Storms and Flooding in California in December 2005 and January 2006–a Preliminary Assessment

Open-File Report 2006–1182

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Inside front cover.

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By Charles Parrett and Richard A. Hunrichs

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U.S. Department of the Interior
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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
Volume		
cubic foot (ft^3)	28.32	cubic decimeter (dm^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
Flow rate		
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

SI to Inch/Pound

Multiply	By	To obtain
Length		
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
Area		
hectare (ha)	0.003861	square mile (mi^2)
square kilometer (km^2)	0.3861	square mile (mi^2)
Volume		
cubic decimeter (dm^3)	0.03531	cubic foot (ft^3)
cubic meter (m^3)	35.31	cubic foot (ft^3)
Flow rate		
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)

Water year: The 12-month period October 1 through September 30. It is designated by the calendar year in which it ends.

NOTE TO USGS USERS: Use of hectare (ha) as an alternative name for square hectometer (hm^2) is restricted to the measurement of small land or water areas.

Acronyms used in this report:

USGS	U.S. Geological Survey
FEMA	Federal Emergency Management Agency

Storms and Flooding in California in December 2005 and January 2006—A Preliminary Assessment

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Abstract

A series of storms beginning before Christmas 2005 and ending after New Year's Day 2006 produced significant runoff over much of northern California. The storms resulted in an estimated $300 million in damages and Federal disaster declarations in 10 counties. Several precipitation stations in the Sierra Nevada had precipitation totals greater than 20 inches for the period December 24 through January 3, and several stations in the Coastal Range had precipitation totals greater than 18 inches. The peak stream discharges resulting from the storms in the north coast area generally had recurrence intervals in the 10- to 25-year range, although the recurrence interval for peak discharge at one station on Sonoma Creek near Agua Caliente was greater than 100 years. In the San Francisco Bay area, peak discharges also generally had recurrence intervals in the 10- to 25-year range. Further south along the central coast and in southern California, peak discharges had smaller recurrence intervals, in the 2- to 5-year range. Upper Sacramento River tributaries draining from the west had peak flows with recurrence intervals in the 2- to 5-year range, whereas upper tributaries draining from the east side had recurrence intervals in the 5- to 10-year range. Further south, Sacramento River tributaries such as the Yuba and American Rivers had peak discharges with recurrence intervals in the 10- to 25-year range. On the east side of the central Sierra around Lake Tahoe, peak discharges had recurrence intervals in the 10- to 25-year range. Further south in the Sierra, streams draining into the San Joaquin River Basin had flows with recurrence intervals ranging from 2 to 5 years.

Introduction

A series of storms beginning before Christmas 2005 and ending after New Year's Day 2006 produced significant runoff over much of northern California, including the north coast and the Sierra Nevada. There were localized evacuations and flooding, some slope failures, and road closures. An estimated $300 million in damages were attributed to the storms (California Office of Emergency Services, 2006). Ten counties subsequently were declared Federal disaster areas: Contra Costa, Del Norte, Lake, Marin, Mendocino, Napa, Sacramento, Siskiyou, Solano, and Sonoma (Federal Emergency Management Agency, 2006). Major flood damages were concentrated primarily in the Napa and Russian River Basins in Napa and Sonoma Counties.

The flooding was widely compared by the media to the floods of 1986 and 1997, although the stream discharges generally were significantly smaller than those of the earlier floods. A storm on January 1 had been predicted to cause problems in southern California also; however, that storm did not develop as predicted. Nevertheless, the storm did manage to rain on the Rose parade for the first time in 51 years.

Summary of Major Storms

On the basis of provisional data obtained from the National Weather Service, California–Nevada River Forecast Center (2006), storm totals recorded by automated rainfall recorders at several precipitation stations on the western slopes of the Sierra Nevada during the December 24–January 3 period were greater than 20 inches. In addition, recorders at several stations at the headwaters of the Russian and Napa River Basins in the Coast Range had storm totals greater than 18 inches. Storm totals at two selected stations in the Coast Range (Willits Howard RS and Venado) and at two selected stations in the Sierra Nevada (Brush Creek and Girard) are presented in *table 1*.

