FLOODS OF FEBRUARY 1980 IN SOUTHERN CALIFORNIA AND CENTRAL ARIZONA

Report prepared jointly by the U.S. Geological Survey
and the National Oceanic and Atmospheric Administration

U.S. DEPARTMENT OF THE INTERIOR

U.S. DEPARTMENT OF COMMERCE

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1494

FLOODS OF FEBRUARY 1980 IN SOUTHERN CALIFORNIA AND CENTRAL ARIZONA

By E.H. CHIN, National Oceanic and Atmospheric Administration,
and B.N. ALDRIDGE and R.J. LONGFIELD, U.S. Geological Survey

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UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON: 1991

UNITED STATES
DEPARTMENT OF THE INTERIOR

MANUEL LUJAN, Jr., ***Secretary***

UNITED STATES
GEOLOGICAL SURVEY

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Library of Congress Cataloging in Publication Data

Chin, Edwin H.
Floods of February 1980 in southern California and central Arizona.

(U.S. Geological Survey professional paper ; 1494)
"Prepared jointly by U.S. Geological Survey and National Oceanic and Atmospheric Administration."
Bibliography: p.
Supt. of Docs. no.: I 19.16:1494
1. Floods—California, Southern. 2. Floods—Arizona. I. Aldridge, B.N. (Byron Neil) II. Longfield, R.J. III. Geological Survey (U.S.) IV. United States. National Oceanic and Atmospheric Administration. V. Series: Professional paper (Geological Survey (U.S.); no. 1494.
GB1399.4.C23C47 1991 551.48′097949 88–600327

For sale by the Books and Open-File Reports Section, U.S. Geological Survey,
Federal Center, Box 25425, Denver, CO 80225

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METRIC CONVERSION FACTORS

For readers who wish to convert measurements from the inch-pound system of units to the metric system of units, the conversion factors are listed below:

Multiply inch-pound units	By	To obtain metric units
inch (in)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
acre	0.4047	hectare (ha)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm^3)
ton, short	0.9072	megagram (Mg)
degree Fahrenheit (°F)	(temp °F−32)/1.8	degree Celsius (°C)

GLOSSARY

[A number of terms are defined below according to their use in this report. If a word can be used as either a noun or a verb, only the noun form is defined.]

Acre-foot.—The quantity of water required to cover 1 acre to a depth of 1 foot. It equals 43,560 cubic feet, 325,851 gallons, or 1,233 cubic meters.

Baroclinic instability.—A hydrodynamic instability arising from the existence of a meridional-temperature gradient.

Capacity (of a reservoir).—The volume of water, in acre-feet, that a reservoir can contain to the top of a spillway or gates.

Contents.—The volume of water, in acre-feet, in a reservoir or lake. Contents is computed on the basis of a level pool or reservoir backwater profile and does not include bank storage.

Convection.—Vertical motions and mixing resulting when the atmosphere becomes thermodynamically unstable.

Convective cloud.—A cloud that owes its vertical development, and possibly its origin, to convections.

Coriolis parameter.—Twice the component of the Earth's angular velocity about the local vertical, $2\Omega \sin \phi$, where Ω is the angular speed of the Earth and ϕ is the latitude.

Crest (of a flood).—The point at which a stream stops rising. Crest is distinguished from "peak," which refers to the highest crest during a flood.

Cubic feet per second (ft^3/s).—A rate of discharge. One cubic foot per second is equal to the discharge of a stream of rectangular cross section 1 foot wide and 1 foot deep, flowing at an average velocity of 1 foot per second.

Cyclogenesis.—Any development or strengthening of cyclonic circulation in the atmosphere.

Cyclonic curvature.—Counterclockwise curvature (in the Northern Hemisphere).

Del-operator.—The operator, written ∇, used to transform a scalar field into the ascendent vector of that field.

Discharge.—The quantity of fluid mixture, including dissolved and suspended particles, or sediment alone, passing a point during a given period of time. The water mixture is measured in cubic feet per second; sediment is measured in tons per day.

Drainage area.—The area, measured in a horizontal plane, that is enclosed by a topographic divide. Drainage area is measured in square miles.

Echos.—In radar terminology, a general term for the appearance of a radar indicator of the electromagnetic energy return from a target.

e-fold time.—Time required for the amplitude of a perturbation wave to grow to e (=2.718...) times its initial amplitude.

Entrainment.—The mixing of environmental air into a preexisting cloud parcel.

Equivalent potential temperature.—The temperature an air parcel would have after undergoing dry adiabatic expansion until all moisture is precipitated out, then dry adiabatic compression to a pressure of 1,000 millibars.

Extratropical Low (extratropical cyclone).—Any cyclone-scale storm that is not a tropical cyclone. Usually refers only to the migratory frontal cyclones of middle and high latitudes.

Flood.—Any abnormally high streamflow.

Flood peak.—The highest value of the stage or discharge attained by a flood.

Front.—The boundary separating two different airmasses.

Gage height.—The water-surface elevation referred to some arbitrary gage datum. Gage height is often used interchangeably with the more general term "stage," although gage height is more appropriate when used with a reading on a gage.

Gaging station.—A particular site on a stream, canal, lake, or reservoir where systematic observations of gage height or discharge are made.

Gas constant.—The constant factor in the equation of state for perfect gases.

Geostrophic approximation.—The assumption that the horizontal wind may be represented by the geostrophic wind (whose direction and speed are determined by a balance of the pressure-gradient force and the force due to the Earth's rotation).

Hydrograph.—A graph showing gage height or stage, discharge, or other property of water with respect to time.

Inflow.—The water flowing into a reservoir or lake. Designates volume, in acre-feet, or discharge, in cubic feet per second, or is used as a general descriptive term.

Instability.—Areas of instability; in this report, areas where the lifted index is less than 4.

Isobar.—A line of equal or constant barometric pressure.

Isohyetal map.—A map showing lateral distribution of precipitation, drawn as contours of equal rainfall amounts.

Isotherm.—A line of equal or constant temperature.

Jetstream.—Relatively strong winds concentrated within a narrow stream in the atmosphere.

K index.—A measure of thunderstorm potential based on the vertical temperature lapse rate, the moisture content of the lower atmosphere, and the vertical extent of the moist layer.

$$K=(T_{850}-T_{500})+T_{d,850}-(T_{700}-T_{d,700}),$$

where T and T_d represent temperature and dew-point temperature, respectively, and numerals denote pressure levels—for example, $T_{d,850}$ is dew-point temperature at 850 millibars.

Knot.—A rate of speed of 1 nautical mile per hour, equal to 1.105 miles per hour. Commonly used to express windspeed.

Lifted index.—A stability index based on the difference, in degrees Celsius, between the 500-millibar environmental temperature and the temperature of a parcel of air lifted adiabatically from or near ground surface to the 500-millibar level.

Millibars.—A pressure unit, equivalent to 1,000 dynes per square centimeter, convenient for reporting atmospheric pressure.

Miscellaneous site.—A site where data pertaining only to a specific hydrologic event are obtained.

National Geodetic Vertical Datum of 1929 (NGVD of 1929).—A geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Peak.—The highest crest during a flood.

Peak discharge.—The highest instantaneous discharge during a flood. Measured in cubic feet per second. Also termed "maximum discharge."

Peak of record.—The highest instantaneous discharge recorded during a period of gaging-station operation.

Peak stage.—The maximum height of a water surface above an established datum plane; same as peak gage height.

Precipitable water.—The total atmospheric water vapor contained in a vertical column of unit cross-sectional area extending between any two specified surfaces (in this report, between ground surface and the 500-millibar level).

Pressure surface.—A surface of constant atmospheric pressure.

Probability.—The likelihood that a specific discharge will be equaled or exceeded in any given year; expressed as a decimal value between 0 and 1.0.

Radiosonde.—A balloon-borne instrument package for measuring and transmitting meteorological data.

Rainfall mass curve.—A graph of the accumulated rainfall depth, plotted as an ordinate, against time or duration of storm, plotted as abscissa; the curve represents total precipitation depth throughout the storm.

Rawinsonde.—A meteorological data-collection system including a radiosonde and reflectors for measuring winds by radar.

Recurrence interval.—As applied to flood events, the average number of years over a long period of time during which a given flood peak will be equaled or exceeded once. For example, a 50-year flood discharge will be exceeded on the average of once in 50 years. If the probability of the flood occurring is 0.02, there is a 2-percent chance that such a flood will occur in any given year.

Ridge.—An elongated area of relatively high atmospheric pressure.

Runoff.—That part of the precipitation that appears in streams. Measured as a volume, in acre-feet, or as a rate, in cubic feet per second.

Saturation.—The condition in which the partial pressure of water vapor is equal to its maximum possible partial pressure under existing environmental conditions.

Scour.—An increase in depth or width of a stream caused by flowing water removing material (usually unconsolidated) from a streambed or streambank.

Sea level.—*See* **National Geodetic Vertical Datum of 1929 (NGVD of 1929).**

Sediment.—Solid particles usually derived from rocks or earth material that have been or are being transported laterally or vertically from one or more places of origin.

Sounding.—A single complete radiosonde observation of the upper atmosphere.

Spill.—The water that passes over the spillway of a dam whether or not the spillway is equipped with gates. Distinguished from the more general term "release," which may include water flowing through penstocks and other openings at lower elevations than the spillway.

Stage-discharge relation.—The relation between gage height and the amount of water flowing in a stream channel.

Temperature.—Expressed in degrees Fahrenheit (°F) or Celsius (°C). The relation between these temperature scales is given in the conversion table at the front of this report.

Time of day.—Expressed in 24-hour time. For example, 6 p.m. is expressed as 1800 hours P.s.t. (Pacific standard time).

Tropopause.—The boundary between the troposphere and the stratosphere, usually characterized by an abrupt change of lapse rate.

Troposphere.—That portion of the atmosphere from the Earth's surface to the tropopause—that is, the lowest 10 to 20 kilometers of the atmosphere.

Trough.—An elongated area of relatively low atmospheric pressure.

Unfilled capacity (of a reservoir).—The volume of storage that is available for controlling the amount of water released. It is the difference between the contents of a reservoir at any given time and the capacity of the reservoir.

Vapor pressure.—The pressure exerted by the molecules of a given vapor; in meteorology, the term is used exclusively to denote the partial pressure of water vapor.

Vorticity.—A vector measure of local rotation in a fluid flow defined as the curl of the velocity vector: $\nabla \times V$. In meteorology, it usually refers to the vertical component:

$$k\left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)$$

Zonal component.—The wind component along the local parallel of latitude.

***Z-R* equations.**—Empirical equations relating the rainfall rate (R) as a function of a measure of the hydrometeor size spectrum (Z).

FLOODS OF FEBRUARY 1980 IN SOUTHERN CALIFORNIA AND CENTRAL ARIZONA

By E.H. Chin of the National Weather Service, National Oceanic and Atmospheric Administration, and B.N. Aldridge and R.J. Longfield of the U.S. Geological Survey

ABSTRACT

A series of six Pacific cyclones struck the Southwestern United States during February 13–21, 1980. Pacific subtropical westerlies drove upper level troughs across the Western United States, thus weakening the normal mean ridge, displacing the Great Basin High, and exposing southern California and Arizona to the storm track. The coastal plains and valleys of southern California received between 5 and 10 inches of rain, and large areas in the coastal mountains received more than 15 inches. The central mountains of Arizona received 3 to 16 inches, and severe flooding resulted.

The floods of February 1980 caused extensive damage along coastal streams of southern California. All but one major reservoir in San Diego County spilled. The peak discharge of the Tijuana River exceeded any previously recorded discharge since 1936. Levee breaks near San Jacinto in Riverside County caused extensive property damage. Lake Elsinore in eastern Riverside County reached the highest level since 1917 and flooded many homes and businesses. Erosion and bridge damage was severe along the Santa Ana River. On many streams the volume of runoff for 7 to 15 consecutive days was the greatest ever recorded for that number of days. Strong winds and high waves damaged the coast of southern California. Many mudflows and slope failures occurred in and near Los Angeles. Damage from flooding, mudflows, and beach-front erosion totaled about $500 million in southern California. Seven southern California counties were declared eligible for Federal disaster aid. Eighteen people lost their lives in California.

Severe flooding occurred near Phoenix, Ariz., when the volume of flow into reservoirs on the Salt, Verde, and Agua Fria Rivers exceeded the unfilled capacity. The floods were the highest since 1905 on the Salt River at Phoenix, since 1919 on the Agua Fria River downstream from Waddell Dam, and since at least 1916 on the Gila River below the Salt River. The flood caused $63.6 million in damage in Maricopa County and at least $16 million in damage in other Arizona counties. Three Arizona counties were declared eligible for Federal disaster aid. Three people died in the flood in Arizona.

INTRODUCTION

Beginning February 13, 1980, six storms moved in from the Pacific Ocean in rapid succession and battered southern California and central Arizona. The storms originated over warm ocean waters at low latitudes, carried abundant moisture, and were steered toward the Southwestern United States by the subtropical jetstream. Precipitation in southern California during February was the highest or second highest over periods of as much as 108 years. In California, the February storms were preceded by two severe storms in January that had soaked soils, decreased unfilled reservoir capacities, and generally set the stage for the flooding caused by the February storms. Severe flooding resulted from the February storms along streams that drain to the Pacific Ocean south of San Francisco and along streams that drain the central mountains of Arizona. The flood area is shown in figure 1.

Strong onshore winds and exceptionally high tides caused coastal flooding and erosion. Extensive flooding occurred in San Diego County. Inflow to reservoirs in Arizona exceeded available storage capacities, and large releases from water-conservation reservoirs caused flooding downstream from the reservoirs. Peaks of record occurred at about 40 gaging stations in California and 10 gaging stations in Arizona. The volume of runoff was among the highest recorded in the 20th century. Large releases from many reservoirs and high lake levels lasted for several months.

Mudflows and slope failures in the Los Angeles metropolitan area destroyed or damaged hundreds of homes. Contamination from raw sewage carried to the ocean by two streams caused several miles of southern California beach to be closed to swimming or surfing for periods as long as 14 months. Many miles of beach were eroded by high surf.

The floods caused 18 deaths and about $500 million damage in California. About $80 million in damage and three deaths occurred in Arizona. Seven counties in southern California—Santa Barbara, Ventura, Los Angeles, Orange, San Bernardino, Riverside, and San Diego—and three counties in Arizona—Gila, Yavapai, and Maricopa—were declared eligible for Federal disaster aid.

Manuscript approved for publication May 4, 1987.

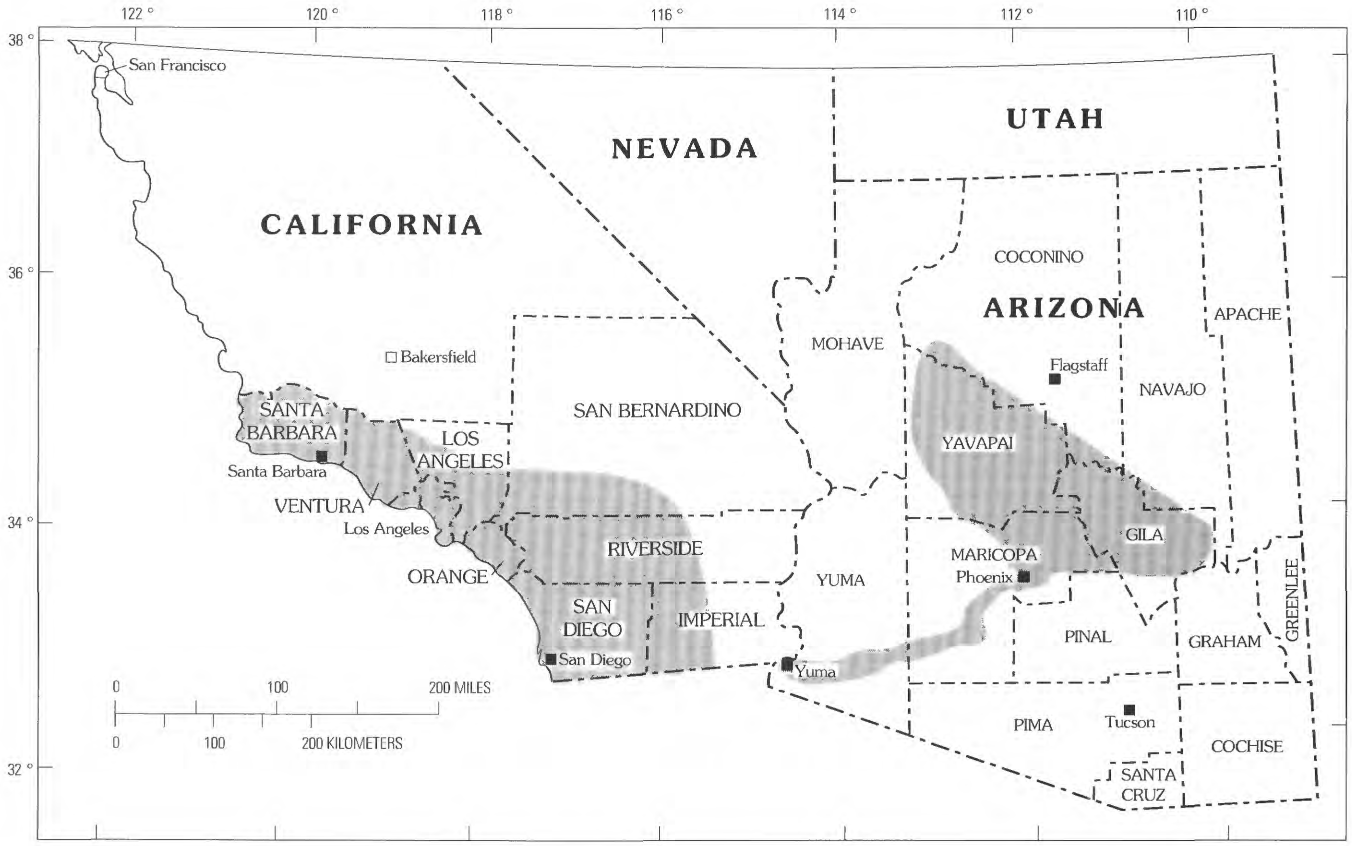


FIGURE 1.—Report area (shaded).

PURPOSE AND SCOPE

This report is one in a continuing series of joint reports undertaken by the National Weather Service in the National Oceanic and Atmospheric Administration (NOAA) of the U.S. Department of Commerce and the U.S. Geological Survey of the Department of the Interior to document flood events. Meteorology associated with the precipitation of February 13–21, 1980, the distribution of the precipitation, flood conditions in a basin-by-basin format, and pertinent hydrographic data are presented. Brief discussions of storms and runoff in January show the antecedent effect of these storms.

Meteorological and hydrological analyses related to the February floods in this report are intended to provide a framework for hydrologic planning, as well as to serve as a comprehensive reference. The report concentrates mainly on flooding in the coastal basins of California south of about latitude 35° N., the Salton Sea basin (pl. 1), the Salt, Agua Fria, and Hassayampa River basins of central Arizona, and the Gila River basin downstream from the Salt River (pl. 2). The report area includes all or parts of the 10 counties that were declared disaster areas (fig. 1). Limited amounts of data are provided for streams in Apache, Coconino, Mohave, and Yuma Counties of Arizona. Precipitation data are summarized for the entire area of the two States. The January floods affected areas outside the general report area. Flooding in those areas was not severe enough to justify a detailed analysis but is discussed in a general way. Stream networks and station locations are shown on plates 1 and 2 (in pocket). All times given in the report are local standard time (Pacific, P.s.t., in California and mountain, m.s.t., in Arizona) unless stated otherwise.

METEOROLOGICAL SETTINGS

ANTECEDENT CIRCULATION PATTERNS

The mean tropospheric circulation over the Pacific Ocean in December 1979, as represented by the mean 700-mb (millibar) map, showed predominantly zonal flow with low-amptitude waves. This pattern was replaced in January 1980 by more amplified waves, together with a blocking ridge over the eastern tip of Siberia and southward-displaced westerlies. Over the central Pacific, a large area of cyclonic curvature was present. Strong westerlies with mean speeds 7 to 8 m/s (meters per second) larger than normal occurred just north of the Hawaiian Islands. The mean 700-mb zonal windspeed profile for the western half of the Northern Hemisphere for January showed a maximum at latitude 30° N. This represented a southward shift of 15° from the position of maximum westerlies in December 1979. As a result, storm tracks over the Pacific were displaced southward and a much higher than normal amount of rain fell over California and Arizona in January.

The southward displacement of the westerlies and the amplification of waves in the mean 700-mb flow continued in February. Meanwhile, a very cold continental polar airmass from the interior of Siberia had been moving off the east coast of Asia. As the cold airmass spread out eastward and southward into the central Pacific, extensive belts of enhanced baroclinicity were formed at relatively low latitudes; the subtropical westerlies were further strengthened, and larger than normal meridional-temperature gradients developed. These led to extremely large vector differences in geostrophic winds and strong westerlies in the middle and upper troposphere.

The extraordinary speed of the westerlies extended throughout the troposphere to the jetstream-axis level of 300 mb. For example, at 0400 hours P.s.t., February 13, the observed 300-mb windspeed over 25° N. 130° W. was 110 knots, compared with the February long-term climatological average 300-mb windspeed there of 49 knots (Gray and others, 1976). The observed 500-mb windspeed over 28° N. 121° W. at 0400 hours P.s.t., February 14, was 85 knots, compared with the February long-term average 500-mb windspeed there of 29 knots.

