-day flow rate of 4,700 m^3/sec (165,000 cfs), but the partially completed Oroville Dam reduced the peak and undoubtedly prevented severe flood damage in the Sacramento Valley.

Except for the December 1966 intense flood in the southern Sierra, most of the middle part of California had a respite for two decades. But 1969 was a very wet water year, with a large snowmelt flood on the San Joaquin River from a snowpack that was 210 percent of average statewide on April 1.

In January 1970 and in the same month in 1974 we saw a pair of very large floods on the upper Sacramento River, with three-day unimpaired flow rates exceed in 5,700 m^3/sec (200,000 cfs) near Red Bluff. These appear to be the largest floods of record here, slightly exceeding the December 1964 event and another large flood in 1940, and definitely more than the 1907 flood on which the system designed was patterned. But these two floods were upper Sacramento floods and, although large, were not unusual on other northern California rivers.

Water year 1983 was the wettest this century, but did not produce any major river floods, except on the upper Sacramento River, although rivers ran high for an extended period. Once again, the high Sierra accumulated an enormous snowpack, over twice average. But shrewd operation of the reservoir system averted major snowmelt flood damage. Tulare Lake, in the southern San Joaquin Valley, even became California's largest fresh water lake for a short time.

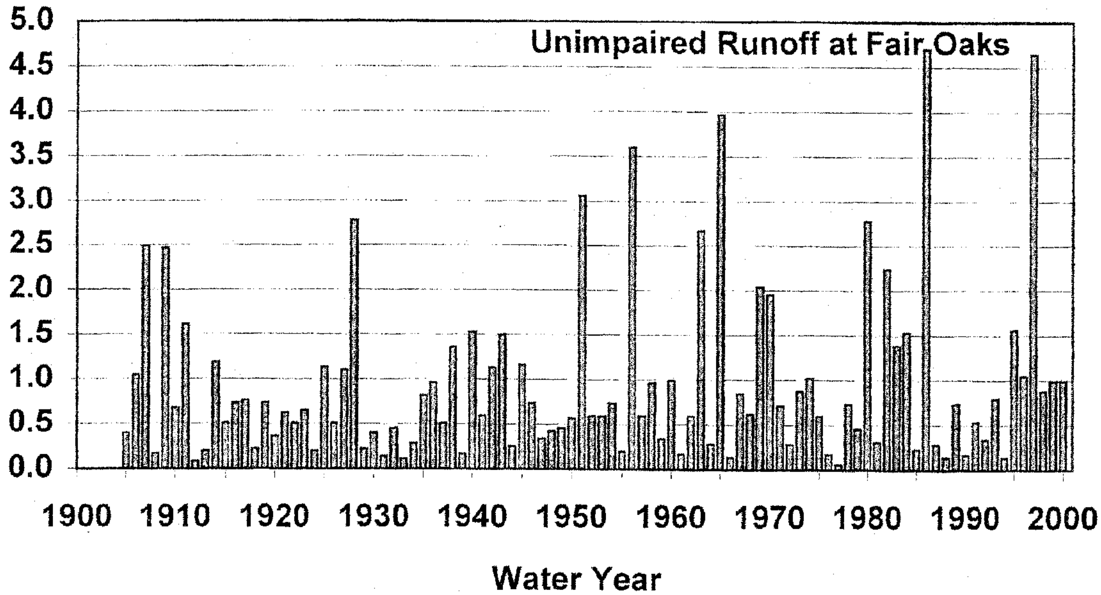
Now we come to a really big one for the north-central part of California – the February 1986 flood. Until nearly the middle of February in that water year, conditions were a little drier than average. Then we got about a half-year's precipitation in ten days. Again it was a classical warm subtropical southwesterly flow situation. The heaviest rain areas were from the northern San Francisco Bay area across the central Sierra. Although flooding occurred on the North Coast and on the upper Sacramento River, floods were not unusually large in those regions.

The Eel River, for example, peaked at 10,300 m^3/sec (364,000 cfs) about half the 1964 flood. But the sheer volume of flow in the mid-Sierra from the Feather River on down through Mokelumne River was astounding, as shown by flood size comparisons on the American River (Figure 5). (The three-day floodflow rate is shown because that time period better indicates the need for foothill reservoir flood control storage).

The lower Sacramento River floodway system was taxed to near design levels. In fact, Fremont Weir and Yolo Bypass stages actually rose over design. The unexpectedly large American River flow (Figure 5) generated, in its aftermath, proposals for more flood control. A few hours more of the steady rain of 8 mm per hour on the watershed could have been disastrous to the Sacramento area.