The 3 days of the 7-day period with the most intense precipitation were December 28, December 31, and January 2. Daily precipitation totals were for a 24-hour period 4:00 a.m. to 4:00 a.m. Precipitation was as much as 4.68 inches on December 28 at the Willits Howard RS station. On December 31, the day of most intense rainfall over most of northern California, more than 5 inches were recorded at all sites, and the Venado and Willits Howard RS stations recorded 6.81 and 7.12 inches, respectively. Although rainfall intensity on January 2 generally was less than on December 28 and December 31, as much as 3.84 inches was recorded at Venado. *Figure 1* shows the areal distribution and amounts of daily rainfall throughout northern California on December 28, 31, and January 2.

Table 1. Precipitation at selected precipitation stations in California, December 24, 2005, through January 3, 2006.

[24-hour period begins at 4:00 a.m.]

Precipitation station	Total precipitation for December 24–January 3 (inches)	Precipitation for 24-hour period (inches)		
		12/28/06	12/31/06	01/02/06
Sierra Nevada				
Brush Creek	22.05	2.75	6.81	2.56
Girad	20.08	3.84	5.04	2.32
Coast Range				
Venado	29.60	4.24	6.88	3.84
Willits Howard RS	18.48	4.68	7.12	0.96

Map color indicates precipitation, in inches, as indicated by the color shade bar scale below. Gray shades indicate 'no data'.

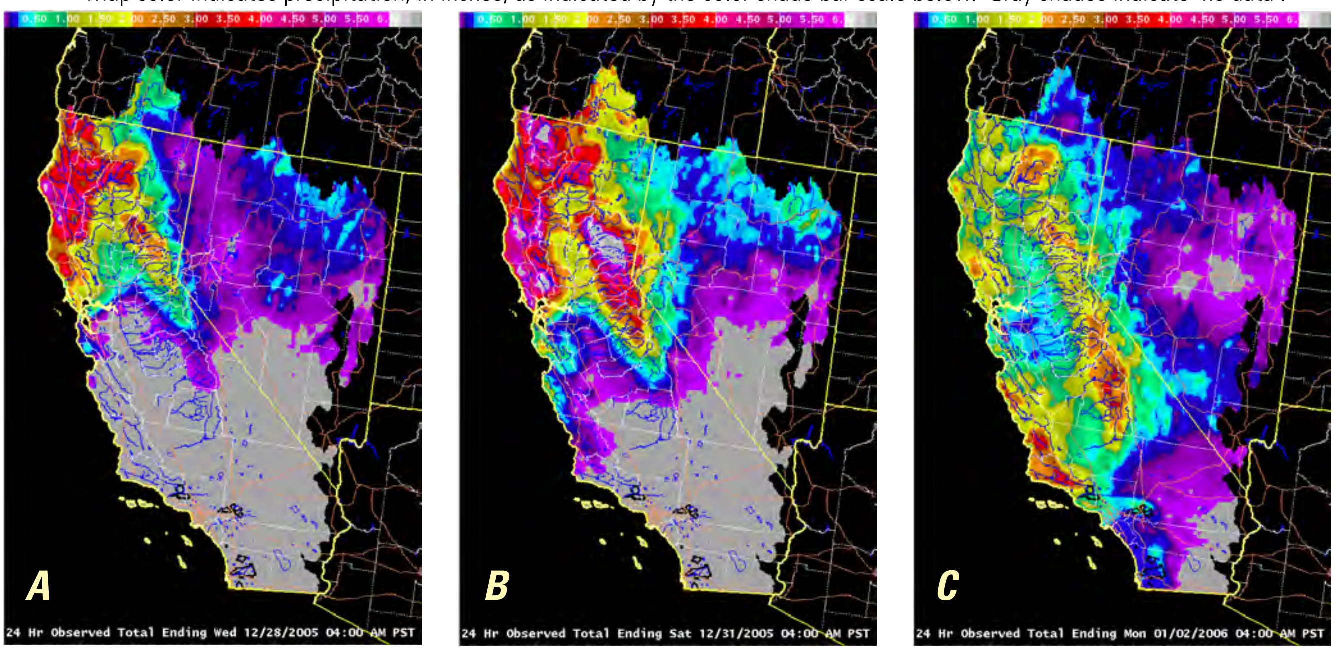

Figure 1. Rainfall over California and Nevada for (A) December 28, 2005, (B) December 31, 2005, and (C) January 2, 2006. (From National Weather Service, California–Nevada River Forest Center, 2006)

Summary of Flooding

Unusually warm storms produced more runoff from higher elevations than normal for December and January. Because the accumulated snow pack had been rather light, snowmelt did not significantly increase runoff. Previous large floods in northern California, including the most recent in 1986 and 1997, had significant runoff from snowmelt as well as from large storms (Hunrichs and others, 1998; U.S. Geological Survey, 1989).