The geostrophic wind is a good first approximation of upper air wind. A very strong upper level wind can exist only when there is strong vertical shear in the geostrophic wind from the ground surface to the pressure surface being considered. That is, ΔV_g is large, where ΔV_g is the vector difference in geostrophic wind between the surface and some upper level. For example, if the upper level is 500 mb, ΔV_g is measured between the ground surface and the 500-mb pressure surface, and is computed as follows:

$$\Delta \mathbf{V}_g = -\frac{R_d}{f} \ln\left(\frac{p_s}{p_5}\right) \nabla_p \bar{T}_v \times \mathbf{k}, \qquad (1)$$

where

ΔV_g = vector difference in geostrophic wind,
R_d = gas constant for dry air,
f = Coriolis parameter,
ln = natural logarithm,
p_s = surface pressure, in millibars,
p_5 = 500 mb,
∇_p = del-operator on a pressure surface,
$\bar{T}_v$ = mean virtual temperature of the layer,
$\nabla_p \bar{T}_v$ = virtual temperature gradient on pressure surfaces integrated through the vertical, and
$\mathbf{k}$ = unit vector, positive upward.

The terms f, R_d, p_s, and p_5 are all constant for a specific geographical location and time under consideration; therefore, ΔV_g becomes mainly a function of the mean virtual temperature gradient on pressure surfaces integrated through the layer.

The virtual temperature T_v is defined as T_v=(1+0.61 m), where m is the mixing ratio, or the mass of water vapor per unit mass of dry air in the mixture. The mixing ratio is usually numerically small. For instance, at 850 mb over middle-latitude regions, the mixing ratio normally ranges from 0.002 to 0.02. Therefore, for all practical purposes $\nabla_p \bar{T}_v$ in the equation can be replaced by $\nabla_p \bar{T}$, which represents the temperature gradient on pressure surfaces integrated through the vertical from the ground surface to the level of interest.

For large-scale motion, the mean meridional-temperature gradient determines the average vertical shear of zonal wind, $-(\partial u/\partial p)$, which becomes $-(\partial u_g/\partial p)$ with the geostrophic approximation. Here, u and u_g are the zonal components of the observed and geostrophic winds, respectively. When $-(\partial u_g/\partial p)$ reaches a critical value, which is dependent on the other variables, it will lead to long-wave instability. The wavelength of the most intense instability gives the space scale, and the e-fold time of the most unstable wave determines the time scale of the large-scale motion.

The severity of the temperature gradient in February 1980 becomes clear from a comparison of the observed meridional-temperature gradients, $-(\partial T/\partial y)p$, which are derived from isotherm analyses at three pressure levels on a sample storm day, February 15, 1980, with the corresponding long-term climatological average $-(\partial T/\partial y)p$ for the month of February (table 1; all tables at end of report). The observed $-(\partial T/\partial y)p$, in most cases, was substantially greater than the climatological average throughout a wide expanse of the Pacific. The larger than normal meridional-temperature gradient supported a large $-(\partial u_g/\partial p)$, which led to the extremely strong westerlies in the middle and upper troposphere. This large meridional-temperature gradient over the central Pacific sustained vertical shears of the westerlies above the threshold value and provided a favorable environment for generation of short-wave perturbations.

The broad circulation pattern immediately preceding the February 13–21 sequence of storms can best be represented by the sectional hemispheric 500-mb analyses for 0400 hours P.s.t., February 11 and 12 (fig. 2).

At 0400 hours P.s.t., February 11, a strong pressure ridge was over Alaska. West of the ridge, a trough extended from about 50° N. 158° E. to 30° N. 143° W. (fig. 2*A*). Twenty-four hours later, the ridge took a more north-south orientation (fig. 2*B*), further impeding the prevailing westerlies. This blocking ridge became the most dominant feature of the upper airflow. A zone of

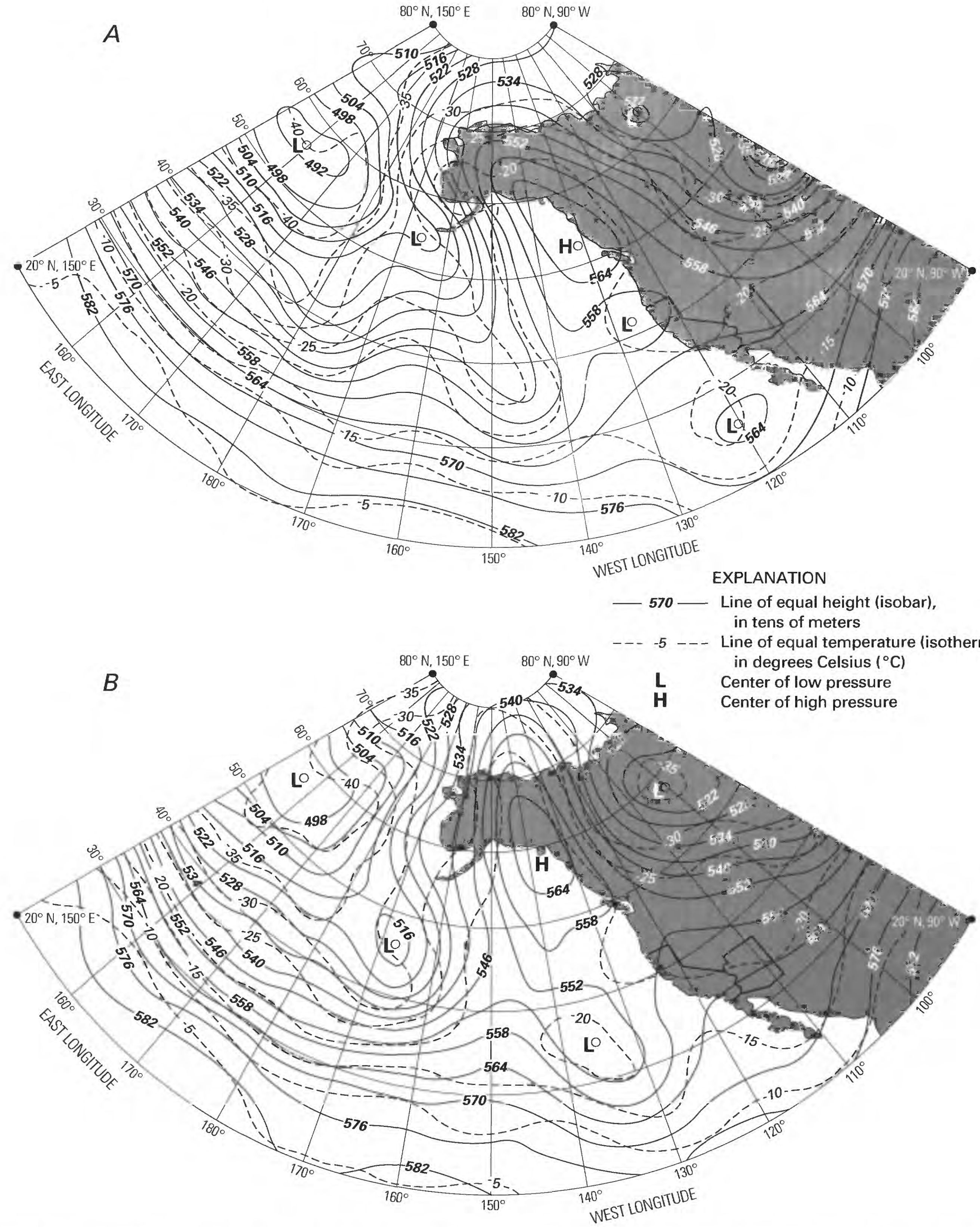


FIGURE 2.—Sectional hemispheric 500-millibar analyses: *A*, 0400 hours P.s.t., February 11, 1980; and *B*, 0400 hours P.s.t., February 12, 1980.

large temperature contrast in the central Pacific, as represented by packed isotherms, extended from about 165° W. westward toward the Asian coast. A Low was located at 56° N. 158° E. The temperature around the Low was less than −40 °C, depicting the dome of cold airmass that had originated in Siberia and had been spreading into the central Pacific. The upper airflow was strongly zonal from the coast of Asia to about 160° W. A dominant blocking ridge sat over Alaska and the Gulf of Alaska along 135° W., and a Low was situated to the south at about 35° N. The general circulation westerlies were split either northward to very high latitudes around the blocking ridge or southward to the south of the Low. The subtropical jetstream was routed to a belt between 25° N. and 35° N., as it penetrated beneath the blocking ridge.

The baroclinic band over the central Pacific was associated with the strong vertical shear of the westerlies and long-wave instability. Strong baroclinic instability existed poleward from the jetstream, and a series of short waves developed. The subtropical westerlies strengthened over the eastern Pacific when mean windspeeds were more than twice the normal along the axis of the jetstream. The Pacific subtropical westerlies were so strong and so extensive that upper level troughs were driven across the Western United States. The troughs weakened the ridge that normally persists there, displaced the Great Basin High, and exposed southern California and Arizona to the storm track. Over a period of 9 days, six short-wave troughs were generated in the upper airflow while cyclogenesis occurred in the lower atmosphere above the ocean surface of the central Pacific between 35° N. and 42° N., beneath the northern side of the jetstream. The sequence of storms during February 13–21, which were identified to the public by numbers, brought heavy rains.

DEVELOPMENT OF STORMS, FEBRUARY 13–21

In subsequent sections, a description of the evolution of the storm sequence is followed by an account of the evolution of relevant meteorological parameters and a more detailed account of the meteorological conditions during the first days of the storms. An examination of the events during the first days of the storm period highlights the transition from fair weather and suffices to depict the large-scale meteorological environments in which subsequent individual storms developed. The development and movement of storms are shown in the GOES infrared photography for February 13–21 (figs. 3*A-I*).

The first storm was identified on satellite photography for February 11 as a wave that was developing on an existing cloud band about 32° N. 142° W. (not shown). The wave grew into a cyclone, moved eastward, and spread rain over southern California on February 13. At 0145 hours P.s.t., February 13, the storm had reached the coast of California (fig. 3*A*). Behind the cold front of this storm were two comma-shaped cloud formations consisting of thick layer-type cloud masses formed from tops of cumulonimbus. Both comma-shaped clouds were related to surface low-pressure centers. By 1000 hours P.s.t., February 13, the storm and cloud formation had extended over all of southern California and western Arizona (fig. 3*B*). The trailing comma-shaped clouds arrived somewhat later. The second comma-shaped cloud moved inland on the morning of February 14 and across Arizona during that day (fig. 3*C*).

While the Southwestern United States was still under the extensive cloud cover of storm 1, storm 2 was at 33° N. 140° W., to the north of the jetstream (fig. 3*B*). To the south of storm 2 was an elongated cloud band. This cloud band was representative of a deep airflow bringing tropical moisture to the west coast. The cloud band later merged with the frontal system associated with storm 2, and the low-pressure center had moved in an arc northeastward into central California by the morning of February 15 (fig. 3*C*). At the same time, storm 3 was identified at 31° N. 150° W. High, cold clouds of subtropical origin between 25° N. and 32° N. preceded the cyclonic center of storm 3, which rotated northeastward toward northwestern California on February 16. The deep layer that continued to bring tropical Pacific moisture to the west coast was represented by this cloud mass, which extended from the central Pacific northeastward across southern California and central Arizona. The bulging portion of the cloud system, which corresponded to the prefrontal system ahead of an occlusion and a warm front at the surface, had moved into California and Baja California by the morning of February 16 (fig. 3*D*). Thunderstorms with a high liquid-water content embedded in the cloud system brought heavy rain. The storm center crossed the coastline late on February 16, and the rains in southern California diminished during the night. The rains in Arizona abated on the morning of February 17.

On February 16, the center of storm 4 was visible near 36° N. 155° W in the central Pacific (fig. 3*D*). The storm was steered eastward by the jetstream, reached the coast of California on the evening of February 17 (fig. 3*E*), and was accompanied by heavy rain. The rain ended in southern California on the morning of February 18; however, as the short-wave trough moved into Arizona, the rain continued throughout most of the day. This storm brought in a large amount of subtropical moisture as the southwesterly flow from the central Pacific continued. Meanwhile, the freezing level over central Arizona had risen from an altitude of less than 5,000 ft (feet)

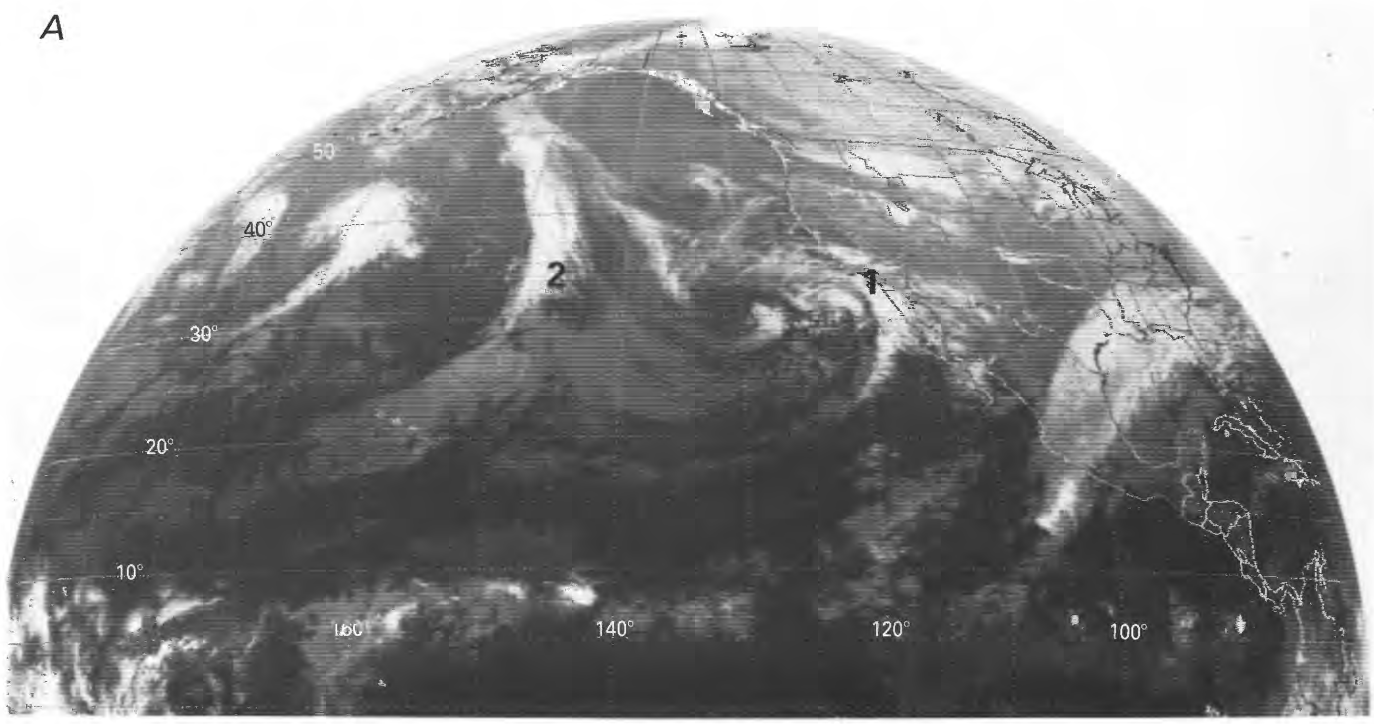


FIGURE 3*A*.—GOES infrared image of storms 1 and 2, 0145 hours P.s.t., February 13, 1980.

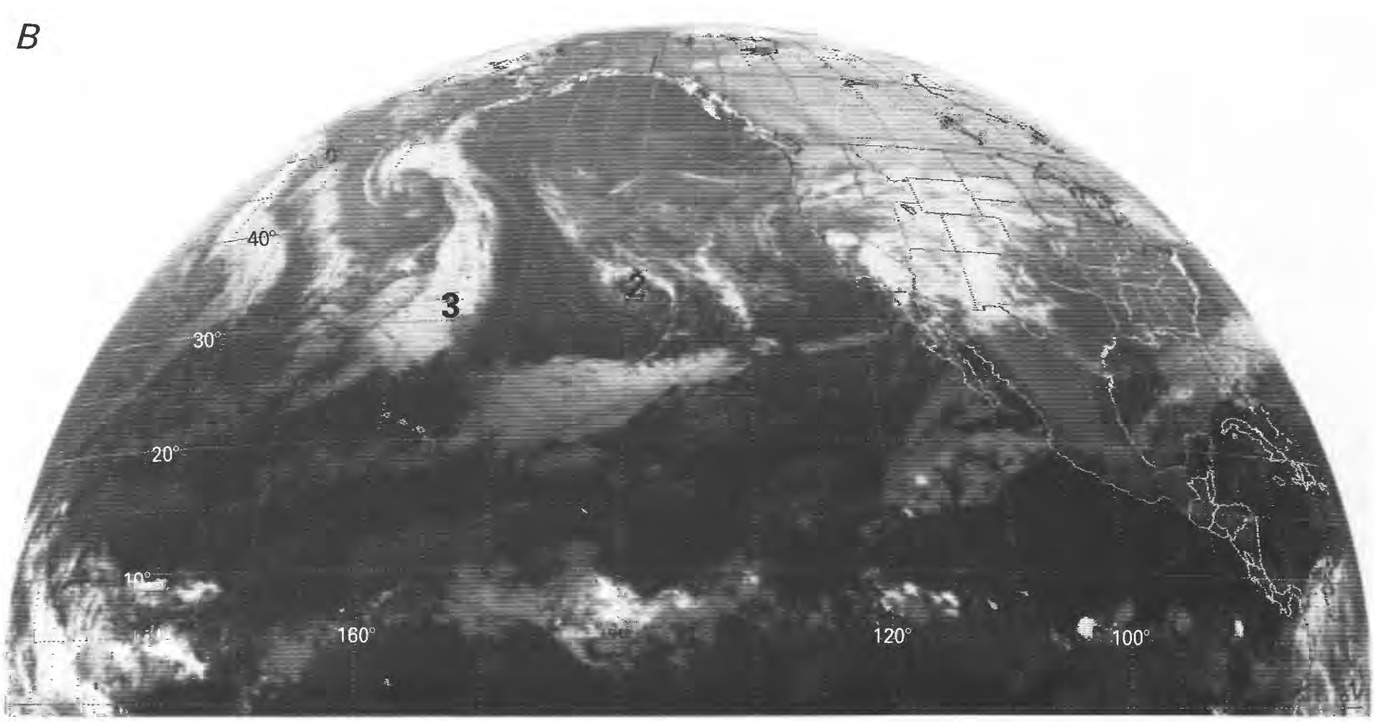


FIGURE 3*B*.—GOES infrared image of storms 2 and 3, 0145 hours P.s.t., February 14, 1980.

C

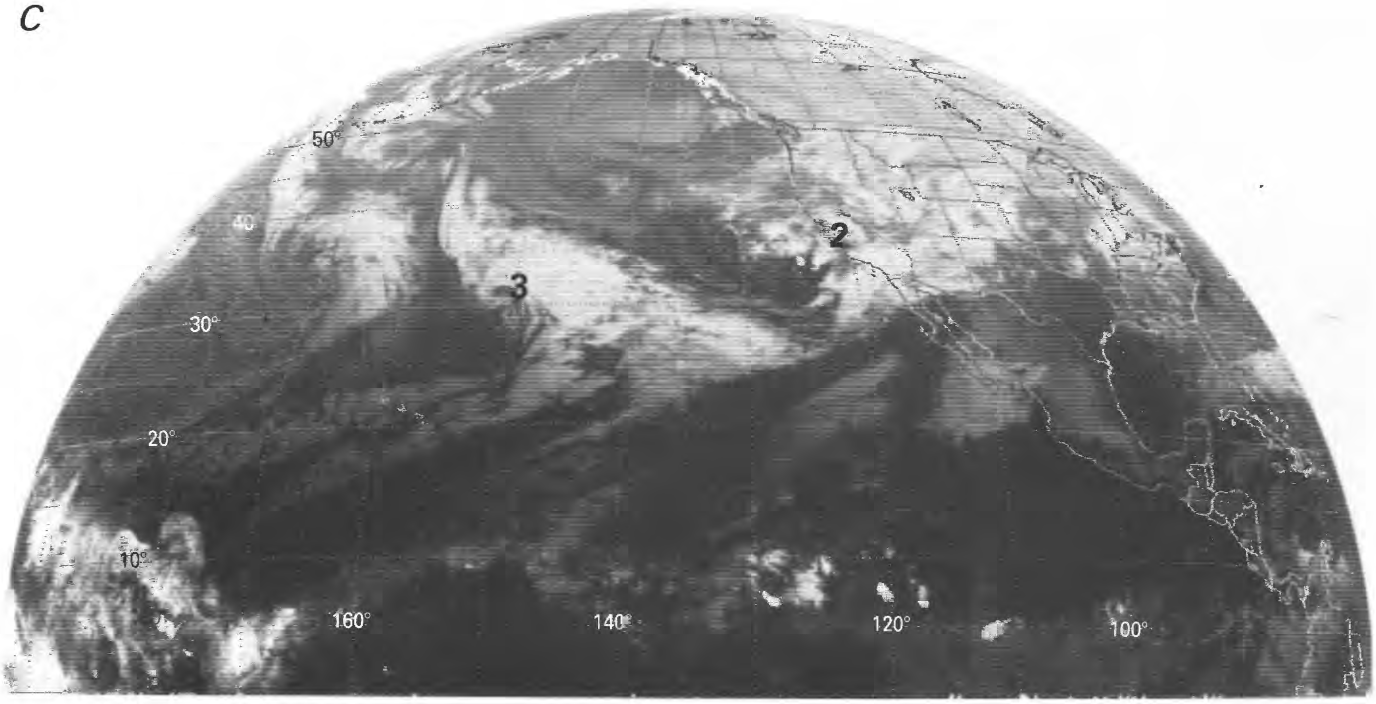


FIGURE 3*C*.—GOES infrared image of storms 2 and 3, 0145 hours P.s.t., February 15, 1980.