From there, the scene shifted into drought, and it was 1995 before significant high water recurred. However, the 1995 floods were not that big on the major rivers of northern California, except near the coast. The Russian River approached its 1986 peak in January,

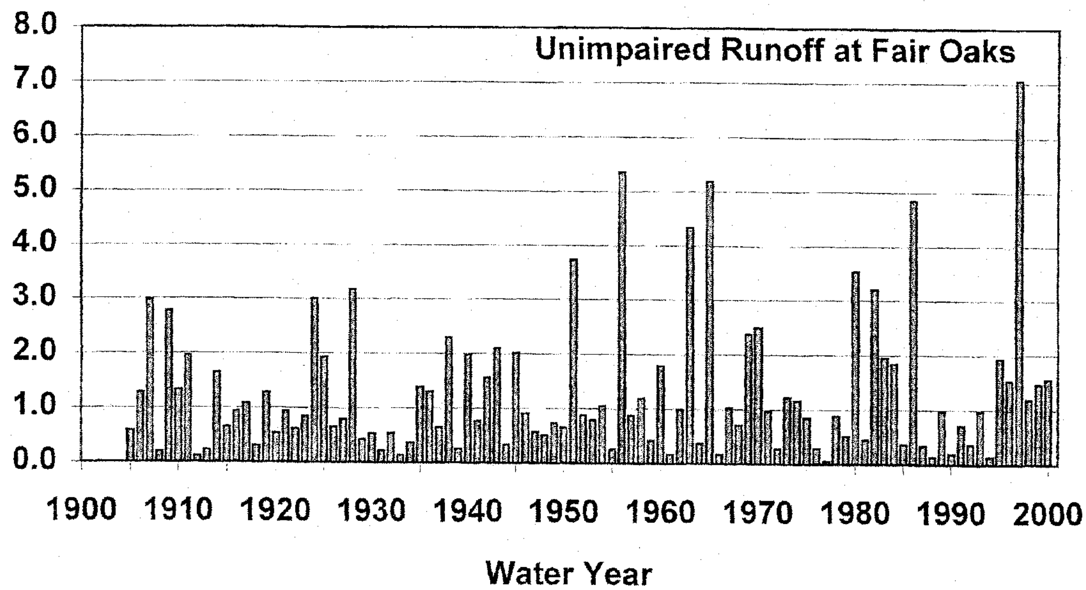
Figure 5. American River Runoff
Annual Maximum 3-Day Flow
1,000 cubic meters per second



and the Napa River reached a peak of record in March. The real surprise was the Salinas River, which crested in March near Spreckels east of Monterey over one meter above the 1952 record. This was within 0.5 m or so of the estimated stage back in the legendary 1862 flood – long before the two upstream Nacimiento and San Antonio dams were built. Further north, the Pajaro River, while exceeding its flood stage at Chittenden gage, did not quite reach the peak of record set in 1958. On the west side of the San Joaquin Valley near Coalinga, Arroyo Pasajero flows near Coalinga collapsed the Interstate-5 bridge crossing; these flows probably were close to a 100-year event.

Last, we come to the biggest flood of all, the New Years Day flood of 1997. This flood was caused by one of the largest storms of the century. The storm represented a classic orographic event with relatively warm winds blowing from the southwest over the Sierra Nevada and dropping astounding amounts of rain at the middle and high elevation. Watersheds were already saturated from previous storms in December. The volume of runoff exceeded previously recorded volumes in most Sierra streams. Many flood control reservoirs filled and made record downstream releases. It was notable in the sustained intensity of rainfall, the volume of floodwater, and the areal extent—from the Oregon border down to the southern Sierra. New flood records were set on many of the major Central Valley rivers. The peak annual one-day American River flood flows are shown in Figure 6.

Figure 6. American River Runoff
Annual Maximum 1-Day Flow
1,000 cubic meters per second



Over the 8-day period peaking on New Year's Day, warm moist winds from the southwest blowing over the Sierra Nevada poured more than 30 inches of rain onto watersheds that were already saturated by one of the wettest Decembers on record. The entire northern Sierra saw 20 inches, 40 percent of average annual precipitation during this short period. The sheer volume of runoff exceeded the flood control capacity of Don Pedro Reservoir on the Tuolumne River and Millerton Lake on the upper San Joaquin River. Most of the other large dams in northern California were full or nearly full in the first days in January.

Floods were produced on the Coast Range as well, but not to record levels. The Russian, Napa, and Pajaro rivers did not rise as high as the severe floods of 1995. Farther north, the Eel, Klamath and Smith Rivers rose higher than in 1995, but did not set records.