Table 2 shows recorded peak discharges, gage heights, and computed recurrence intervals associated with the peak discharges at selected USGS streamflow-gaging stations. The peak discharges of record at the sites are also shown. The peak-discharge data are from near-real time stations, and the data are provisional and may change based on further review. As indicated by table 2, five sites, with periods of recorded data ranging from 24 to 64 years, had peaks of record (rank 1) on December 31, 2005. *Figure 2* shows the locations of the streamflow-gaging stations and the recurrence intervals for the December–January peak discharges and the locations of 4 selected precipitation stations.

Table 2. Peak discharge data for selected U.S. Geological Survey streamflow-gaging stations in California.

[Rank, position of the December-January peak discharge in a ranked, from largest to smallest, list of all recorded annual peak discharges for the period of record. mi^2, square mile; ft^3/s, cubic foot per second; ft, foot. <, less than the actual value shown; > actual value is greater than value shown]

Station number	Station name	Drainage area (mi^2)	Flooding of December–January: Date of peak discharge	Peak discharge (ft^3/s)	Gage height (ft)	Reccurrence interval (years)	Rank	Years of record	Historic alflooding: Maximum peak (ft^3/s)	Year
10308200	East fork Carson River below Markleeville Creek near Markleeville	276	12/31/2005	19,300	11.81	25–50	1	44	18,900	1997
10310000	West fork Carson River at Woodfords	65.4	12/31/2005	3,010	14.36	10–25	8	89	8,100	1997
10336660	Blackwood Creek near Tahoe City	11.2	12/31/2005	2,260	7.43	10–25	2	44	2,940	1997
10336676	Ward Creek at Hwy 89 near Tahoe Pines	9.7	12/31/2005	1,660	8.44	10–25	3	32	2,530	1997
10336780	Trout Creek near Tahoe Valley LIF	36.7	12/31/2005	623	9.7	25–50	1	43	535	1963
10338000	Truckee River near Truckee	553	12/31/2005	6,030	6.97	10–25	5	35	11,900	1997
10346000	Truckee River at Farad	932	12/31/2005	10,100	10.77	10–25	9	105	17,500	1950
11098000	Arroyo Seco near Pasadena	16	1/2/2006	1,120	4.58	2–5	26	90	8,620	1938
11111300	Sespe Creek near Filllmore	251	1/2/2006	20,800	16.5	2–5	19	66	73,000	1998
11143250	Carmel River near Carmel	247	12/31/2005	3,010	10.55	<2	21	39	16,000	1995
11147500	Salinas River at Paso Robles	390	1/2/2006	6,950	11.84	2–5	22	59	28,400	1995
11152000	Arroyo Seco near Soledad	244	12/31/2005	12,900	10.95	2–5	28	99	28,300	1958
11159000	Pajaro River at Chittenden	1,186	1/3/2006	5,030	19.25	2–5	28	65	25,100	1998
11161000	San Lorenzo River at Santa Cruz	115	12/31/2005	13,900	21.55	5–10	5	25	30,400	1955
11162500	Pesdero Creek near Pesdero	45.9	12/31/2005	6,000	15.95	5–10	8	53	10,600	1998
11164500	San Francisquito Creek at Stanford University	37.4	12/31/2005	4,840	10.35	10–25	4	64	7,220	1998
11169500	Saratoga Creek at Saratoga	9.22	12/31/2005	1,120	6.31	5–10	14	71	2,730	1955
11189500	South fork Kern River near Onyx	530	1/2/2006	1,600	7.54	2–5	23	71	28,700	1966
11119940	Maria Ygnacio Creek at University Drive near Goleta	6.4	1/2/2006	299	2.95	<2	23	33	2,500	1992
11266500	Merced River at Pohono Bridge near Yosemite	321	12/31/2005	10,200	12.54	5–10	10	88	24,600	1997
11335000	Cosumnes River at Michigan Bar	536	12/31/2005	35,100	13.68	10–25	8	98	93,000	1997
11336580	Morrison Creek near Sacramento	53.4	12/31/2005	2,420	9.67	10–25	3	35	2,730	1986
11345500	South fork Pit River near Likely	247	12/31/2005	772	4.69	5–10	9	73	1,620	1971
11372000	Clear Creek near Igo	228	12/30/2005	4,400	8	2–5	33	64	24,500	1955
11377100	Sacramento River above Bend Bridge near Red Bluff	8,900	12/31/2005	118,000	30.09	<2	40	123	291,000	1940
11379500	Elder Creek near Paskenta	92.4	12/30/2005	7,650	10.93	2–5	15	56	17,700	1983