D

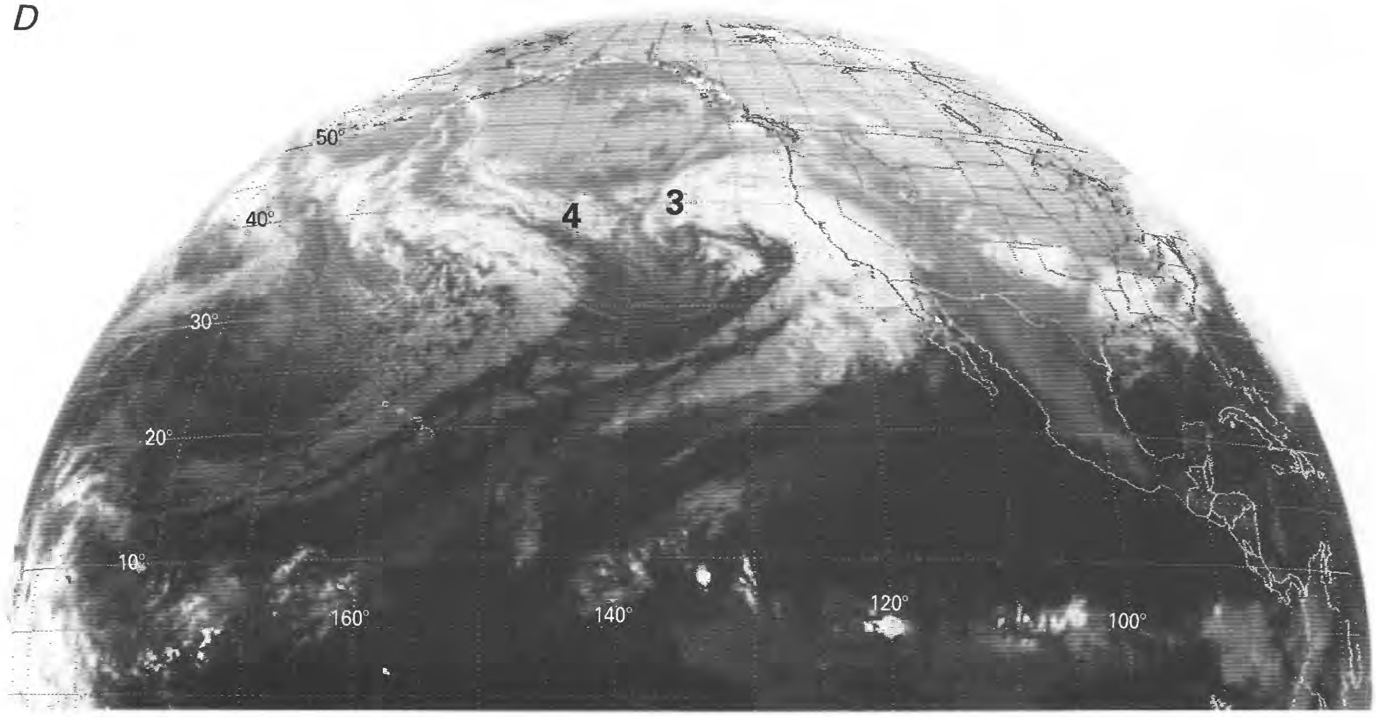


FIGURE 3*D*.—GOES infrared image of storms 3 and 4, 0415 hours P.s.t., February 16, 1980.

E

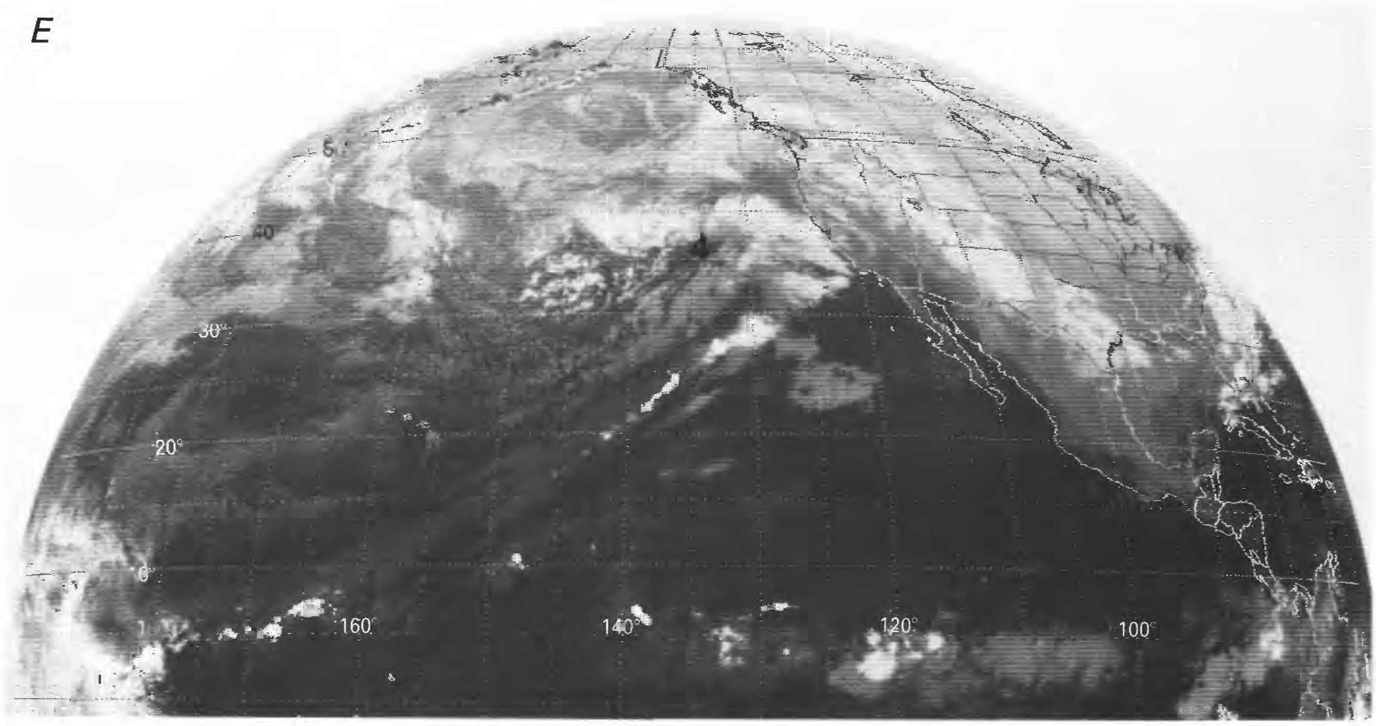


FIGURE 3E.—GOES infrared image of storm 4 near the coast of California, 0415 hours P.s.t., February 17, 1980.

F

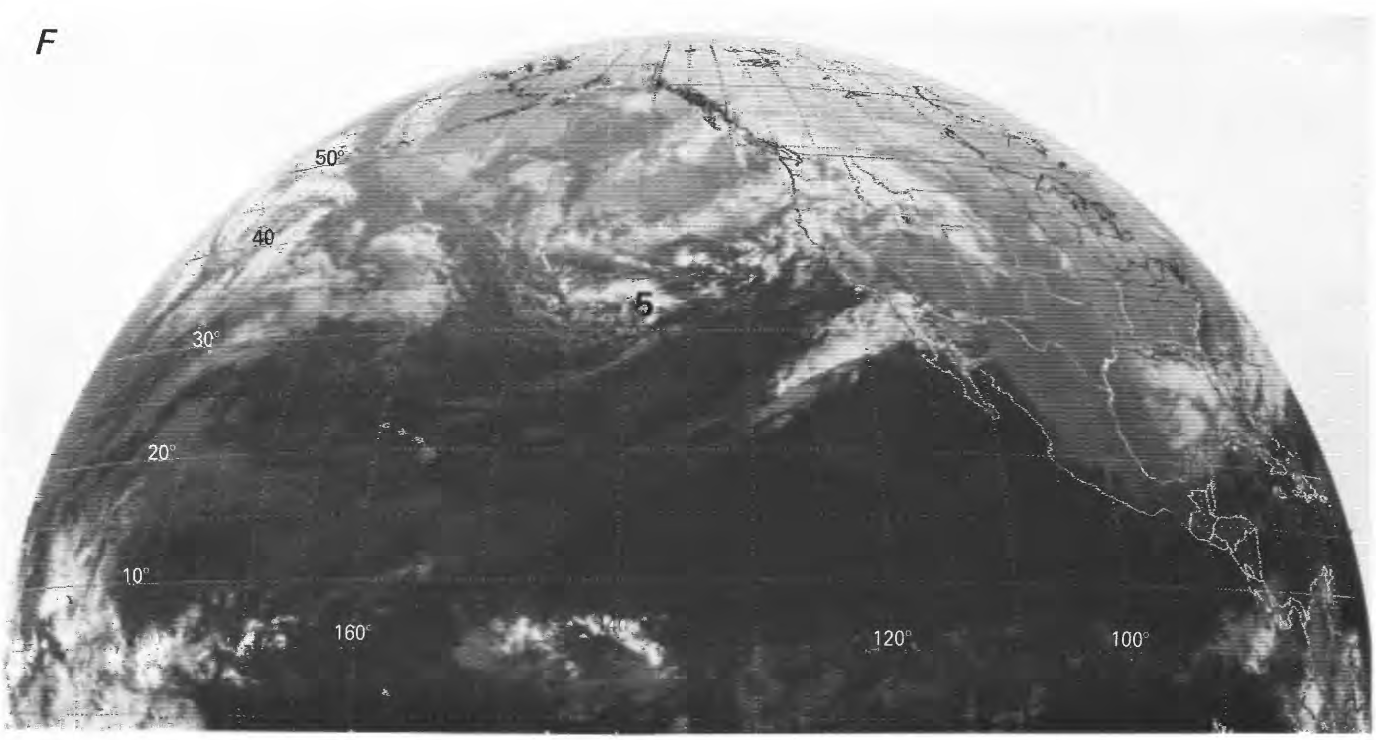


FIGURE 3F.—GOES infrared image of start of storm 5, 0415 hours P.s.t., February 18, 1980.

G

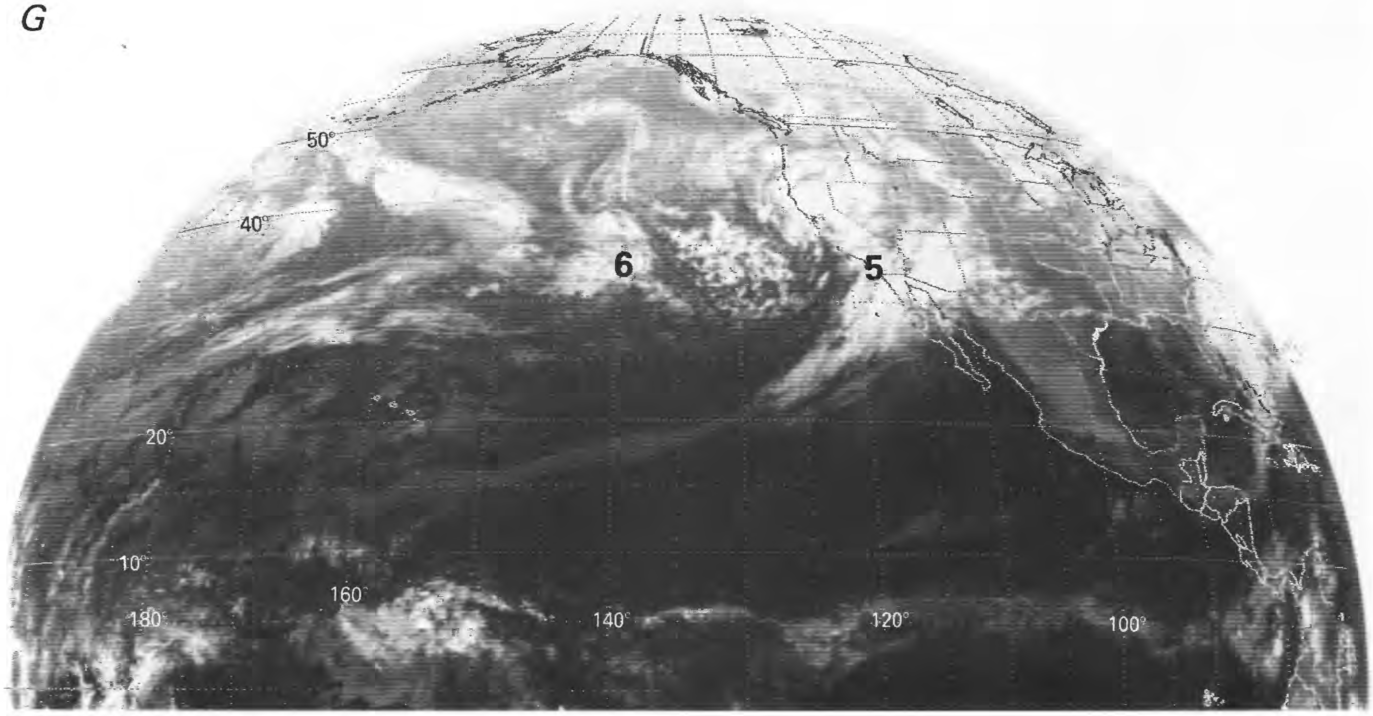


FIGURE 3*G*.—GOES infrared image of storms 5 and 6, 0415 hours P.s.t., February 19, 1980.

H

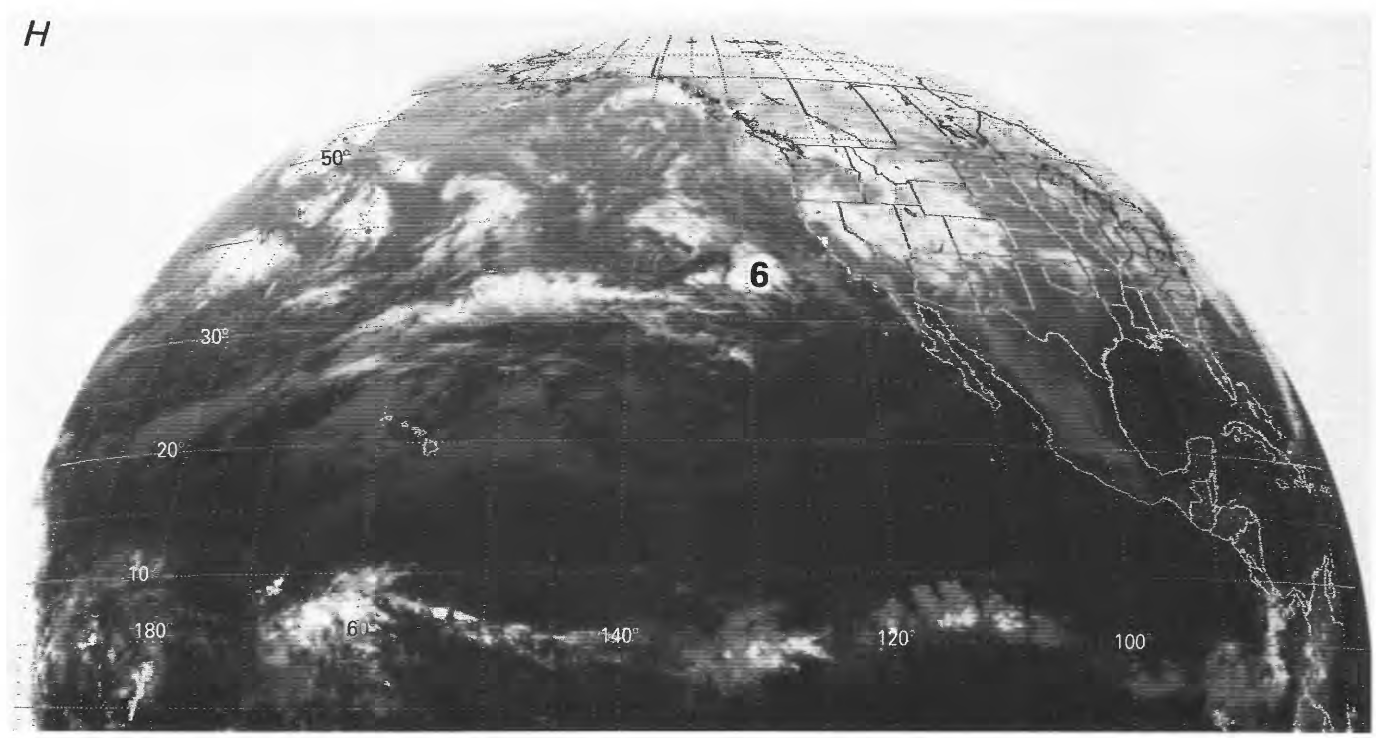


FIGURE 3*H*.—GOES infrared image of storm 6 as it moved eastward, 0415 hours P.s.t., February 20, 1980.

I

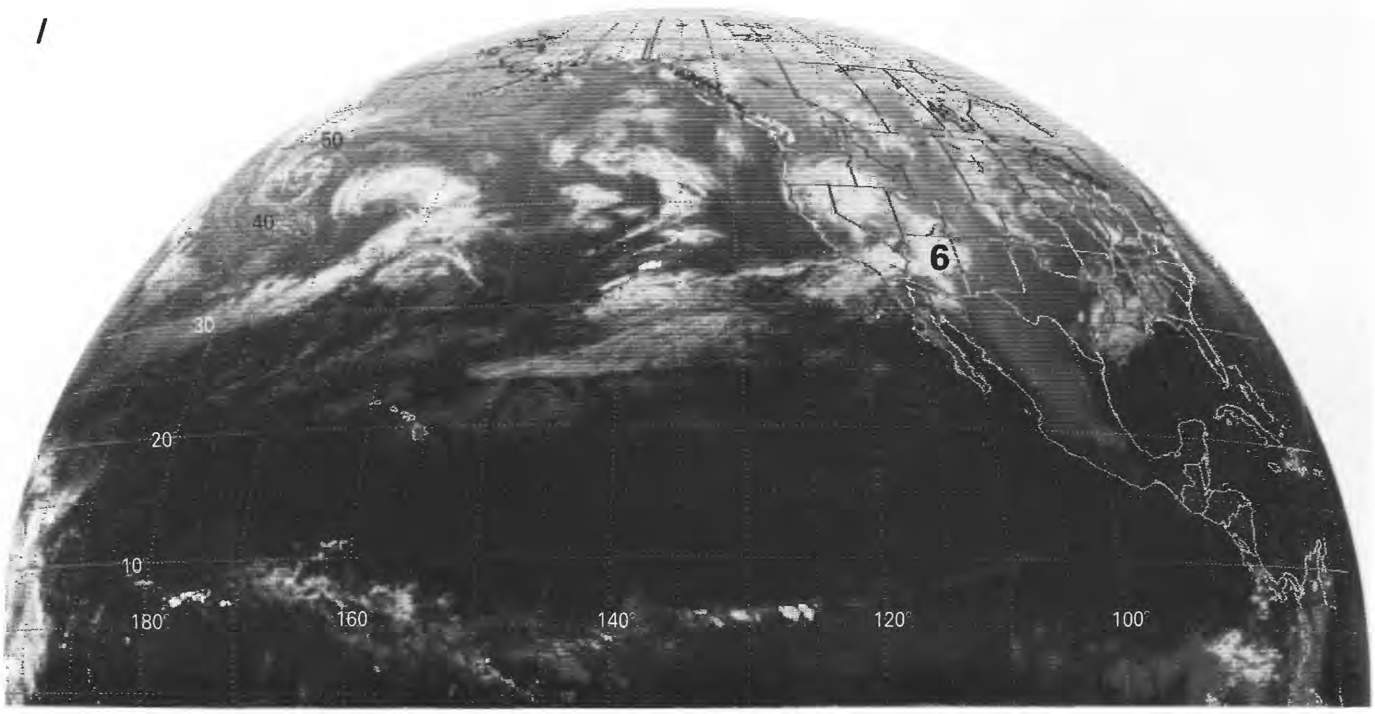


FIGURE 3*I*.—GOES infrared image of storm 6 over Arizona, 0415 hours P.s.t., February 21, 1980.

on the morning of February 13 to an altitude of about 10,000 ft above sea level on the morning of February 18.

Cyclogenesis north of the Hawaiian Islands led to storm 5. At 0415 hours P.s.t., February 18, that storm was centered at 33° N. 140° W. (fig. 3*F*). The storm, moving rapidly eastward at about 50 knots, crossed the west coast and arrived over California on the night of February 18. Meanwhile, storm 5 reinforced the remnants of storm 4, which was in the form of a trailing cloud band over southern California and offshore waters. This trailing cloud band originated over a relatively warm ocean with sea-surface temperature exceeding 20 °C. A vorticity center also developed and caused showers and thunderstorms over southern California and Arizona on February 19.

Storm 6 was a breakoff from a cloud mass 1,000 mi (miles) north of the Hawaiian Islands that occurred on February 19 (fig. 3*G*). During the night of February 19, the breakoff cloud became disorganized and was seemingly dissipated by the westerly jetstream along 35° N. Only scattered remnants of cold, high-top clouds remained. Then a portion of the scattered clouds merged, and growth renewed. The cold cloud-top area enlarged rapidly over a period of several hours while moving toward the coast. At 0415 hours P.s.t., February 20, the cloud-top area was centered at 34° N. 129° W. (fig. 3*H*); it reached the coast in the afternoon and evening. Because of the lack of a well-organized cyclonic circulation, storm 6 entrained less moisture than the previous storms. Intermittent moderate to heavy rain was observed over southern California and central Arizona until the afternoon of February 21 (fig. 3*I*). A ridge of high pressure had developed over the central Pacific by February 21 and diverted subsequent storms to a more northerly track; the next storm approached the west coast of Oregon north of 40° N.

RAINFALL POTENTIAL

The most important factor that influences precipitation from a storm is the availability of an adequate moisture supply. The moisture supply is measured as inches of precipitable water. Large amounts of precipitable water were maintained over the study area throughout the storm period. Amounts of precipitable water in the layer between ground surface and the 500-mb pressure surface at Vandenberg Air Force Base, Calif. (northwest of Santa Barbara), San Diego, Calif., and Tucson, Ariz., are shown in figure 4.