A few days before the flood, on December 23, 1996, a very cold snowstorm produced heavy snows to low elevations (125 mm of water content at Blue Canyon). The big storm then dropped over 750 mm of rain in some locations, melting the existing snowpack at the lower elevations. The middle and high elevation snowpack remained; the rain percolated through the pack, and little snow was lost. This contrasts with the public's impression that the melting snow caused the floods. Snowmelt from lower elevations only seems to have added about

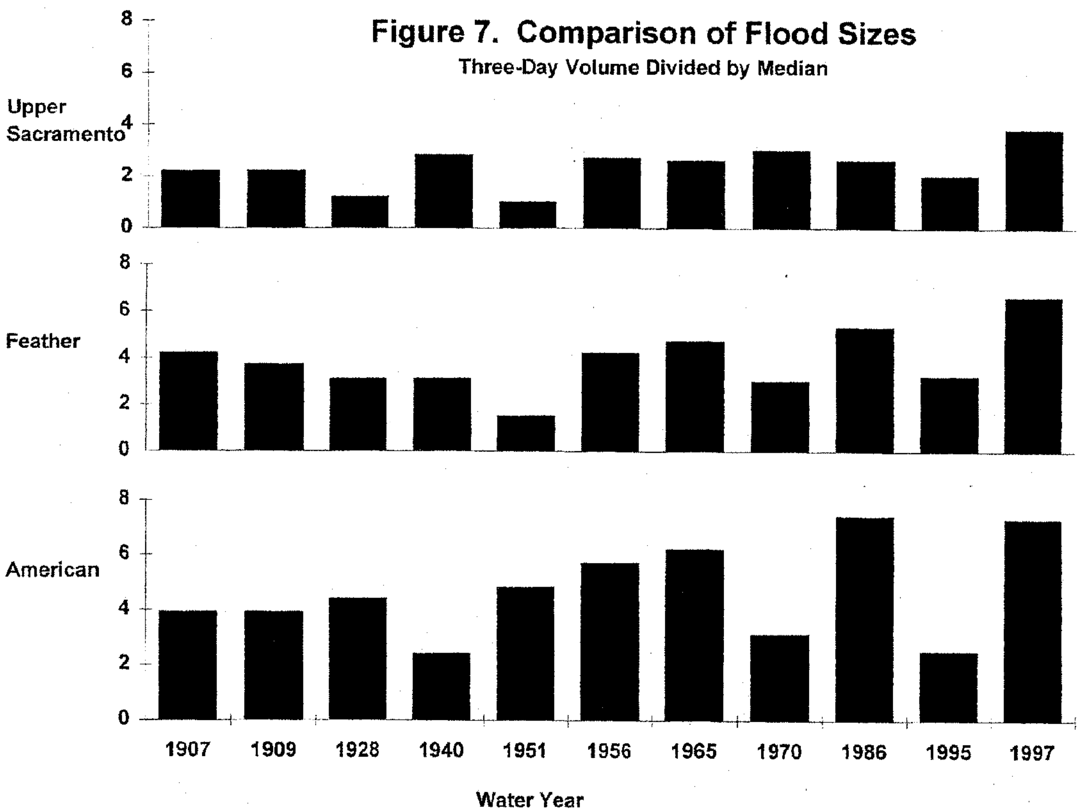
15 percent to the runoff. The bulk of runoff was simply caused by too much rain, which in a normal year would have been snow and held in "cold storage" instead of flowing to the rivers.

Rainfall was relatively light after January 3, allowing the flood control system to drain and restoring much of the reservoir flood control space. In late January, another siege of heavy rain occurred. This was not as heavy as the December-January storms (about two-thirds as much) and, although warmer than normal, snow levels were about 2,000 feet lower, which helped hold more water on the mountains. Even so, runoffs were large with high peaks on a few streams which caused considerable concern in areas where levees previously had been breached or damaged.

Immediately after the 1997 flood, a Governor's emergency task force reviewed impacts of the event and made over 50 recommendations which are now the basis for the State's flood policy. Estimated damages were over 2 billion dollars and at least 65,000 hectares of land flooded from levee failures. By and large, however, the system of reservoirs, levees, and floodways worked, preventing many billions in flood damage and saving lives. The recommendations included a comprehensive study of the Sacramento and San Joaquin River systems, which is now underway, seeking ways to provide better flood protection without environmental degradation.

Figure 7. Comparison of Flood Sizes

Three-Day Volume Divided by Median



The magnitude and duration of the 1997 floods affected the calculation of return periods for all the affected basins. Some of the statistics were more than 15 years old, and incorporating data from the 1997 flood is changing the risk statistics. The resulting new statistics are changing the size of flood events at all return frequencies (including the 100-year frequency which is used as a flood insurance and zoning benchmark).

CONCLUSION

There you have the biggest California floods of this century. There seems to be a trend for bigger events. Is it real? Figure 7 shows a history of comparative flood sizes on three major rivers. We would like to be sure we are not under-designing, but do not wish to over-design either because large water and flood control projects are costly.

There are always strange quirks. Certain regions are always experiencing unusual flooding. Water year 1996 was not especially noteworthy in the flood department in California, mostly a "normal" year. But during a west-northwest flow pattern with relatively high pressure at the end of December 1995, the Mad River near Arcata (in the Eureka area) was above flood stage for the highest level since the big North Coast flood of 1964. Stay tuned, be alert, be prepared!

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