Table 2. Peak discharge data for selected U.S. Geological Survey streamflow-gaging stations in California—Continued.

[mi², square mile; ft³/s, cubic foot per second; ft, foot. <, less than the actual value shown; > actual value is greater than value shown]

Station number	Station name	Drainage area (mi²)	Flooding of December–January	Peak discharge (ft³/s)	Gage height (ft)	Reccurrence interval (years)	Rank	Years of record	Historic alflooding	Year
			Date of peak discharge						Maximum peak (ft³/s)	
11383500	Deer Creek near Vina	208	12/31/2005	10,300	11.15	5–10	16	88	24,000	1997
11390000	Butte Creek near Chico	147	12/31/2005	13,800	9.41	5–10	8	74	35,600	1997
11413000	North Yuba River below Goodyears Bar	250	12/31/2005	27,200	19.57	10–25	6	74	45,500	1997
11425500	Sacramento River at Verona	21,251	1/3/2006	85,600	38.72	10–25	3	75	94,000	1997
11427000	North fork American River at North Fork Dam	342	12/31/2005	51,600	10.48	10–25	5	63	65,400	1964
11447360	Arcade Creek near Del Paso Heights	31.4	12/31/2005	3,510	15.88	10–25	1	24	3,320	1998
11456000	Napa River near St Helena	78.8	12/31/2005	18,000	21.61	25–50	1	64	16,900	1986
11458000	Napa River near Napa	218	12/31/2005	29,600	29.85	10–25	3	48	37,100	1986
11458500	Sonoma Creek at Agua Liente	58.4	12/31/2005	17,600	32.51	>100	1	29	8,880	1955
11463000	Russian River near Cloverdale	503	12/31/2005	50,700	26.2	25–50	4	53	55,200	1964
11467000	Russian River near Guerneville	1,338	1/1/2006	85,800	44.21	10–25	6	65	102,000	1986
11468000	Navarro River near Navarro	303	12/31/2005	55,700	39.81	10–25	3	54	64,500	1955
11468500	Noyo River near Fort Bragg	106	12/31/2005	13,700	25.09	5–10	8	53	26,600	1974
11475560	Elder Creek near Branscomb	6.5	12/31/2005	1,040	7.49	2–5	10	38	3,660	1964
11476500	South fork Eel River near Miranda	537	12/28/2005	88,400	32.59	5–10	12	64	199,000	1964
11477000	Eel River at Scotia	3,113	12/31/2005	328,000	52.71	5–10	10	93	752,000	1964
11481000	Mad River near Arcata	485	12/30/2005	47,300	22.72	5–10	10	57	81,000	1964
11473900	Middle fork Eel River near Dos Rios	745	12/30/2005	94,700	26.52	10–25	2	39	135,000	1997
11517500	Shasta River near Yreka	793	12/30/2005	9,320	11.59	25–50	3	69	21,500	1964
11523000	Klamath River at Orleans	8,475	12/30/2005	216,000	34.8	10–25	5	77	307,000	1964
11530000	Trinity River at Hoopa	2,853	12/31/2005	108,000	40.68	5–10	10	78	231,000	1964
11530500	Klamath River near Klamath	12,100	12/31/2005	416,000	47.12	25–50	7	91	557,000	1964
11532500	Smith River near Crescent City	641	12/30/2005	124,000	29.55	10–25	12	73	228,000	1964