A second factor important to many storms is the degree of instability, which is indicated by the K index and the lifted index. The K index is a measure of thunderstorm potential based on the vertical temperature lapse rate, the moisture content of the lower atmosphere, and the vertical extent of the moist layer. An index of less than 15 corresponds to a thunderstorm probability of zero percent. As the index increases, the

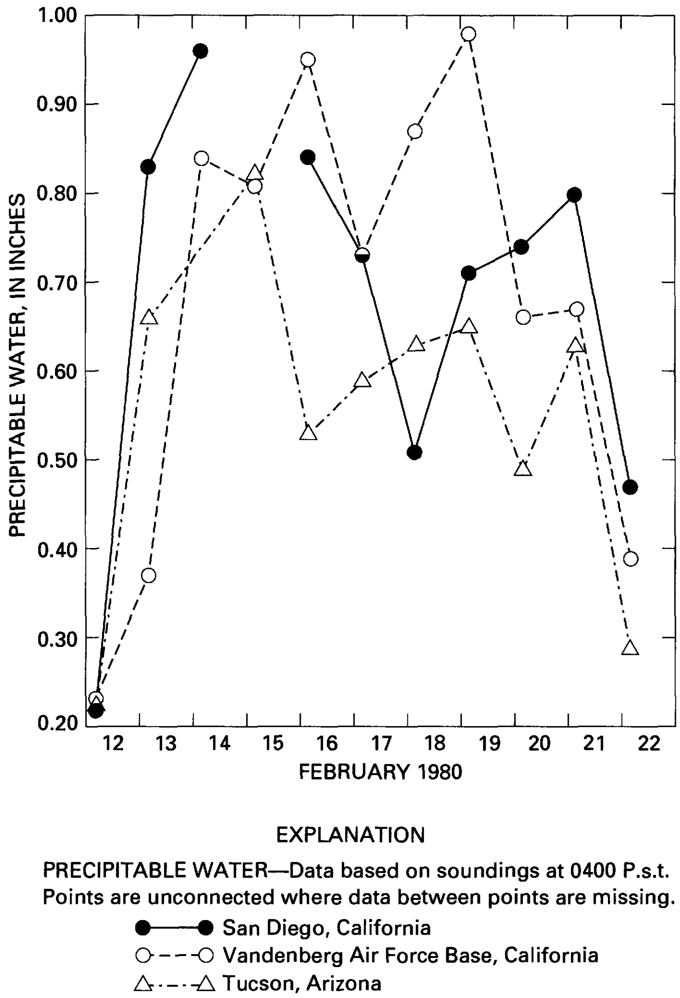


FIGURE 4.—Evolution of precipitable water, February 12–22, 1980.

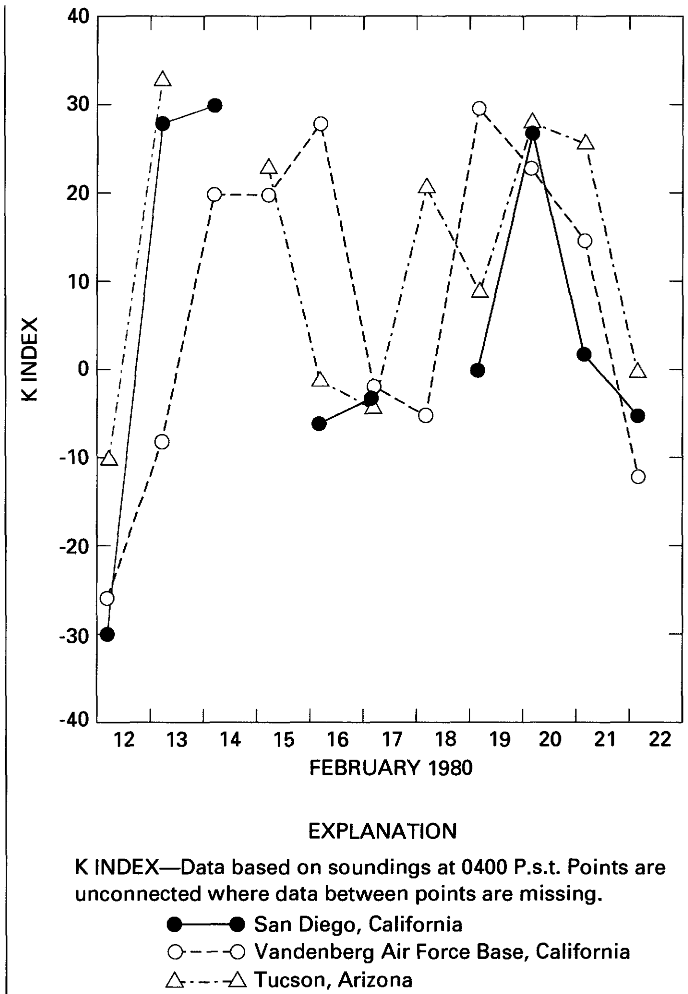


FIGURE 5.—Evolution of K index, February 12–22, 1980.

probability increases until the index reaches 40, at which level the thunderstorm probability approaches 100 percent. The lifted index is computed by theoretically lifting a parcel 25 mb above the surface dry adiabatically to the lifting condensation level and then moist adiabatically to 500 mb. The observed temperature at 500 mb minus the parcel temperature is the lifted index. A lifted index of 4 or less indicates unstable conditions; values above 4 indicate stable conditions. A highly negative value indicates that the energy required to lift a parcel of air to its level of free convection is much exceeded by the positive energy released by the parcel between the starting level and 500 mb. Therefore, convection will be self-sustaining once a parcel has passed the level of free convection.

A high stability criterion does not preclude convective precipitation. The stability indices can be calculated only for stations in the radiosonde network where temperature structure and moisture content are measured. The average spacing between such stations is about 200 mi, and the time interval between soundings is 12 hours. The typical convective cell has a dimension of 6 mi and a life of 1 hour; therefore, convective storms can occur when indices indicate a stable atmosphere. The tenuous relationship between the lifted index and rainfall shown in figure 6 bears this out indirectly.

The evolution of the K index and the lifted index during the storm period is shown in figures 5 and 6, respectively. The lifted index indicated unstable conditions over southern California on February 14, 15, 17, 19, 20, and 21. Unstable conditions existed over Tucson, Ariz., on February 13, 15, 17, 19, and 20.

The changes in moisture and stability parameters for San Diego and Tucson prior to the onset of the storms is typical of what happened over much of the study area. At San Diego, precipitable water at 0400 hours increased from 0.22 in (inch) on February 12 to 0.83 in on February 13 and 0.96 in on February 14. (The mean of the semimonthly maximum is 0.80 in, and the maximum observed semimonthly value over 27 years of record is 1.28 in.) During the 24-hour period ending at 0400 hours

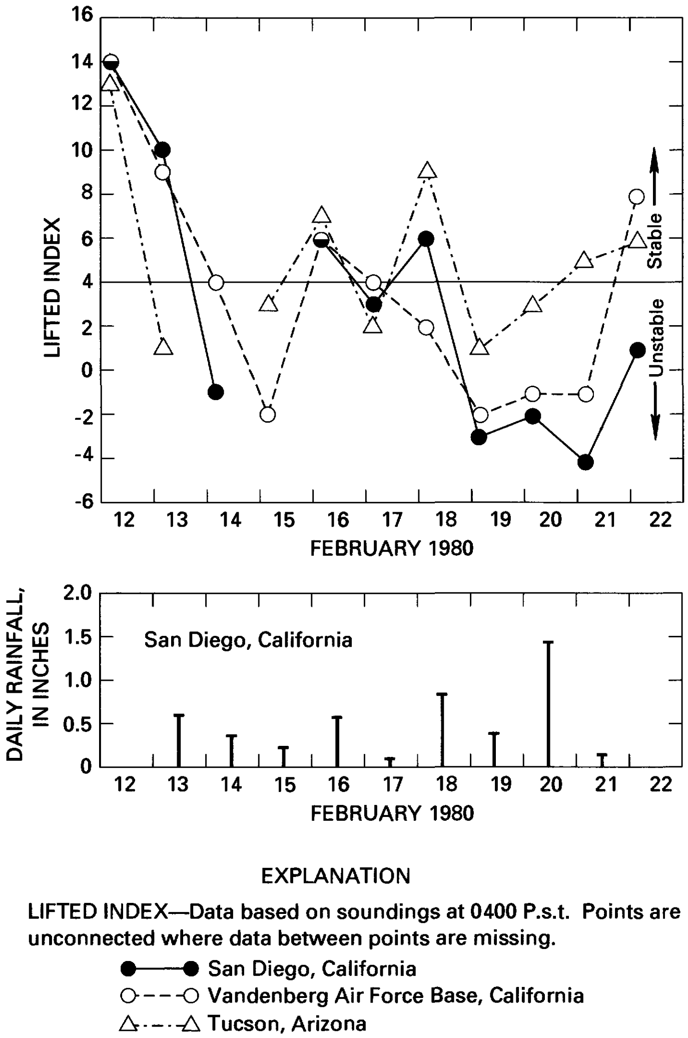


FIGURE 6.—Evolution of lifted index at three locations, and daily rainfall at San Diego, Calif., February 12–22, 1980.

on February 13, the K index increased from −30 to +28 and the lifted index decreased from 14 to 10.

The extreme change in the K index of 58 in 24 hours indicated a drastic shift in the nature of the airmass from a very dry and stable thermostructure to a structure with high moisture content below the 700-mb level. A K index of 28, by itself, would show a 50-percent probability of thunderstorm occurrence. A K index of 28 combined with a lifted index of 10 (fig. 6) indicated a thermostructure that inhibited free convection. A rainfall of 0.01 in between 0400 and 0500 hours on February 13 at San Diego was followed by moderate rain beginning about 0900 hours. The earlier rain most likely came from layer clouds associated with an extratropical cyclone. Precipitable water at Tucson increased from 0.23 in on February 12 to 0.66 in on February 13 and 0.82 in on February 15. (The mean of the semimonthly maximum is 0.54 in, and the maximum observed semimonthly value over 21 years of record is 0.89 in.)

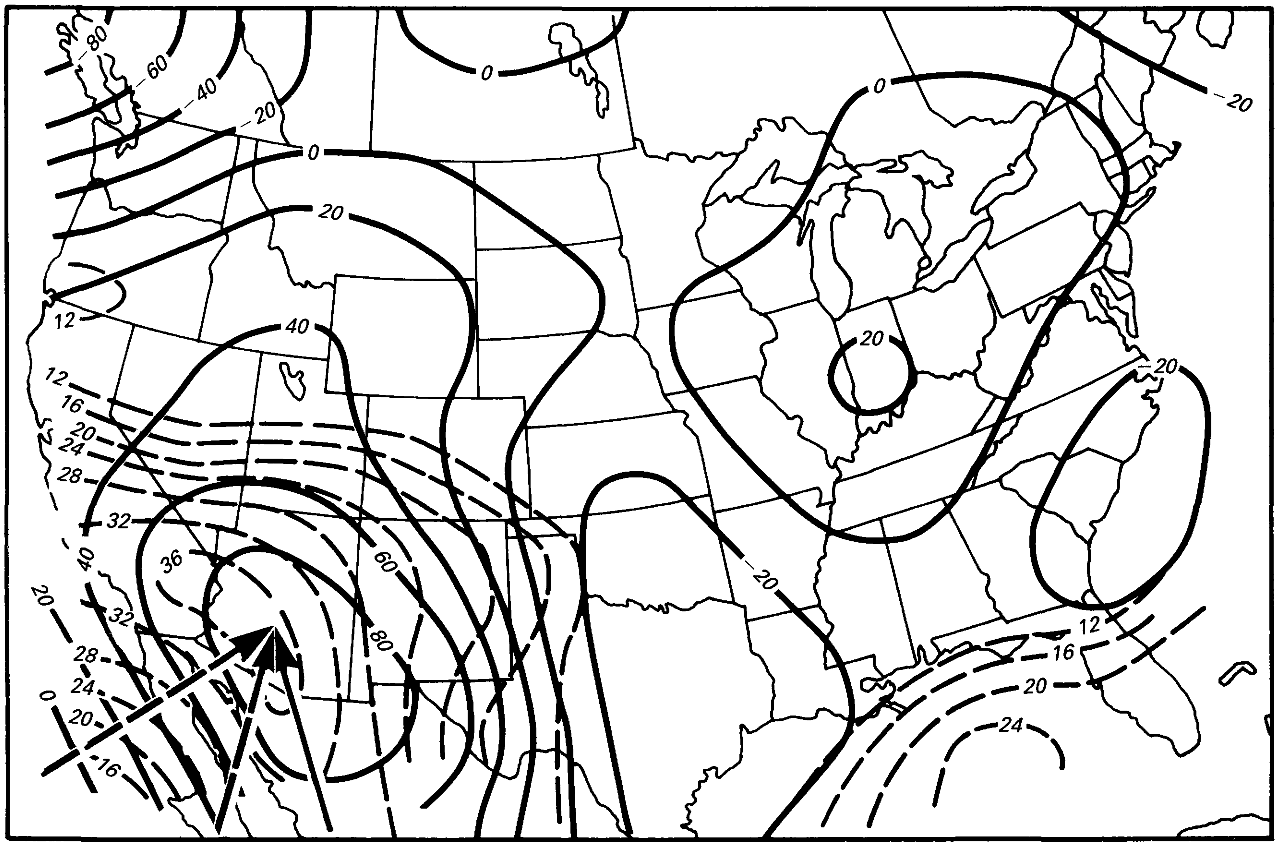
The prognostic K index and 700-mb 12-hour net vertical displacement at 0400 hours on February 14 are shown in figure 7. Over most of southern California the net vertical displacement was an ascent of more than 50 mb in 12 hours, and over most of Arizona the ascent exceeded 80 mb in 12 hours. The latter is approximately equivalent to a net rising of 900 m (meters). Significant rising motion on a synoptic scale provided a favorable environment for individual convective cells to develop within the large extratropical cyclone. The prognostic K-index value exceeded 32 over the study area, and it exceeded 36 over a limited area. These high indices indicated a thunderstorm probability of 70 to 85 percent. The available observations of stability indices indicated reasonable agreement between observed and forecast yields.

Interpreted trajectories of air parcels for three pressure levels—surface, 700 mb, and 850 mb—at Phoenix at 0400 hours on February 14 are shown in figure 7. A region of the Pacific Ocean just off Baja California, in which sea-surface temperatures between 18 and 22 °C were observed in mid-February 1980, was a significant source of moisture for central Arizona. Moist maritime air from that region was brought directly into Arizona by the southwesterly flow without passing through southern California.

The average relative humidity from the surface to 500 mb and the instantaneous vertical velocity at the 700-mb level at 1600 hours on February 13 and at 0400 hours on February 14 are shown in figure 8. At both times, relative humidity exceeded 70 percent over the study area. Vertical velocity exceeded 2.24 cm/s (centimeters per second) over southern California. Over central Arizona, vertical velocity was positive, but was smaller than 2.24 cm/s at the first sampling time and greater than 2.24 cm/s at the second. At 0400 hours on February 14 a 500-mb trough approached the study area. Rising motion on the lower troposphere over the study area was associated with the passage of storm 1.

BEGINNING METEOROLOGICAL CONDITIONS, FEBRUARY 13–14

Meteorological conditions at the beginning of the storm sequence are represented by surface air and upper air analyses at 1600 hours on February 13 and at 0400 hours on February 14 (figs. 9–12). The 300-mb analyses (fig. 9) showed that the subtropical jetstream was located between 25° N. and 30° N. over the eastern Pacific and passed over Baja California, northern Mexico, and southeastern Texas. The jetstream meandered during the 9-day storm period; its most frequent position was over Baja or southern California. At 126° W., windspeeds along the jetstream at 0400 hours on February 14



EXPLANATION

—— 20 —— Line of equal displacement of the 700-millibar pressure surface—Positive values indicate a rising pressure surface; negative values indicate a sinking pressure surface. Interval 20 millibars

— — 32 — — Line of equal K index—Interval 4 units

Trajectory of air parcels arriving at Phoenix, Arizona

Surface

At 850-millibar pressure surface

At 700-millibar pressure surface

FIGURE 7.—Net vertical displacement of the 700-millibar pressure surface during the 12-hour period ending at 0400 hours P.s.t., February 14, 1980, and K indices and trajectories of air parcels at the ending time.

reached 120–130 knots (140–150 mi/h (miles per hour)), which is more than twice the climatological normal. This strong subtropical jetstream drove the upper level troughs across the Western United States, weakened the normal mean ridge, and displaced the Great Basin High over Nevada and Utah. The High had been the primary obstacle blocking the storm path into southern California. As a result, Pacific storms were permitted to invade southern California and Arizona. The meteorological settings were very similar to those associated with the sequence of four major storms of January 1969, which inundated southern California.

Storm centers were generated continually over the central Pacific beneath the northern side of the jetstream. An example of such a storm center was the Low centered near 32° N. 125° W. at 1600 hours on February 13, which was apparent at all levels from 500 mb to the ground surface (figs. 10*A*, 11*A*, 12*A*). At 1600 hours on

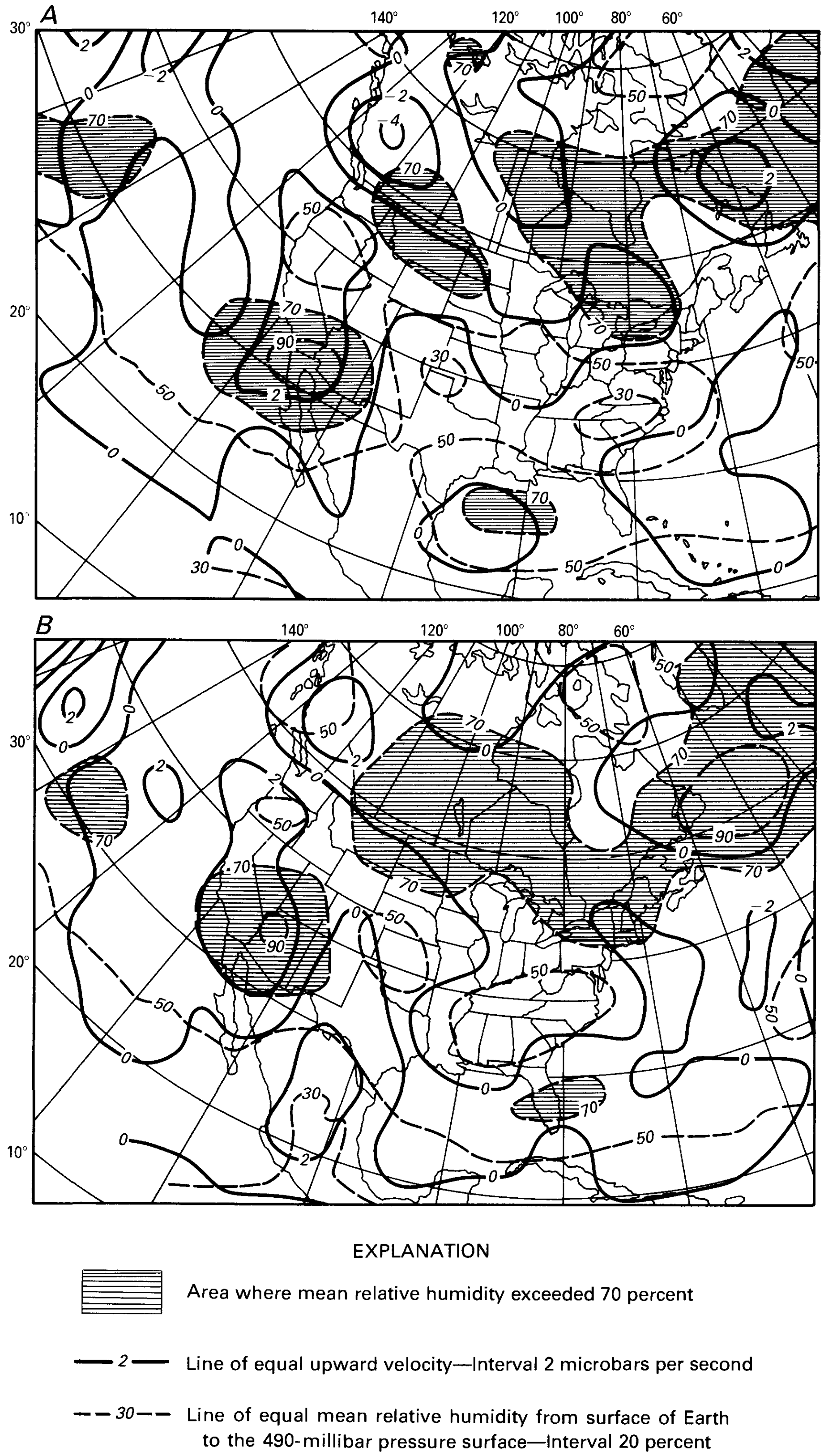
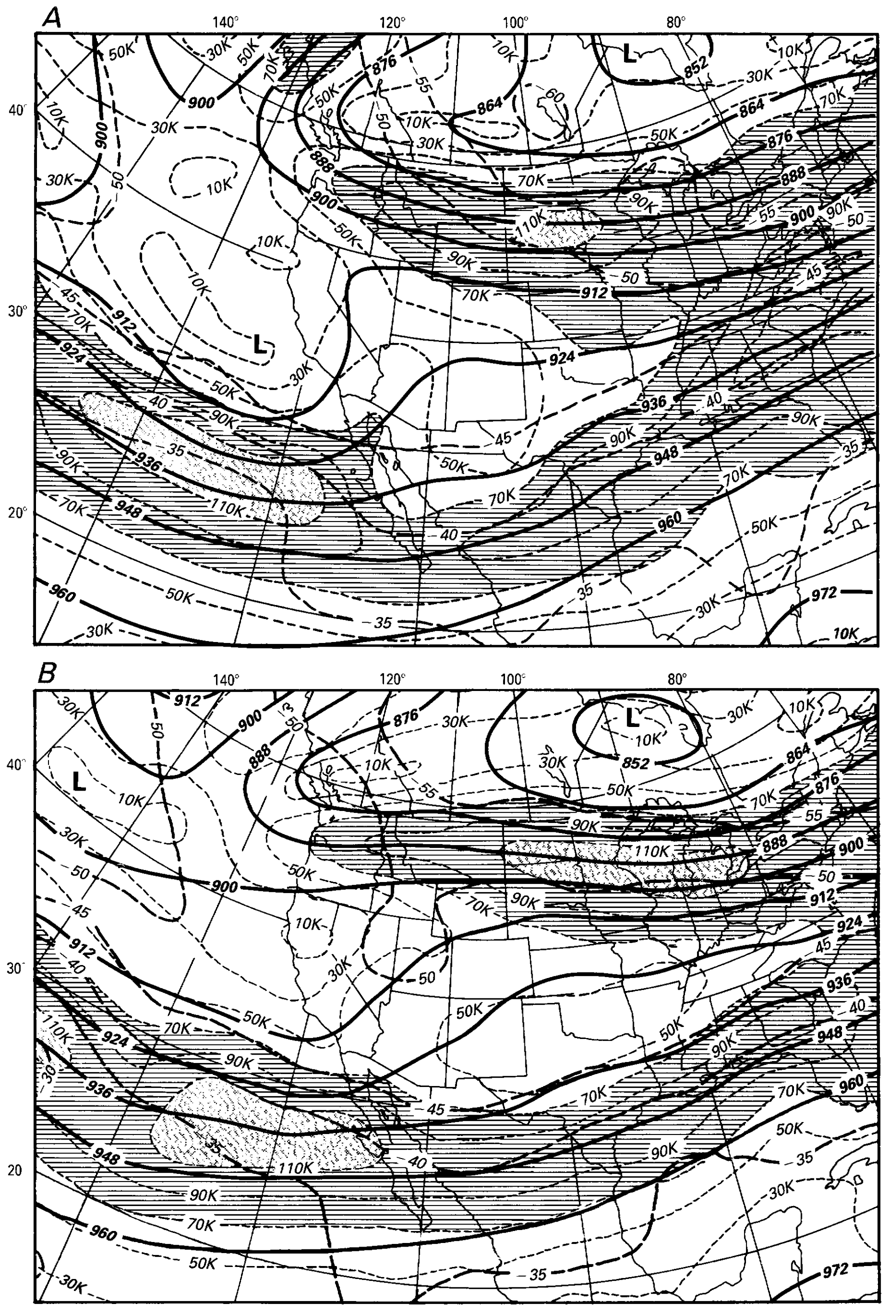


FIGURE 8.—Analyses of relative humidity and vertical velocity: *A*, 1600 hours P.s.t., February 13, 1980; and *B*, 0400 hours P.s.t., February 14, 1980.