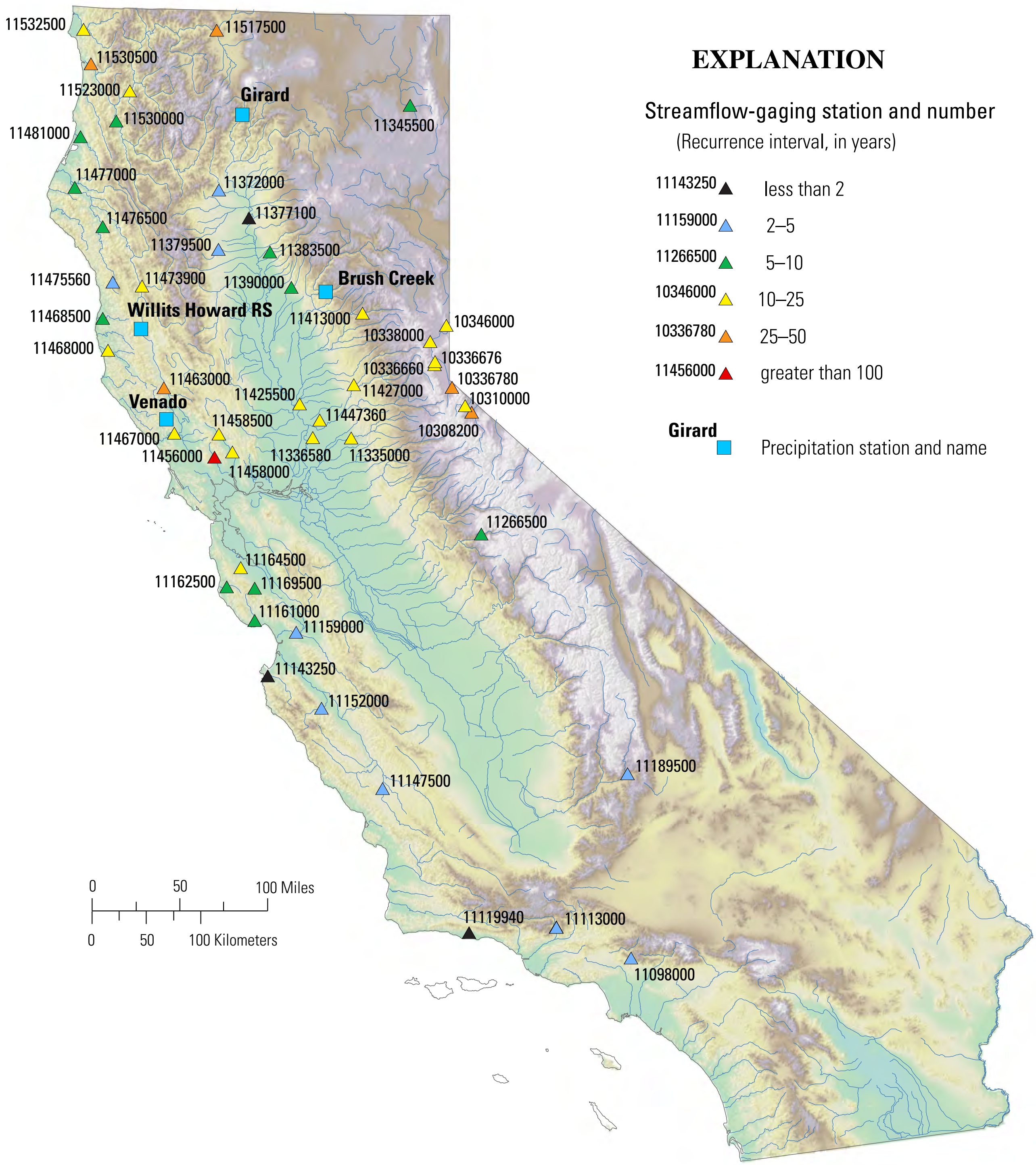

Figure 2. Location of selected streamflow-gaging stations, precipitation stations, and recurrence interval ranges for peak discharges in California, December 2005 and January 2006.