EXPLANATION

Area where windspeeds were between 70 and 110 knots

Area where windspeeds exceeded 110 knots

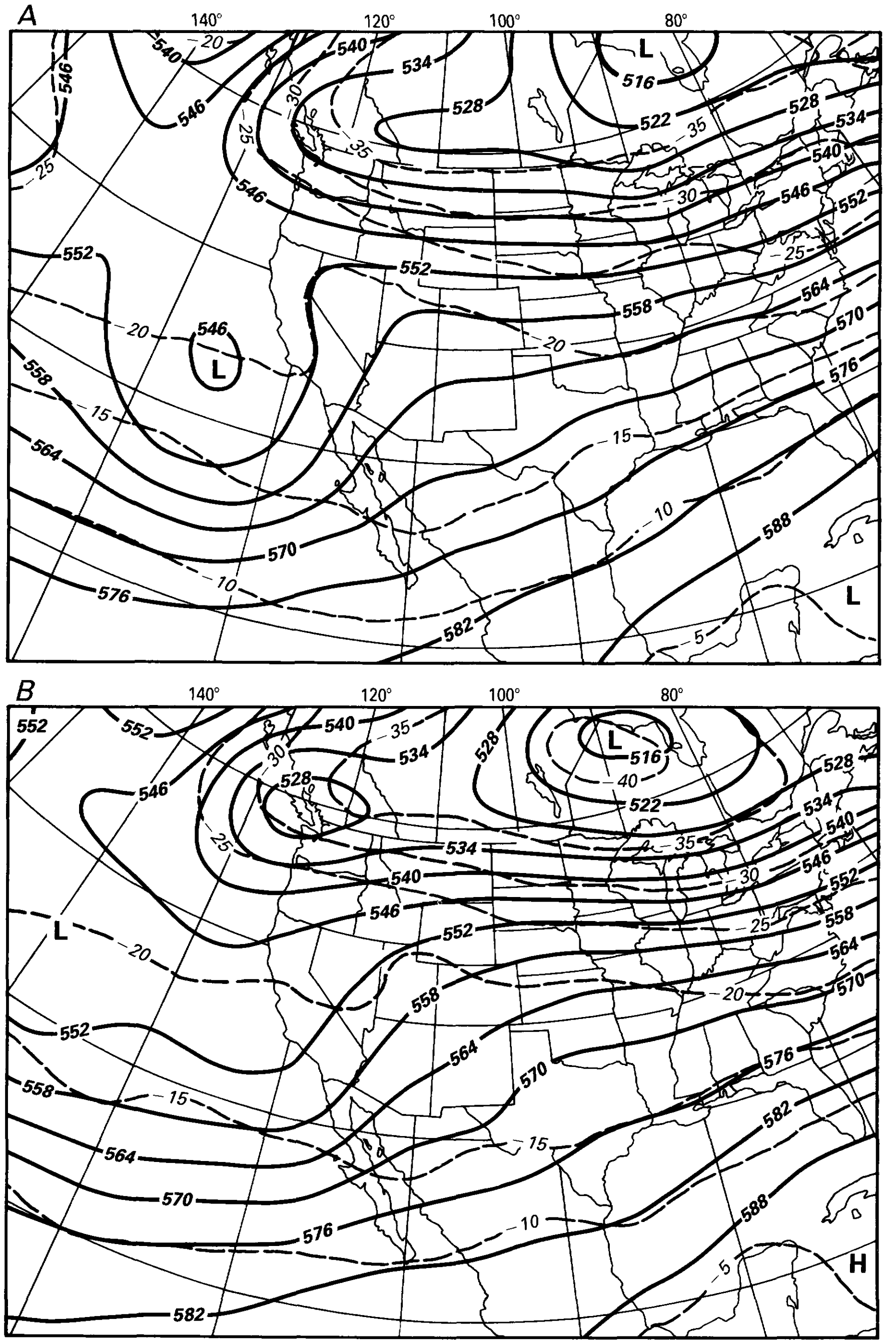
— — −30 — — Line of equal temperature (isotherm), in degrees Celsius

- - - 10K - - - Line of equal windspeed (isotack), in knots

—— 900 —— Line of equal height (isobar), in tens of meters, showing altitude above sea level where atmospheric pressure equals 300 millibars

L Center of low pressure

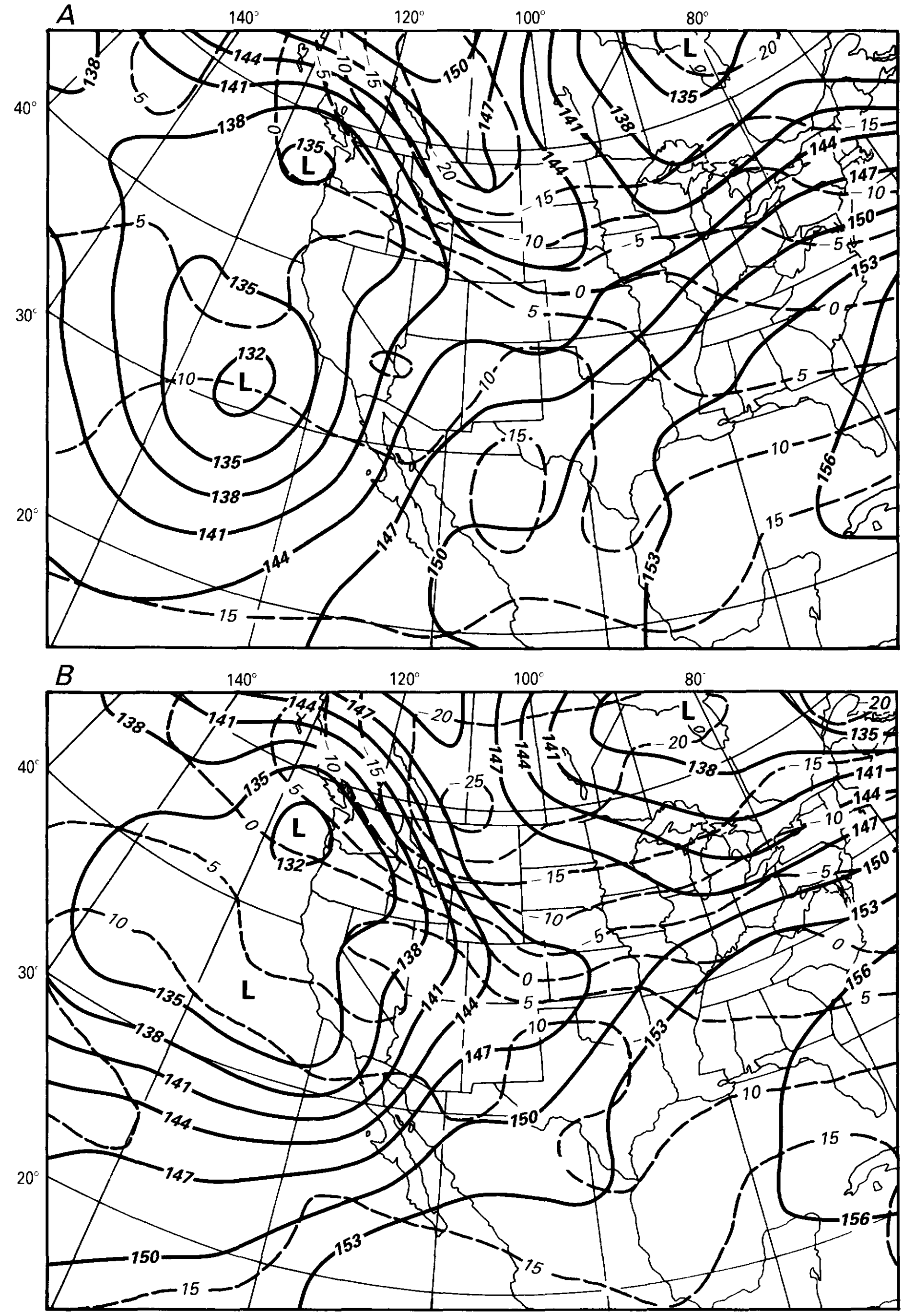
FIGURE 9.—300-millibar analyses: *A*, 1600 hours P.s.t., February 13, 1980; and *B*, 0400 hours P.s.t., February 14, 1980.



EXPLANATION

— — – 10 — —	Line of equal temperature (isotherm), in degrees Celsius
——— 552 ———	Line of equal height (isobar), in tens of meters, showing altitude above sea level where atmospheric pressure equals 500 millibars
L	Center of low pressure
H	Center of high pressure

FIGURE 10.—500-millibar analyses: *A*, 1600 hours P.s.t., February 13, 1980; and *B*, 0400 hours P.s.t., February 14, 1980.



EXPLANATION

— — 10 — —	Line of equal temperature (isotherm), in degrees Celsius
—— 141 ——	Line of equal height (isobar), in tens of meters, showing altitude above sea level where atmospheric pressure equals 850 millibars
L	Center of low pressure

FIGURE 11.—850-millibar analyses: *A*, 1600 hours P.s.t., February 13, 1980; and *B*, 0400 hours P.s.t., February 14, 1980.

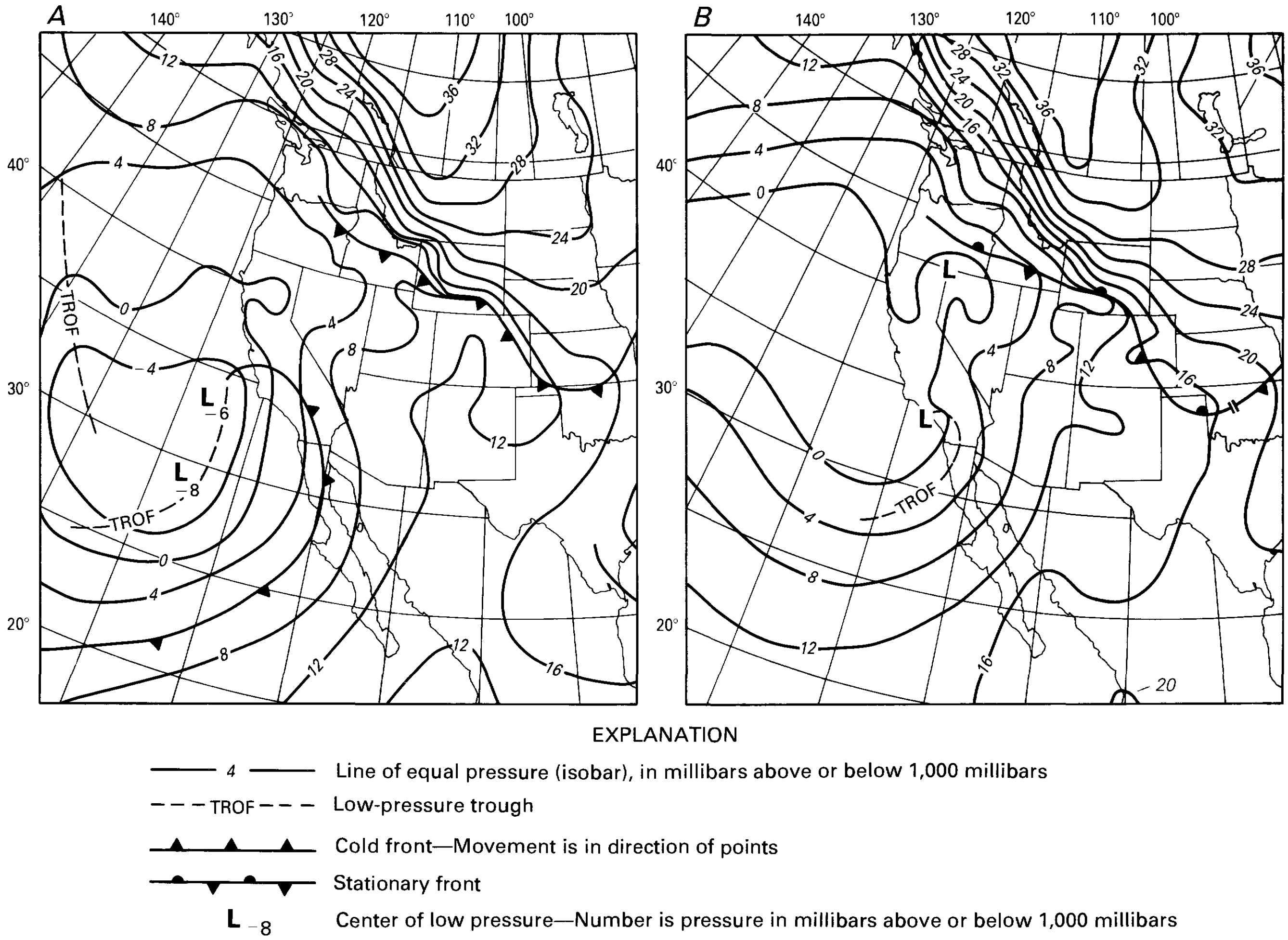


FIGURE 12.—Surface analyses: *A*, 1600 hours P.s.t., February 13, 1980; and *B*, 0400 hours P.s.t., February 14, 1980.

February 13, the surface cold front of storm 1 was progressing eastward through southern California, which was then under a 500-mb trough-to-ridge contour pattern. An absolute vorticity maximum (not shown) with a magnitude greater than 14×10^{-5} was just off the coast, indicating that strong positive vorticity advection into the region could be expected. On the 850-mb surface (fig. 11), the deep trough off the coast of Baja California facilitated a southwesterly flow of moist maritime air over southern California and Arizona. The blocking ridge and High were positioned over Alaska and the Gulf of Alaska. This is a typical location for a high-latitude, warm anticyclone, with temperature in the High greater than the surrounding environment at all levels from 850 to 300 mb. Above 300 mb (the tropopause) (fig. 9*A*), the temperature gradient reversed, and temperatures in the High were lower than those in the surrounding environment. The accumulated airmass in the lower stratosphere overcame the density deficiency in the troposphere, and the High and the ridge were maintained. The persistent ridge of high pressure blocked the zonal circulation and divided it into two branches, as mentioned earlier. The jetstream followed the northern route as late as February 11, while the subtropical westerlies over the Pacific were weak. On February 12 and 13, the subtropical westerlies strengthened greatly, and a subtropical jetstream formed. The subtropical jetstream penetrated "beneath" the Alaskan ridge and pulled the storm track southward.

The 500-mb short-wave trough (fig. 10) associated with storm 1 was at approximately 122° W. at 1600 hours on February 13. This short wave progressed eastward through the basic long-wave pattern and was just off the coast of southern California and Baja California on the morning of February 14.

Meanwhile, a new cyclone was growing offshore. The low-pressure center of storm 2 was located at 33° N. 138° W. at 0400 hours on February 14 (figs. 9*B*, 10*B*, 11*B*, 12*B*). The Low extended through 850 mb and was reflected on the 500-mb level as another short-wave trough. The short wave associated with this Low again moved rapidly through the long-wave pattern and

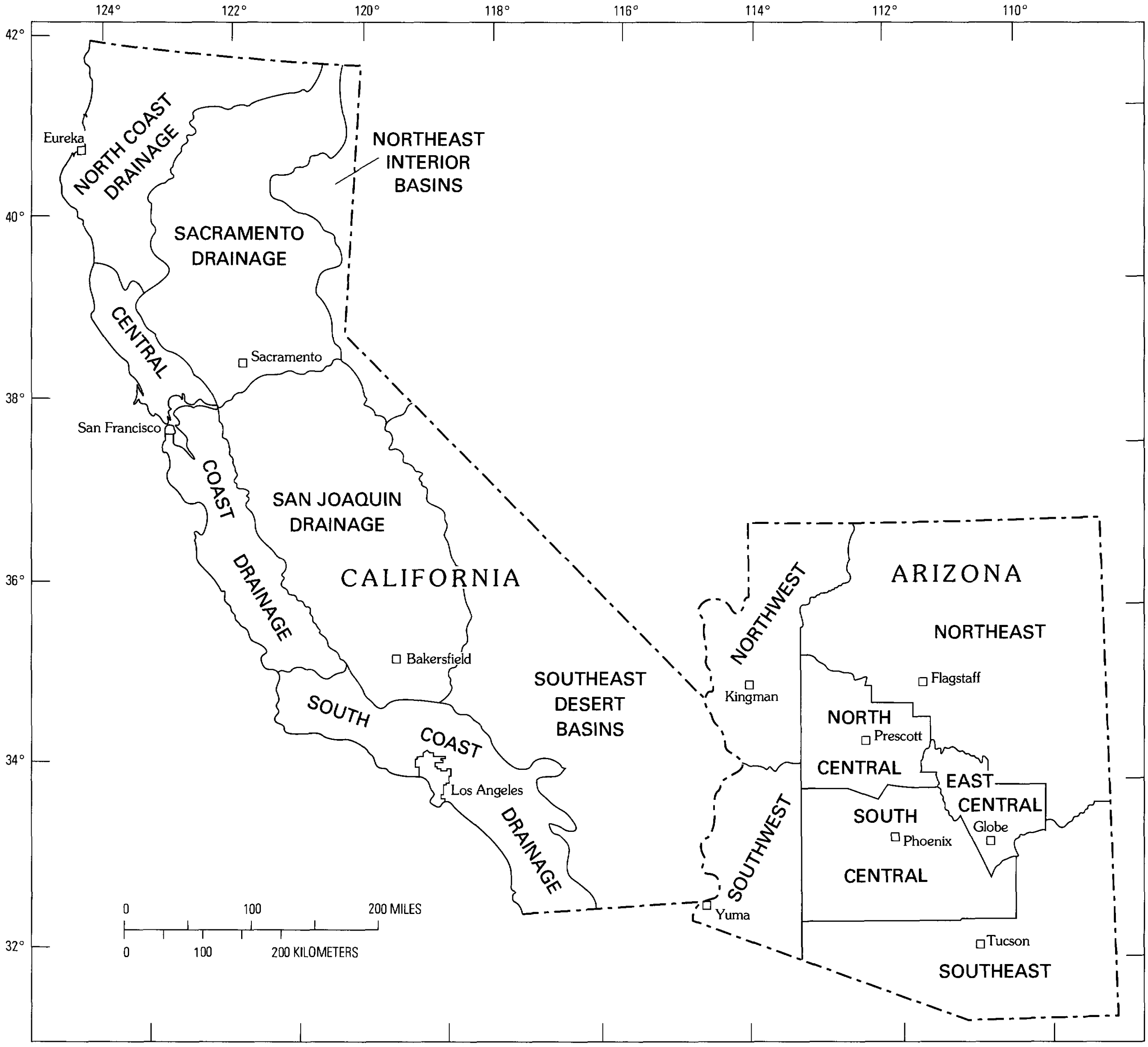


FIGURE 13.—Climatic divisions in California and Arizona.

propelled the Low toward southern California; meanwhile, the long-wave trough off the coast was almost stationary near 130° W. Variations of the sequence of events described for storms 1 and 2 were repeated as subsequent storms developed on the polar side of the jetstream over the central or eastern Pacific in the 30° N. to 42° N. latitude belt and moved toward the coast of California.