Recurrence intervals, which express the average length of time in years between exceedances of peak flood discharges as large as those recorded during the December–January flood period, provide an indication of the frequency of flooding. For example, a peak discharge with a recurrence interval of 10 years is likely to be exceeded, on average, once every 10 years. The reciprocal of recurrence interval is the annual exceedance probability of a peak discharge. A peak discharge with a recurrence interval of 10 years has an annual exceedance probability of 0.10, or 10 percent. During any year, the probability of having a peak discharge greater than a peak discharge with a 10-year recurrence interval is 0.10, or 10 percent.

Flood frequencies (recurrence intervals) for the December–January peak discharges were determined by fitting a log Pearson Type 3 probability distribution to the period of recorded annual peak discharges (through 2004 and including the December 2005–January 2006 peak discharge) at each site using methods described in Bulletin 17B by the Interagency Advisory Committee on Water Data (1982). The flood-frequency analyses were based on regional skew values provided in Bulletin 17B and did not include any adjustments for historical floods, high or low outliers, comparison with other stations, or other procedures described in the bulletin. The flood-frequency analyses also did not account for streamflow regulation or land-use changes over time, such as urbanization. These recurrence intervals are thus provisional and likely to change after a more thorough and rigorous analysis of flood frequency in California. The need for updated flood-frequency information in California is highlighted by the bar chart in *figure 3,* which shows that the three largest annual peak discharges at the Napa River at Napa (USGS station 11458000) were in water years 1986, 1995, and 2006 (December 31, 2005), after the last (1977) statewide systematic updating of flood-frequency data for USGS gage sites (Waananen and Crippen, 1977).

The most commonly used recurrence intervals for analyses of peak discharges are 2, 5, 10, 25, 50, and 100 years. These recurrence intervals were also used for the December–January peak discharges analyzed in this study. The intervals are presented in *table 2* and *figure 2* for the following ranges: less than 2 years, 2 to 5 years, 5 to 10 years, 10 to 25 years, 25 to 50 years, and greater than 100 years.

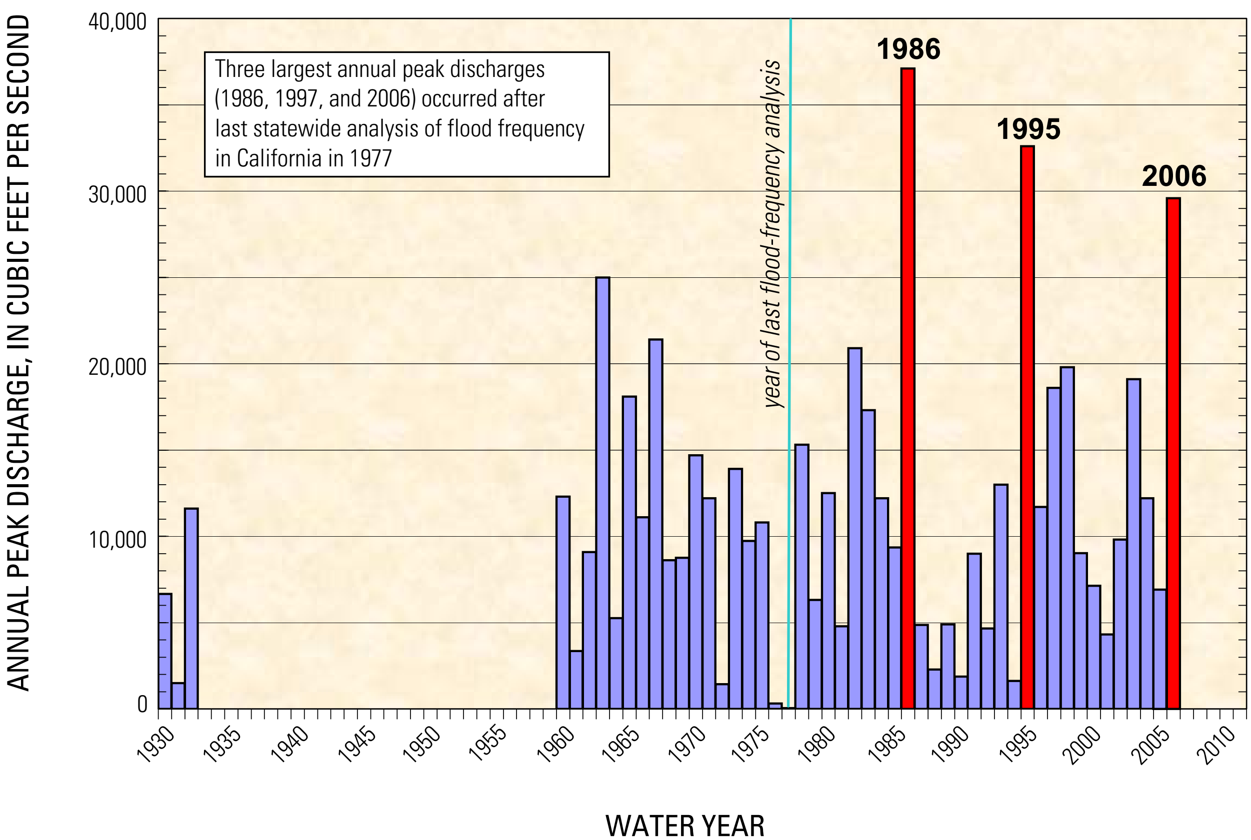

Figure 3. Recorded annual peak discharges for the streamflow-gaging station at the Napa River at Napa, California.

In the north coast area, the recurrence intervals for the peak flows generally were in the 10- to 25-year range. Discharge for some stations, particularly those near the mouth of the Klamath River and in the upper Russian River Basin (*fig. 4*), showed more extreme flows, with recurrence intervals in the 25- to 50-year range. The peak discharge for the Sonoma River at Agua Caliente (USGS station 11458500) had a recurrence interval greater than 100 years and was about twice as big as the previous peak of record. Records at this site, however, do not include data for the large-flood years of 1986 or 1997.

The Russian River at Guerneville (USGS station 11467000), where significant flooding also occurred, had a recurrence interval in the 10- to 25-year range. Other streams, particularly those in the Eel River Basin, had less extreme peak discharges, with recurrence intervals in the 5- to 10-year range.

Streams in the San Francisco Bay area, including the Napa River Basin, had peak discharges with recurrence intervals generally in the 10- to 25-year and 25- to 50-year ranges. Along the central coast (Carmel River and Salinas River, for example) and in southern California (Sespe Creek and Arroyo Seco, for example), recurrence intervals generally were in the 2- to 5-year range.

Flows in the mainstem of the Sacramento River stayed within the capacity of the flood-control system, as relief weirs and bypass channels were brought into operation. The peak discharge on the Sacramento River above Bend Bridge near Red Bluff (USGS station 11377100), which is regulated by Lake Shasta, had a recurrence interval of less than 2 years. Unregulated peak streamflows from tributaries draining the Coast Range on the west side of the upper Sacramento River Basin showed recurrence intervals in the 2- to 5-year range, whereas peak discharges from tributary streams draining the southern Cascade Mountains and the Sierra Nevada on the east side of the Sacramento River Basin had recurrence intervals in the 5- to 10-year range. Recurrence intervals for peak discharges from tributary streams farther south in the Sacramento River Basin (Yuba River and American River) generally were in the 10- to 25-year range (*fig. 5*). High flows, coupled with high tides and high winds, caused problems along levees in the Sacramento–San Joaquin River delta. At some locations, wind waves overtopped, but did not collapse, levees. Officials noted more than 40 episodes of erosion or seepage in the levees.

On the east side of the central Sierra Nevada around Lake Tahoe, these warm storms generally brought runoff peaks with recurrence intervals in the 10- to 25-year range. Further south, streams draining from the Sierra Nevada into the San Joaquin River Basin had peak flows with recurrence intervals ranging from 2 to 5 years.

Figure 4. Flooding from the Russian River along Highway 101 near Hopland, California, December 31, 2005. View is looking north. Photograph by Ken Markham, U.S. Geological Survey.

Figure 5. Streamflow on the South Yuba River passing under old Highway 29 Bridge, California, December 31, 2005. View looking upstream. Photograph by Ian O'Halloran.

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