PRECIPITATION DISTRIBUTION

Rainfall over California during the 3 months ending December 31, 1979, was not excessive. Average precipitation during the period ranged from a high of 127 percent of normal over the North Coast Drainage climatic division to a low of 22 percent of normal over the Southeast Desert Basins climatic division (fig. 13). In December, the South Coast Drainage climatic division had an average precipitation of 0.70 in, which was 28 percent of the normal December average for that division.

Rainfall over Arizona during the last 3 months of 1979 was less than normal. It ranged from 94 percent of normal in the Northeast climatic division to 19 percent of normal in the Southwest climatic division. Average precipitation during December 1979 for the South Central and North Central climatic divisions was 0.19 and 0.63 in, respectively. These values are 17 and 43 percent of normal December precipitation.

Two significant storms struck California and Arizona in January 1980. The first occurred January 7–19 over California and January 9–22 over Arizona. Rainfall, often heavy, was recorded at most reporting stations in California for 10 consecutive days. This storm was warm and produced rainfall in the Sierra Nevada at elevations as high at 9,000 ft. Rainfall was reported over most of Arizona each day during the period January 9–22, except January 16. The second storm occurred January 23–31 over both States. The January precipitation at many stations in the two States was much above normal. Amounts of precipitation at selected stations shown in figures 14 and 15 are given in table 2. Average amounts for the various climatic divisions are given in table 3. The January 1980 mean precipitation in all climatic divisions, except in the North Coast Drainage division of California, greatly exceeded the normal. In California, the highest percentages of normal occurred in the South Coast Drainage and Southeast Desert Basins divisions; in Arizona, the highest percentage occurred in the North Central division. The respective percentages for these three divisions are 298, 239, and 442.

These three climatic divisions also received the highest above-normal precipitation in February (table 3). In California, the South Coast Drainage and Southeast Desert Basins climatic divisions had February amounts of 413 percent and 374 percent of normal, respectively. In Arizona, the North Central climatic division had 562 percent of normal.

Precipitation over California and Arizona was negligible during the first 6 days of February. The North Coast Drainage climatic division of California had an average rainfall of 1.5 in, the Sacramento Drainage climatic division had about 0.5 in during February 7–9, and the Southeast division received 0.75 in during February 8–9. Otherwise, the period February 1–12 was dry.

The six storm systems of February 13–21 brought above-normal precipitation to large areas in California, Arizona, New Mexico, Nevada, and Utah. Occasionally, wet conditions extended farther east. Southern California and central Arizona received more precipitation from this sequence of storms than did other areas.

The effect of orography on the distribution of precipitation was significant. In southern California, the coastal plains and valleys received an average of 5 to 10 in, while most stations in the coastal mountain ranges had more than 15 in and a few stations had more than 30 in. Los Angeles Airport and Los Angeles Civic Center in the coastal plain had 9.37 and 12.75 in, respectively (fig. 14). Mount Wilson 2 had a storm total of 30.71 in, and Crestline Fire Station had 30.10 in. The 30.89 in at Lytle Creek Ranger Station was the largest total precipitation on record for the month of February in California. In central Arizona, terrain dependence was reflected by the fact that 10 in or more fell in a band approximately parallel to the Mogollon Rim (fig. 19), which extends diagonally across central Arizona. Heaviest precipitation fell over the headwaters of the northern tributaries to the Salt River. Compared with southern California, storm precipitation over central Arizona was usually of less intensity and shorter duration, and had longer intervening breaks. Rainfall amounts ranged from 1–3 inches in the extreme south, west, and northeast to 3–12 in over the central basins, Mogollon Rim, and White Mountains, at the head of Black River, a main fork of Salt River. The most rainfall recorded in Arizona was 16.63 in at Crown King, 55 mi north of Phoenix in the Bradshaw Mountains (fig. 15). The amount was 0.32 in less than the record monthly amount for Arizona, which occurred at Crown King in August 1951.

At higher elevations in Arizona, part of the precipitation became snow. GOES data indicated that 14 percent of the Verde River basin was covered with snow on February 12, and that 26 percent was covered on February 23. The corresponding coverages for the upper drainages of the Salt River were 19 and 23 percent. The water contents of snow cover were measured by the SNOTEL (SNOw-survey TELemetry) data system operated by the U.S. Soil Conservation Service at 15 snow courses in the Salt River basin, 16 in the Gila River basin, and 17 in the Verde River basin. The average water equivalent of the snow cover increased substantially during February, particularly during the latter half of the month. The average water equivalent of the snow cover in the Salt River watershed increased from 6 in on February 1 to 6.75 in on February 15 and 10.5 in on March 1. The average water equivalents on these dates were 7.0, 7.5, and 9.6 inches in the Verde River watershed and 4.8, 5.6, and 7.2 inches in the Gila River watershed (U.S. Soil Conservation Service, 1980). At three individual snow-survey courses, the increases in the water equivalents of the snow cover exceeded 15 inches in February. The facts suggest that most of the storm precipitation in the high mountains fell in the form of snow, was retained as snow, and made no contribution to the flood runoff.

The storm series also affected the normally arid region between the major precipitation centers in coastal southern California and central Arizona. This arid region consists of the southern deserts of California and the Colorado River Valley and lies in the lee of the southern California coastal mountains. Storm rainfalls over this arid region were an order of magnitude smaller than those over the coastal plains and mountains but were very significant compared with local precipitation

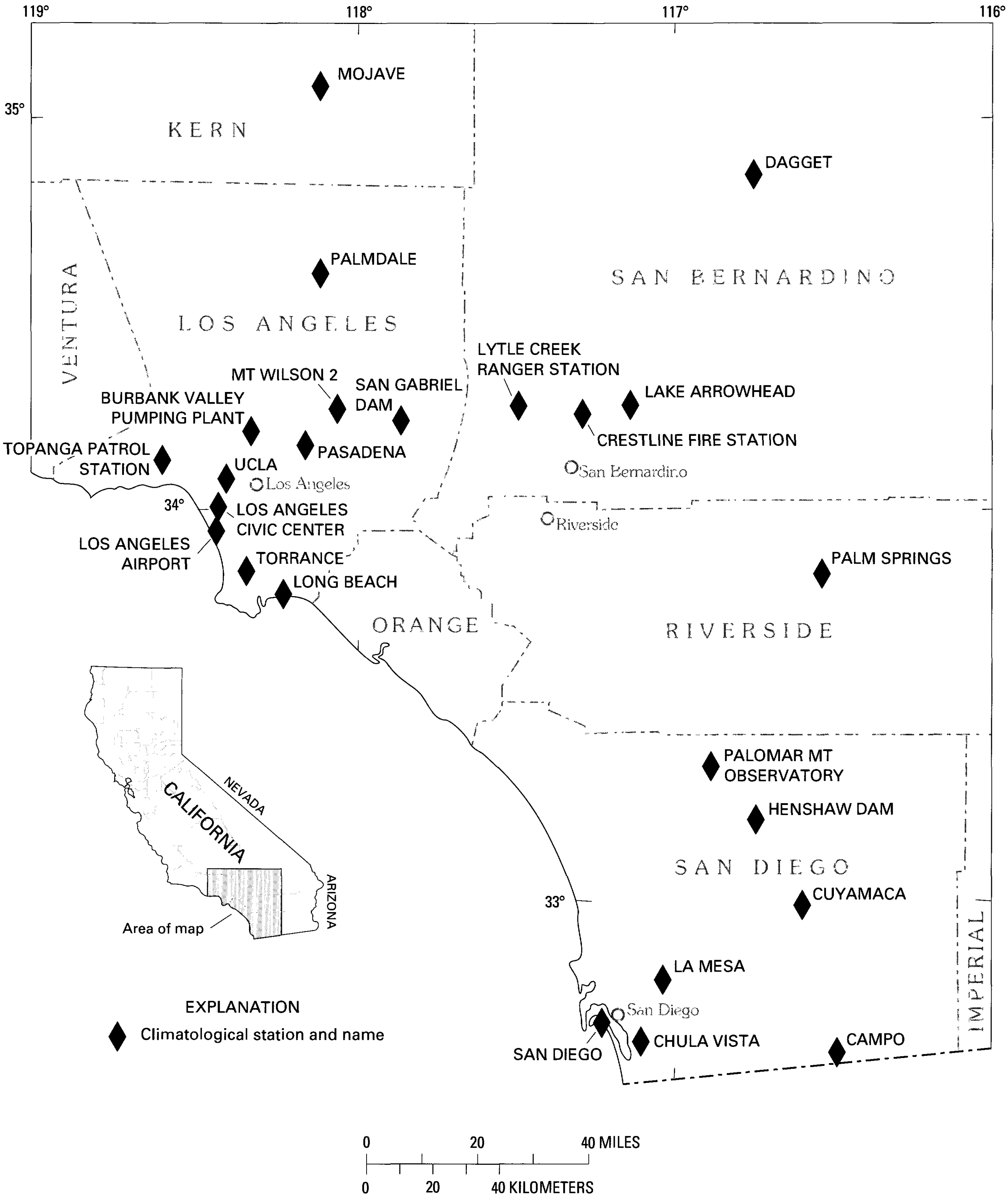
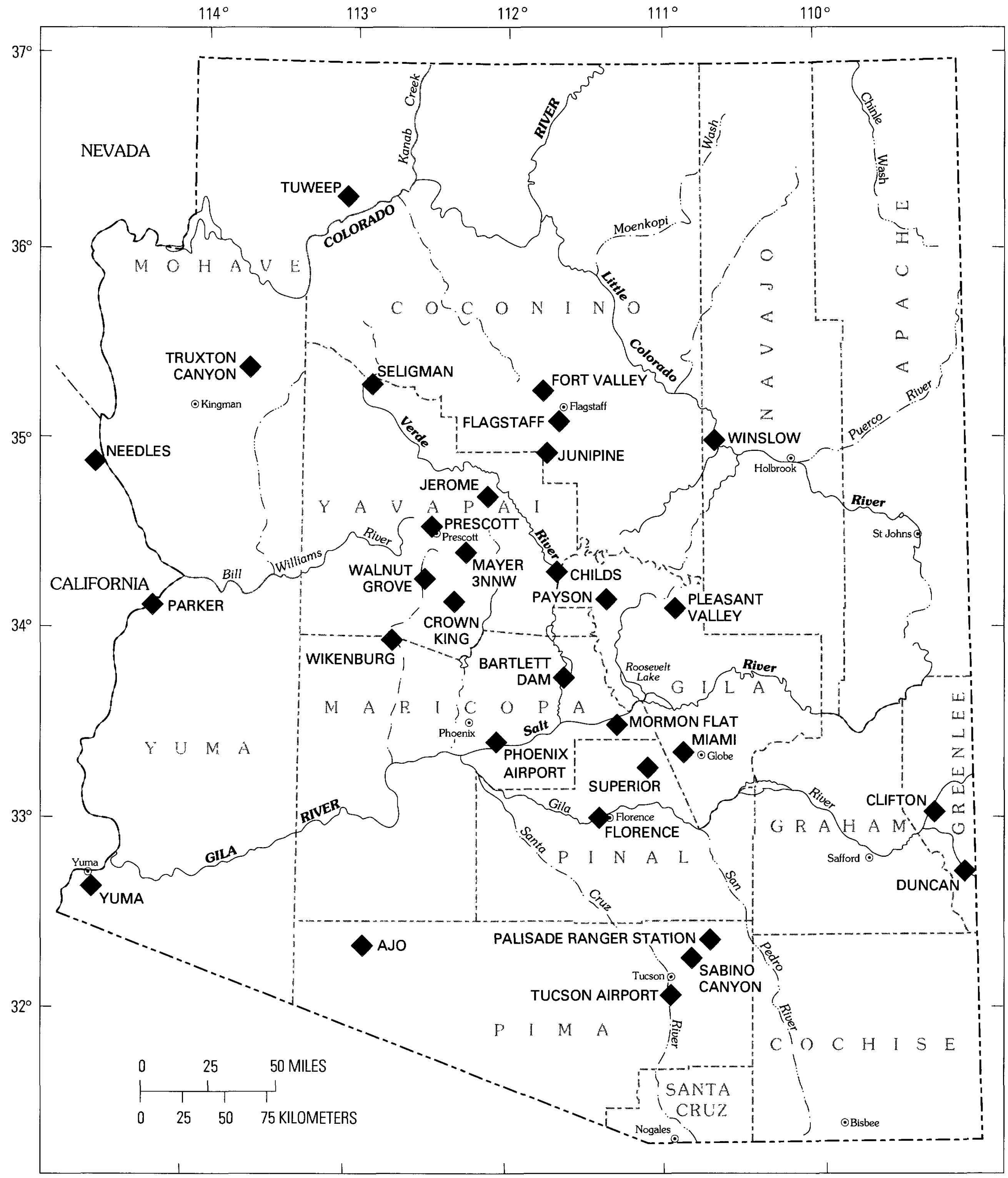


FIGURE 14.—Selected climatological stations in southwestern California.



EXPLANATION

◆ Climatological station and name

FIGURE 15.—Selected climatological stations in Arizona and southeastern California.

climatology. Needles, Calif. (30°50′ N. 114°35′ W., fig. 15), recorded 1.21 inches in February, or 378 percent of normal; Dagget, Calif. (34°52′ N. 116°47′ W.), had 1.76 in, or 490 percent of normal; and Mojave (35°03′ N. 118°10′ W.) received 4.25 in, or 421 percent of normal. Yuma, Ariz. (32°40′ N. 114°26′ W.), had a February total of 0.37 in, or 270 percent of normal. All the aforementioned precipitation fell February 13–21.

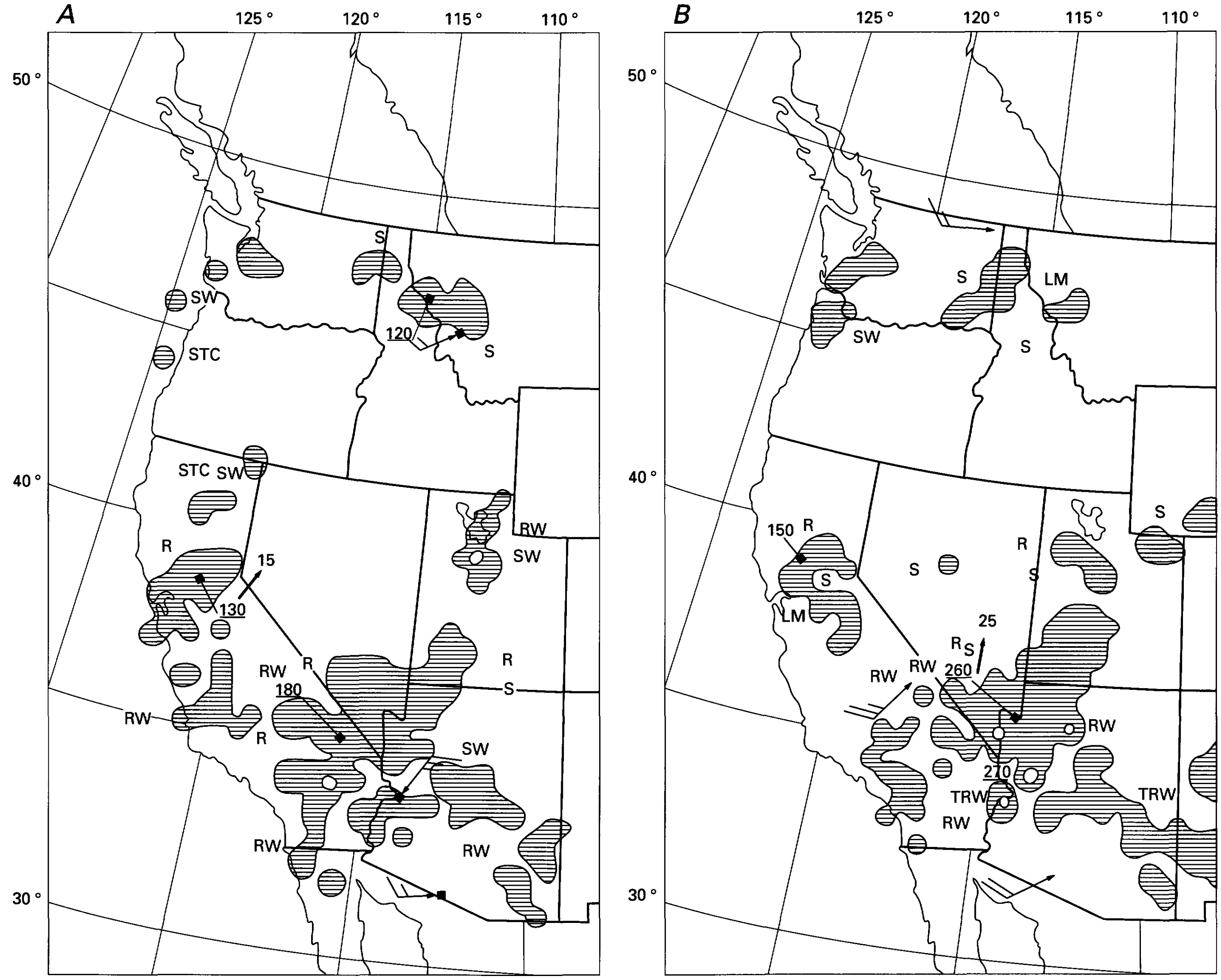
A study of radar summary maps of the Western United States (fig. 16) indicated that the precipitation patterns were quite persistent with respect to time over central Arizona and part of the southern California coastal mountains. Radar can be used to show the areal extent of rainfall and some degree of gradient in precipitation, but the maps do not provide a reliable measure of intensity or depth. Estimates of depth from radar have large systematic errors. Radar measurement of precipitation is based on the premise that rainfall intensity is a function of the radar-reflectivity factor. The radar senses a volume-integrated reflectivity of the precipitation pattern in the atmosphere. It provides a means of estimating rainfall intensity over an area of up to 10^5 mi^2 (square miles) with a resolution of 1 nautical mile by 2° azimuth angle. The conversion of the reflectivity factor into rain intensity is determined empirically as a function of drop-size spectrum. This relationship is affected by geography, observational duration, and types of rain (stratiformis, thunderstorm, or orographic). There are many different Z-R equations (relating rainfall rate, R, to drop-size spectrum, Z) published in the literature based on regression studies at a variety of locations, during different seasons, over varied durations, and for particular types of rain. No single equation fits all situations. An accurate measurement of point rainfall is obtained only from a rain gage, but the gage does not define the areal pattern of rainfall. The areal pattern obtained by analyzing all available gage data for a specific storm is affected by the density of the gage network and the reliability of reports. It would be fortuitous for any gage to capture the maximum rainfall that occurred during any given storm. The optimum method for combining the accuracy of point rainfall given by rain gages and the areal pattern given by radar in order to arrive at a more accurate representation of rainfall in relation to space and time remains an unresolved problem and is the topic of much research.

As for rainfall depth, the Video Integrator and Processor (VIP) component of a weather radar system, level 1 corresponds to a precipitation rate of up to 1.1 in/h (inch per hour) for convective storms. Considering that in synoptic observations any rate greater than 0.3 in/h is classified as "heavy" precipitation, VIP level 1 thus covers the whole spectrum of synoptic rainfall intensities from drizzle up to extremely heavy rain. Such a coarse classification is inadequate for many quantitative applications.

Precipitation mass curves for selected stations are shown in figure 17. The mass curve for Crown King, Ariz., was derived from curves for Mayer 3 NNW and Payson, for which hourly data were available. Precipitation contributed by each storm in the sequence is indicated on four of the mass curves, by storm number.

Generalized isohyetal analyses of total precipitation during February 13–21 for southern California and central Arizona are shown in figures 18 and 19. Storm precipitation amounts for 1-day and 10-day periods at selected stations are compared with 100-year events in table 4. Wherever hourly data were available, the 24-hour maximums are listed; otherwise the 1-day values are used in the comparison. The maximum observed 1-day total at Palisade Ranger Station in the Santa Catalina Mountains near Tucson of 4.83 in was the highest 1-day total in Arizona during February 1980. At all other stations, including Topanga Patrol Station northeast of Los Angeles, where the greatest 1-day rainfall in California in February 1980—8.30 in—occurred, the daily maximums were much smaller than the 100-year amounts. The 10-day total precipitation (February 13–22) is approximately equal to, and for seven stations greater than, the 100-year 10-day amounts (Miller, 1964).

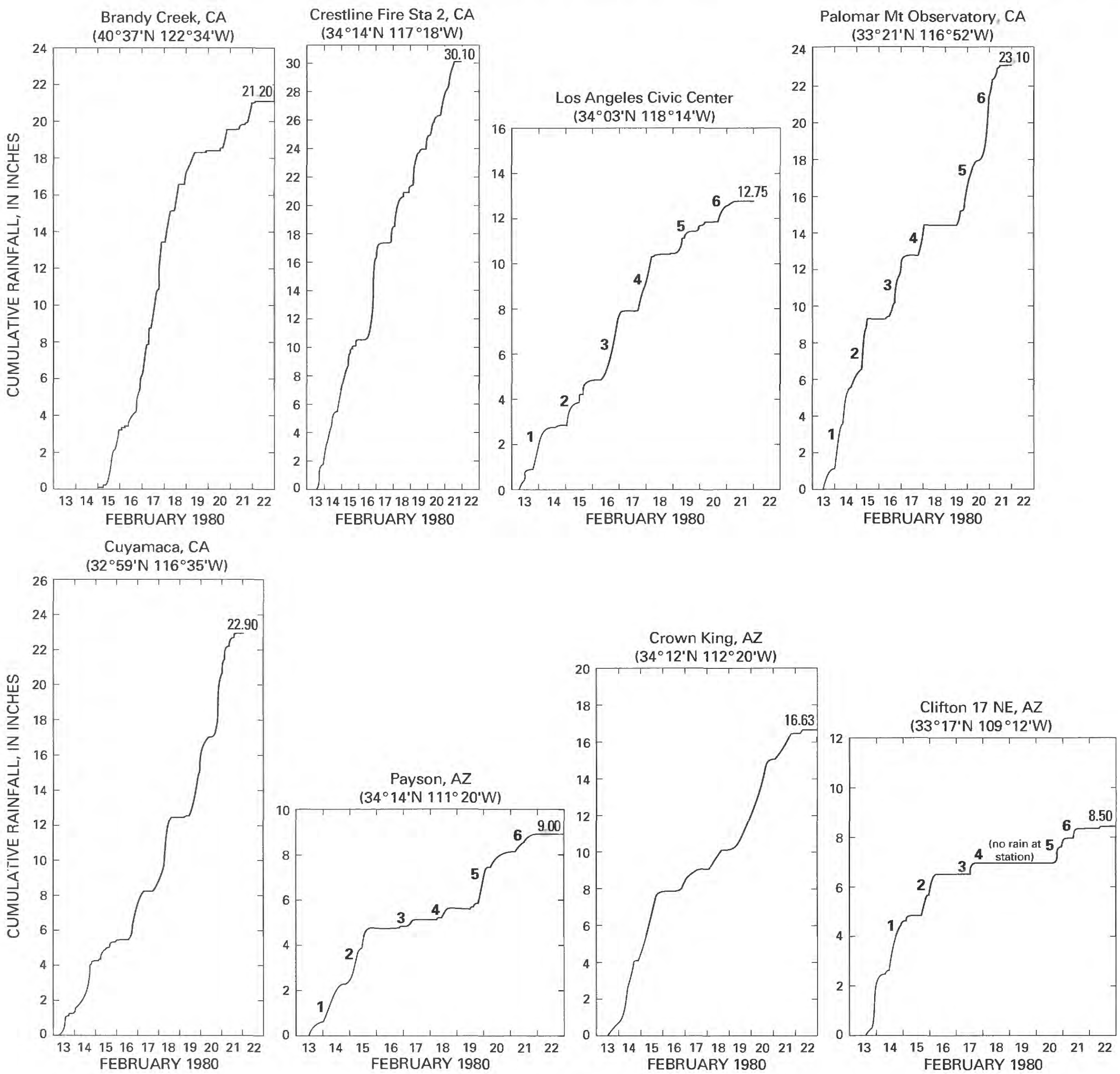
Comparisons of maximum storm rainfall over durations of a day or less with total rainfall over a 1- or 2-month period are revealing. For example, January–February total rainfall at Cuyamaca, Calif., was 45.27 in, the highest since recordkeeping started in 1888, and February rainfall—23.34 in—is the third highest of record, but the maximum 24-hour rainfall of 5.90 in is about equal to the 5-year 24-hour rainfall. The maximum 6-hour rainfall of 3.1 in also has a 5-year recurrence interval (Miller and others, 1973). At Los Angeles Civic Center, the February rainfall of 12.75 in is the second highest in the month of February since recordkeeping began in 1872; a rainfall of 13.37 in occurred in February 1884. The combined January–February rainfall of 20.25 in is also the second largest, exceeded only by the 22.97 in during January–February 1969. The 1-day maximum of 3.03 in that was measured during the storm period is less than the 5-year daily amount of 3.81 in. At Henshaw Dam, the February rainfall of 21.40 in is the second largest since the beginning of recordkeeping in 1912, and the combined January–February rainfall of 35.94 in is the largest; however, the daily maximum of 3.85 in is a 5-year rainfall. At University of California, Los Angeles (UCLA), in west Los Angeles, the February 1980 rainfall of 18.37 in is the highest since recordkeeping started in 1933 and exceeded the magnitude of the 200-year event. The combined January–February 1980 rainfall of



EXPLANATION

[shaded box]	Area of radar echo
130	Altitude above sea level of cloud top, in hundreds of feet
[arrow with tail bars]	Direction and velocity of echo movement—Arrow indicates direction. Tail bars indicate velocity; each long bar equals 10 knots, and the short bar equals 5 knots
→ 15	Direction and velocity of individual cell movement—Arrow indicates direction; number indicates velocity, in knots
R	Rain
RW	Rainshowers
S	Snow
TRW	Thunderstorm rain shower
SW	Snow shower
LM	Little movement
STC	Light precipitation may be detected

FIGURE 16.—Radar summary maps, February 14, 1980: *A*, 0635 hours P.s.t.; and *B*, 1335 hours P.s.t.



EXPLANATION

3 Storm number— Indicates amount of rainfall received during that storm

16.63 Total amount of precipitation received at the station

FIGURE 17.—Precipitation mass curves for selected stations in southern California and central Arizona, February 13–22, 1980.

25.72 in also established a record for the 2-month period; however, the observed maximum daily rainfall of 4.14 in is less than the 5-year amount. Similar situations can be found in records for many other stations in southern California and central Arizona.

It can be concluded that the February 1980 floods in southern California and central Arizona were caused by the cumulative effect of precipitation events, each of moderate and occasionally high intensity, and not by extreme rainfall of short duration. Examination of

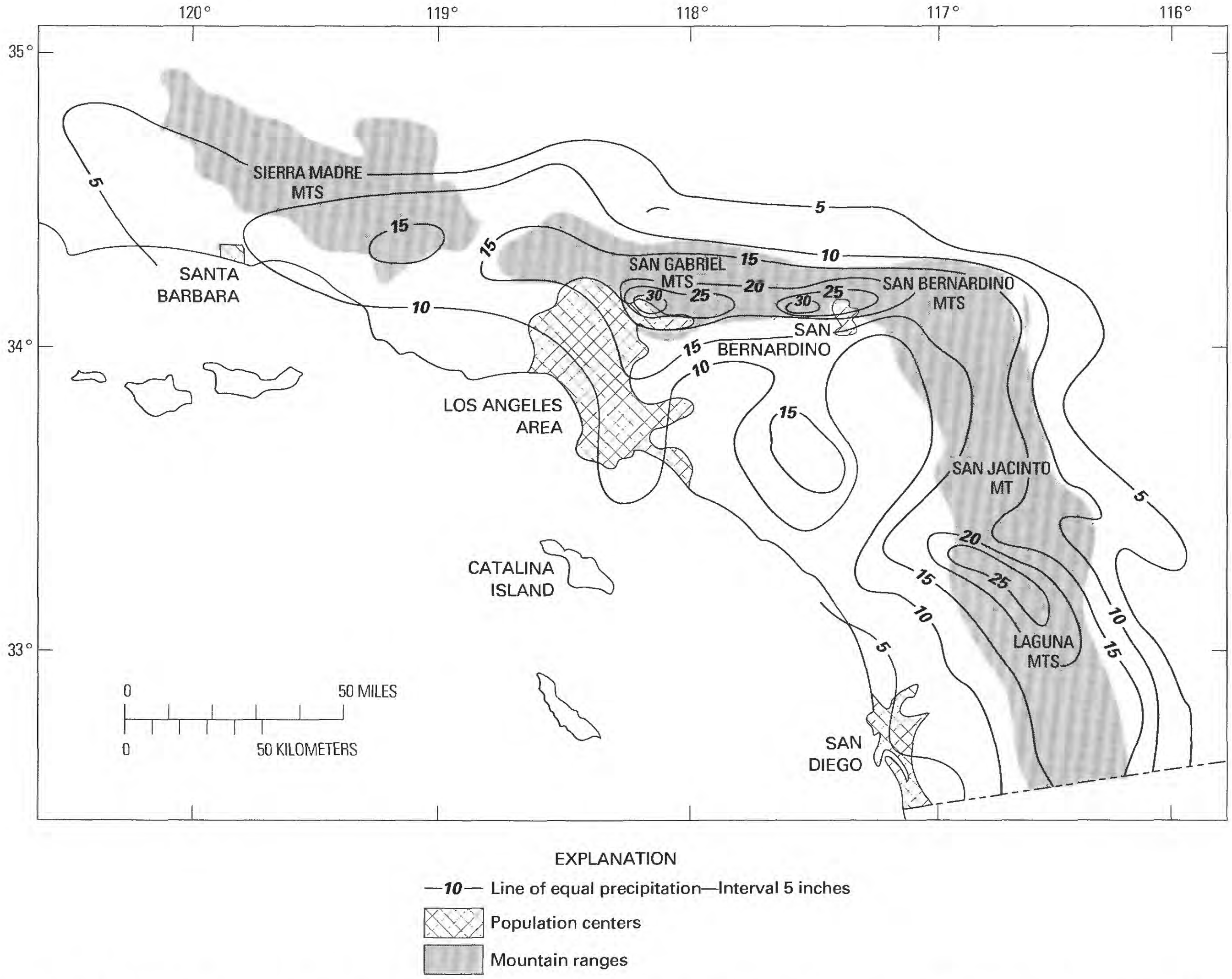


FIGURE 18.—Isohyetal analysis of total storm precipitation greater than 5 inches in southern California from approximately 0600 hours P.s.t., February 13, through 2400 hours P.s.t., February 21, 1980.

NOAA hourly precipitation data further revealed a lack of extreme events with durations of 1 to 24 hours, a characteristic that has been recognized as associated with winter precipitation brought about by extratropical cyclones.

CALIFORNIA FLOODS

Storms of January and February 1980 caused three distinct periods of significant flooding over most of California; each period affected different areas of the State (fig. 20). The storm of mid-January covered the entire State, but most of the flooding was caused by runoff from the Sierra Nevada and the Sierra foothills. Subsequent storms affected primarily southern California and coastal areas northward to San Francisco. On many streams in southern California the floods of late January or mid-February are the highest since either 1927 or 1938. The February floods are the most costly of any that have occurred in southern California. The main emphasis of this report is on the February floods in coastal basins south of 35° N. A brief discussion of the January floods is included to develop a background for the discussion of the February floods.

GEOGRAPHIC SETTING

The report describes flooding along streams that drain the Peninsular and Transverse Ranges (fig. 21) in Imperial, San Diego, Riverside, Orange, San Bernardino, Los Angeles, Ventura, and Santa Barbara Counties (fig. 1). The Peninsular Ranges include many small ranges that parallel the coastline southeast of Los Angeles. Many

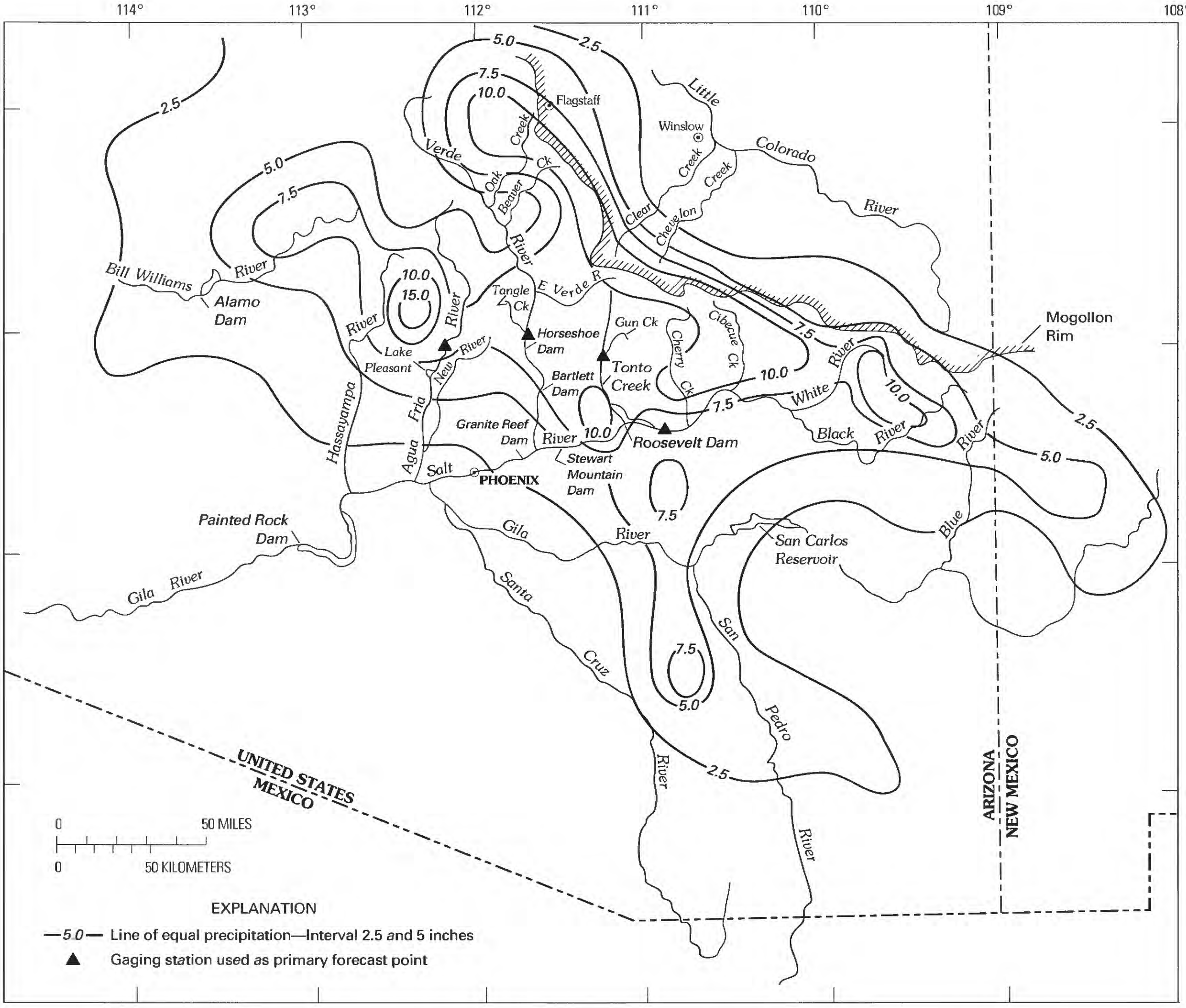


FIGURE 19.—Isohyetal analysis of total storm precipitation greater than 2.5 inches in central Arizona from approximately 0600 hours m.s.t., February 13, through 2400 hours m.s.t., February 21, 1980.

streams draining these mountains are oriented almost perpendicular to the coastline and drain large mountain basins. The Transverse Ranges follow a general east-west line north of Los Angeles.

The Santa Ynez Mountains form the westernmost part of the Transverse Ranges. The Santa Monica Mountains, another unit of the Transverse Ranges, start near Point Mugu and extend eastward. Between the Santa Ynez and Santa Monica Mountains is the Oxnard plain, a large coastal lowland that was formed from sediments deposited by the Ventura and Santa Clara Rivers. The Los Angeles plain, which is the largest coastal plain in southern California, lies southeast of the Santa Monica Mountains and south of the San Gabriel Mountains, another unit of the Transverse Ranges. This large plain, which encompasses the greater Los Angeles metropolitan area, was formed from alluvium deposited by the Los Angeles and San Gabriel Rivers and many small streams that debouch from steep canyons. The entire plain and many of the small canyons are highly urbanized.

The major river basins, discussed from south to north, are Tijuana, San Diego, San Dieguito, San Luis Rey, Santa Margarita, Santa Ana, San Gabriel, Los Angeles, Santa Clara, Ventura, Santa Ynez, and Santa Maria. Data are also given for many small basins interspersed among these major basins, and for streams in the Salton Sea basin, especially those tributary to Whitewater River and San Felipe Creek. The headwaters of the latter two streams finger into the Peninsular Ranges between streams that drain to the ocean.

Almost all the runoff in southern California originates in the mountains and higher foothills and is directly from

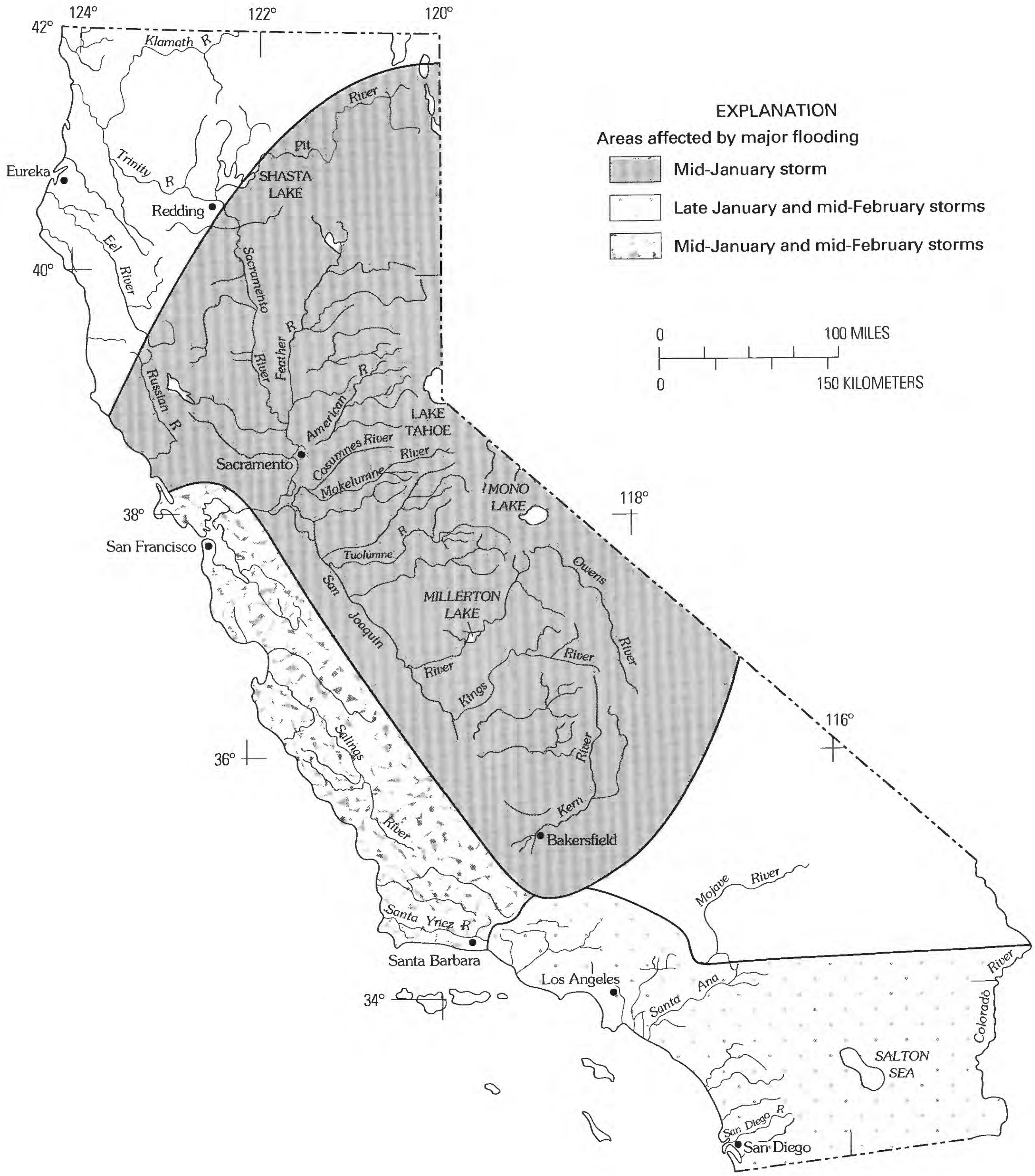


FIGURE 20.—Approximate areas of California affected by major flooding in January and February 1980.

rainfall. Because of the steep slopes, the generally shallow soil mantles, and the very sparse vegetation, runoff is sporadic, with short, rather intense floods followed by long periods of little or no flow.

FLOODS OF JANUARY 1980

The January rainfalls, discussed in an earlier section, helped the floods of February to develop by wetting the

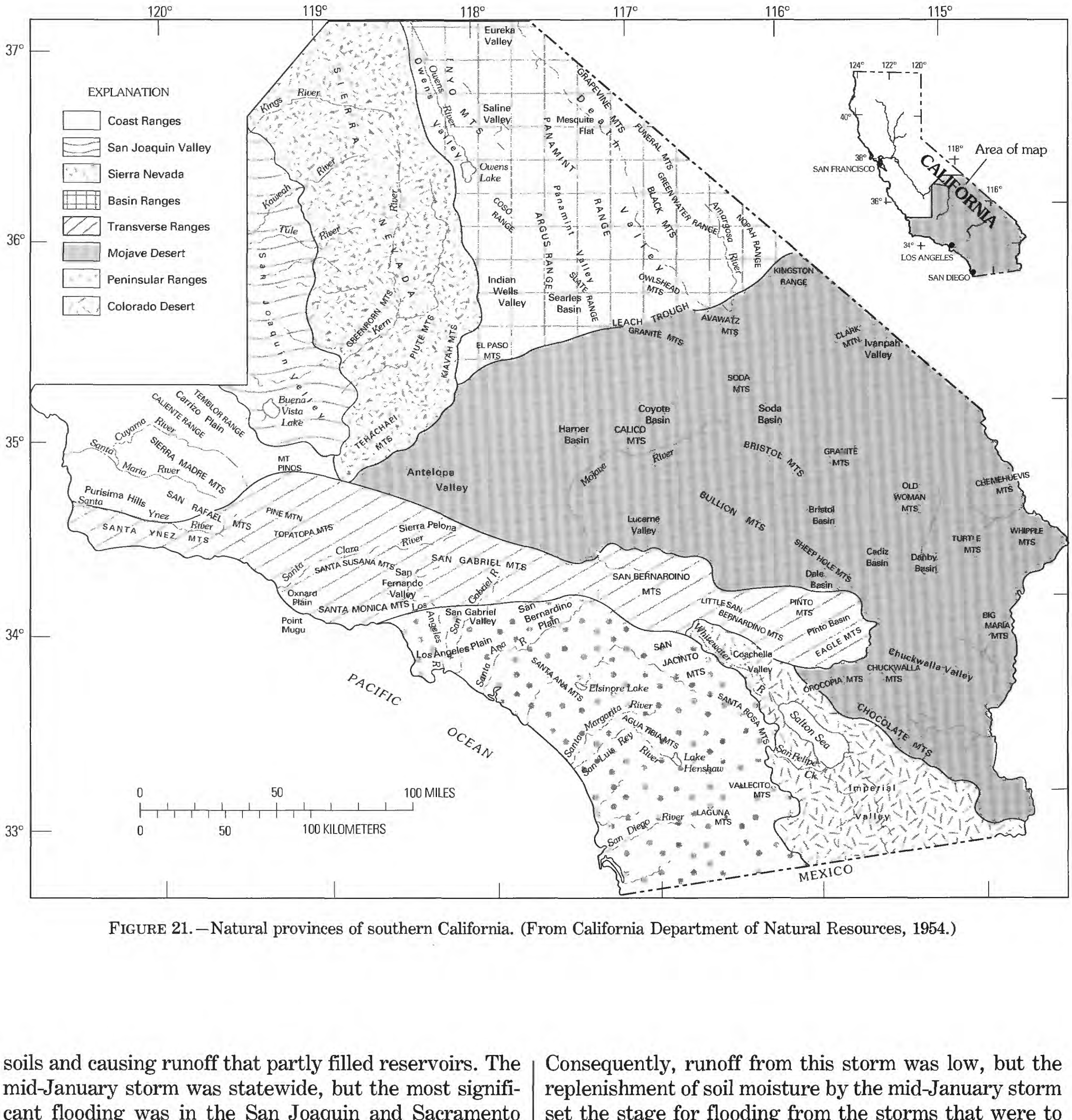


FIGURE 21.—Natural provinces of southern California. (From California Department of Natural Resources, 1954.)

soils and causing runoff that partly filled reservoirs. The mid-January storm was statewide, but the most significant flooding was in the San Joaquin and Sacramento River basins and in coastal basins between Santa Barbara and San Francisco. Although flooding was widespread in the affected areas, peak discharges at most gaging stations were generally lower than the peak of record. Peak discharges in the basins of the Tuolumne, Mokelumne, Cosumnes, and American Rivers (fig. 20) were among the highest in 20 years. Rainfall totals in southern California had been well below normal prior to the mid-January storm, and soil moisture was low. Consequently, runoff from this storm was low, but the replenishment of soil moisture by the mid-January storm set the stage for flooding from the storms that were to follow in late January and February.

The storm of January 28–31 brought large amounts of rainfall to the South Coast Drainage and Southeast Desert Basins climatic divisions (fig. 13), but only light precipitation to other areas of the State. Stations at Cuyamaca Reservoir and Henshaw Dam in San Diego County (fig. 22) reported 3-day totals of 9.23 and 8.14 in, respectively. Lake Arrowhead (fig. 14) reported a 1-day rainfall of 6.26 in on January 28.

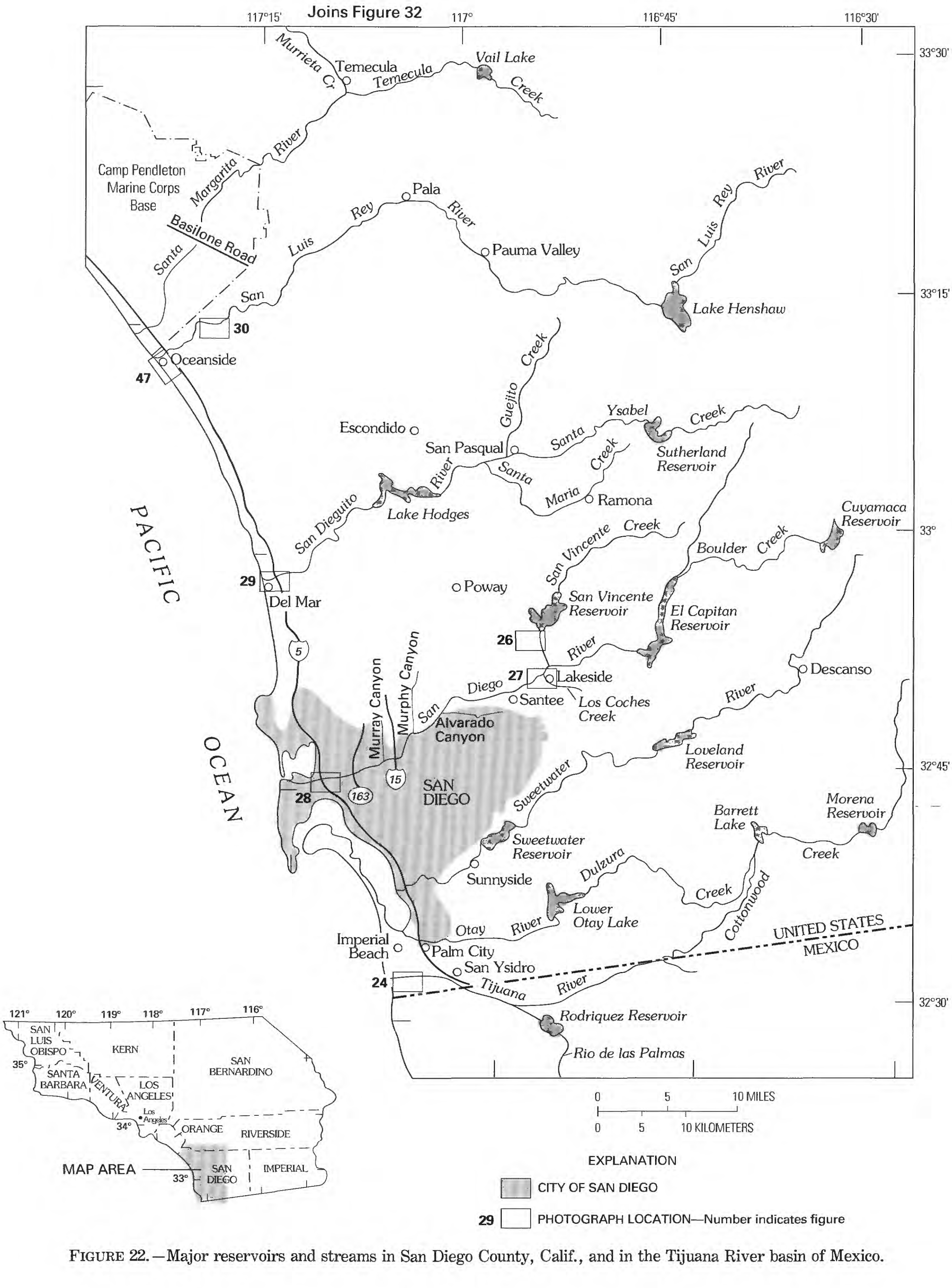


FIGURE 22.—Major reservoirs and streams in San Diego County, Calif., and in the Tijuana River basin of Mexico.

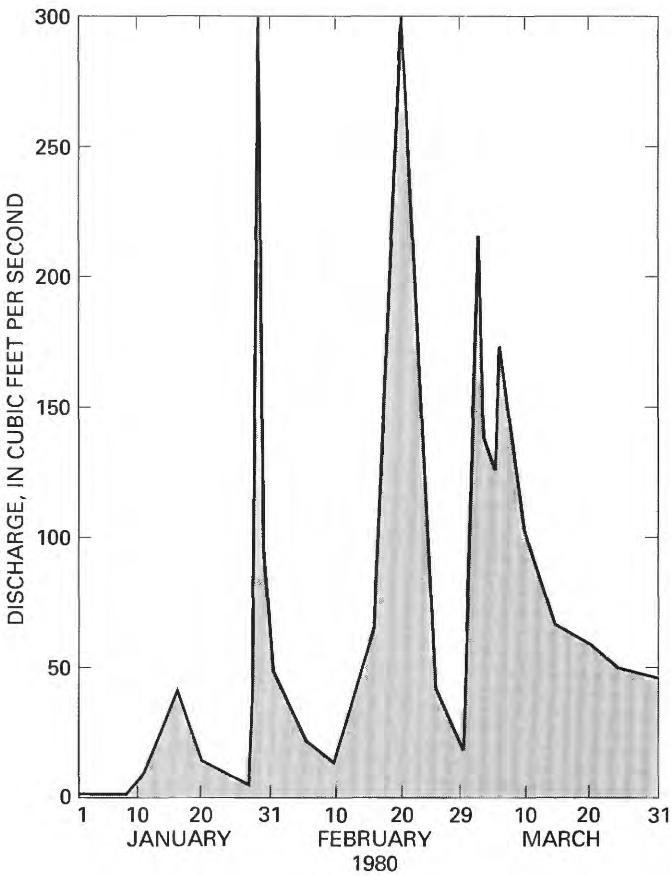


FIGURE 23.—Daily discharge for East Twin Creek near Arrowhead Springs, Calif. (station 11058500; site 52, pl. 1), January–March 1980.

At most gaging stations in southern California, the peak discharge that resulted from the January storm was much less than those in previous years, but at a few stations the peak became the new peak of record. These stations can be identified in table 23 by the fact that the year given under the heading "Maximum prior to February 1980" is 1980. At 8 or 10 other sites, the January peak was greater than the February peak but was less than the peak of record. None of the January peaks at these sites was outstanding, and those data are not presented in this report.

The peak discharge of 3,710 ft^3/s (cubic feet per second) in January at the gaging station on East Twin Creek near Arrowhead Springs (site 52, pl. 1) is the highest since at least 1919. The daily discharge hydrograph for East Twin Creek near Arrowhead Springs is shown in figure 23.

Farther south, in the Tijuana River basin in Baja California, Mexico, the severe rain of January 29–30 produced heavy runoff from the Rio de las Palmas, which flows into Rodriquez Reservoir about 10 mi southeast of Tijuana. The reservoir is formed by a thin-shell, concrete-arch dam completed in 1936; storage began in 1937. The reservoir stores water for irrigation of about 3,000 acres downstream and also for the municipal supply for the city of Tijuana. The large amount of runoff caused concern for the safety of the dam and necessitated large but controlled releases of floodwater. Records of contents since 1937 indicate that the reservoir had spilled previously only during March 1938, September 1940, February to May 1941, March 1942, and February and March 1944.

Reservoir contents and elevation records supplied by the Ministry of Hydraulic Resources, Government of Mexico, through the International Boundary and Water Commission, United States Section (written commun., 1981) show that on January 29, at 0600 hours, Rodriquez Reservoir was at an elevation of 388.58 ft, its contents was 84,570 acre-ft, and it was not spilling. Twenty-four hours later, on January 30, the reservoir had risen 26 ft to an elevation of 414.69 ft, the contents had increased to 118,000 acre-ft, and there was a maximum spill of 28,600 ft^3/s. Releases on January 30 combined with the floodwaters from the Tijuana River to produce an estimated peak discharge of 32,000 ft^3/s at Tijuana River near Nestor (site 19), where the previous peak of record was 17,700 ft^3/s in 1937. Flooding was widespread along the Tijuana River downstream from the end of the levees (about 2 mi from the international boundary and 0.5 mi upstream from Dairy Mart Road) to the Pacific Ocean (fig. 24). This is a sparsely populated area, and most damage occurred to farmland and livestock.

FLOODS OF FEBRUARY 13–21, 1980

As a result of the six storms that struck California during February 13–21, large quantities of rain fell over the western part of the Salton Sea basin and coastal basins south of San Francisco. This series of storms, like that at the end of January, was most severe in southern California and Baja California, but it also produced some flooding to the north in the San Francisco Bay area and in the Salinas River basin. Although the pattern followed by the individual storms of January–February 1980 is not unusual, the number of storms and the short intervals between them are unusual. Soils became saturated, and each succeeding rainfall produced substantial runoff. Few of the storms alone would have caused major flooding; however, the rapid sequence of storms resulted in extreme volumes of runoff and severe flooding.

Each of the six storms caused peaks on small streams. Distinct peaks occurred at one or more sites each day from February 14 through February 21, except February 17. Each peak was followed by a recession to near base flow. The maximum peaks generally occurred late on February 20 or early on February 21 in the Salton Sea

FIGURE 24A.—Flooding along the Tijuana River in California on January 30, 1980, near Interstate Highway 5 and Dairy Mart Road looking southwestward at outlet to Pacific Ocean. (Photograph courtesy of San Diego Department of Public Works.)

basin and coastal basins in San Diego County, and on February 16 in the Santa Ana River basin and in coastal basins in Ventura and Santa Barbara Counties. Outstandingly high discharges occurred spottily from near Los Angeles to the international boundary. Peaks of record occurred on three streams in the Salton Sea basin and on most streams in the Tijuana River basin.

The Los Angeles River carried the highest discharge since at least 1928. The peak of record occurred at a few stations in the basins of the San Dieguito and Santa Margarita Rivers, and of Los Penasquitos and San Diego Creeks, but in most of the study area peak discharges in 1980 were small compared with discharges that occurred in 1862, 1864 (California Department of Water Resources, 1980), 1891, 1916 (McGlashan and Ebert, 1918), 1927, and 1938 (Troxell and others, 1942). According to studies by the San Diego County Department of Sanitation and Flood Control (1975), the floods of 1862 and 1916 were the largest ever in San Diego County. In the San Diego River basin, the peak discharges in 1938 also exceeded those of 1980; in the Santa Ana River basin and basins north of Los Angeles, discharges in 1966 (Waananen, 1971) and 1969 (Waananen, 1969, 1975) exceeded those in 1980. Table 5 shows peak discharges for years in which major floods occurred over a large part of the present study area. Other significant floods may have occurred on individual streams or in localized areas, such as the 1966 flood near Los Angeles. Data have not been adjusted for the change in reservoir storage. Many of the southern California dams were built after the 1938 floods. In spite of some large peak discharges, the significance of the 1980 floods in southern California lies

B

FIGURE 24*B*.—Flooding along the Tijuana River in California on January 30, 1980, at Imperial Beach Naval Air Station looking southward downstream from levees about 3 miles from international boundary. (Photograph courtesy of San Diego Department of Public Works.)

more in the volume and duration of runoff and the large economic losses than in the magnitude of peak discharges.

Riverine flooding was only one of the problems caused by the storms. High winds and wave action caused heavy damage in several coastal areas, mudflows and slope failures due to saturated soils caused extensive property damage, and broken sewer lines caused contamination of beaches. Seven southern California counties—San Diego, Riverside, Orange, San Bernardino, Los Angeles, Ventura, and Santa Barbara—were declared disaster areas.

VOLUMES OF RUNOFF AND EFFECT ON RESERVOIRS

Many streams south of Los Angeles discharged the highest 7- and 15-day volumes of record. Streams to the north, although unusually high, discharged volumes substantially less than those previously recorded for 7 and 15 days. Table 6 shows, for selected sites, the highest average discharge for periods of 7 and 15 consecutive days in 1980, their rank compared with other 7- and 15-day averages during the period of record, and the previous highs. The large volumes of runoff had a major impact on the numerous reservoirs in the study area. Most major streams in the report area are regulated at reservoirs used for either municipal supplies, irrigation (conservation reservoirs), or flood control. Although not specifically designed for such, the conservation reservoirs normally provide a great deal of flood control. Above-average runoff in 1978 and 1979 had significantly increased the contents of the reservoirs. At the end of December 1979, most reservoirs in the southern part of the study area were filled to about 50 to 70 percent of capacity. Some reservoirs farther north held more than 85 percent of capacity.

The January runoff caused many reservoirs to reach nearly full levels. The runoff from the February storms brought most conservation reservoirs to a full state, and water was spilled from many of them. At most major flood-control reservoirs, the contents did not exceed 60 percent of capacity. The maximum outflow from most reservoirs was less than the peak inflow. Evelyn (1982) credits flood-control reservoirs in the Santa Ana, San Gabriel, and Los Angeles Rivers with having prevented $900 million in damage during the 1980 water year. Recorded and estimated inflow and outflow at selected reservoirs are given in table 7.

FLOODS IN MAJOR RIVER BASINS

The following sections discuss peak discharge, reservoir spills, and physical damage in major basins in geographical order, starting at the Salton Sea basin, moving to the Tijuana River basin, and proceeding northwesterly through Santa Barbara County.

Salton Sea Basin

The natural drainage area of the Salton Sea is unusual, as about one-fifth of the basin is below or only slightly above sea level. Most major streams originate in the mountains that rim the basin on the western and northeastern sides. From these mountains, which range from 3,000 to 11,500 ft in altitude, the streams flow in diverse terrain to below sea level and into the Salton Sea. Because the Salton Sea basin is extremely arid, natural runoff is insufficient to maintain streamflow, and most streams are intermittent and experience periods of no flow each year.

On most streams in the Salton Sea basin, peak discharges in 1980 did not approach the peak of record; however, San Felipe Creek near Julian (site 2, pl. 1), in the western part of the basin, did have a peak discharge almost six times the previous peak of record. The peak discharge at Palm Canyon Creek near Palm Springs (site 11) is almost double the previous peak of record. Floodwater from this normally almost-dry tributary to the Whitewater River ripped out levees, damaged a road crossing, and inundated parts of a golf course in the Palm Springs area. Newspapers reported that on February 18, floodwater from a flood-control channel near Palm Springs destroyed greens and fairways on four well-known golf courses—Tamarisk, Cathedral Canyon, Rancho La Palomas, and Ironwood Country Clubs.

Tijuana River Basin

In the upper Tijuana River basin, large spills from Barrett and Morena Reservoirs (fig. 22) caused discharges at Cottonwood Creek above Tecate Creek, near Dulzura (site 16) and at Tijuana River near Dulzura (site 18) to be nearly twice as large as those that occurred in January 1980. The January discharges were much larger than those of 1937 (peak of record for 1936–79). Peak discharges during the February flood have a recurrence interval of about 100 years. Little damage resulted because both streams flow through wide valleys, and because the adjacent flatlands are used primarily for livestock grazing.

As in late January, high runoff from the Rio de las Palmas (in the Tijuana River basin in Mexico) into Rodriquez Reservoir caused concern for the safety of Rodriquez Dam, and again large amounts of water were spilled from the reservoir. The daily mean spills on February 20 and 21, 16,400 ft^3/s and 16,200 ft^3/s, respectively, were slightly greater than the daily mean spill of 15,600 ft^3/s on January 30. Although the maximum spill from Rodriquez Reservoir on February 21 was only 18,400 ft^3/s, it produced an estimated peak discharge downstream on the Tijuana River near Nestor (site 19) of 33,500 ft^3/s, slightly larger than the previous record peak that had occurred 3 weeks earlier on January 30, 1980. Flooding was extensive downstream from San Ysidro.

The Tijuana River reenters the United States from Mexico near San Ysidro and flows northwestward in an improved, 200-ft-wide channel between earthen levees lined with rock riprap. The unlined channel bottom is composed of sand and is at natural grade, except for a concrete cutoff wall near the downstream end of the levees. The improved channel extends from the international boundary downstream 2,500 ft. Channel degradation and migration occurred downstream from where floodwaters left the confines of the levees, about 0.5 mi upstream from Dairy Mart Road. Flooding similar to that on January 30 (as shown in fig. 24) occurred.

A new river channel formed between the end of the levees and the Pacific Ocean, a distance of about 5 mi. This new channel, located south of the former channel, averaged about 500 ft wide and 4 ft deep. Farmlands were obliterated by channel migration, roads were severed, bridges on Dairy Mart Road and Hollister Street (location of gaging station near Nestor) were left unusable, and sewer lines were broken. Some of the ocean beaches in the city of Imperial Beach were posted and placed under quarantine for almost 14 months because of pollution. Figure 25 is the hydrograph of daily discharge on the Tijuana River near Nestor at the international boundary.

Otay and Sweetwater Rivers

The 1980 runoff caused the first spill from the present Lower Otay Reservoir, which is formed by Savage Dam on the Otay River. This reservoir was completed in 1919

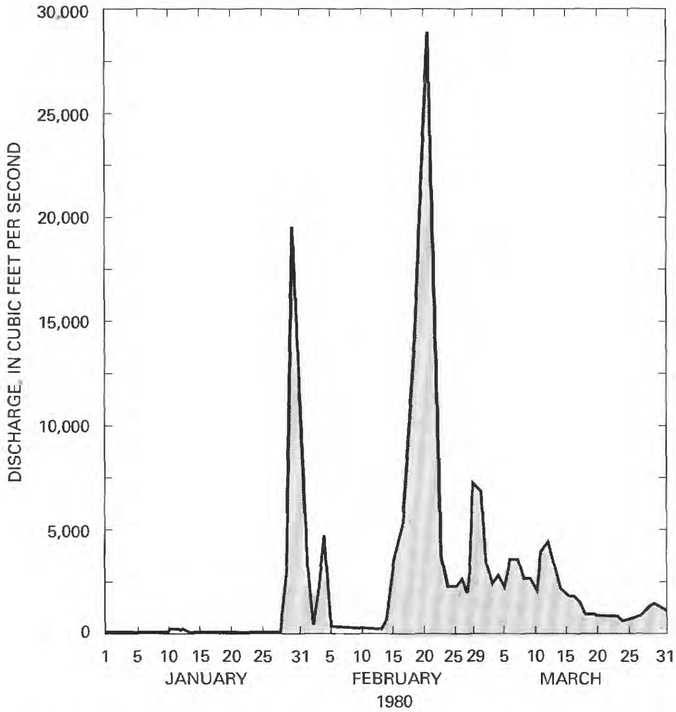


FIGURE 25.—Daily mean discharge for Tijuana River near Nestor, Calif. (station 11013500; site 19, pl. 2), January–March 1980.

after an earlier dam washed out in 1916. It has a capacity of 56,520 acre-ft and a drainage area of 99.0 mi^2. The maximum spill from Lower Otay Reservoir, 350 ft^3/s, did not occur until March 11.

The Sweetwater River heads in the Laguna Mountains of south-central San Diego County and flows southwestward to the southern part of San Diego Bay. Two reservoirs, Loveland and Sweetwater, which are located about 20 river miles apart, regulate the discharge. Upstream from Loveland Reservoir, the Sweetwater River and its major tributaries flow in narrow valleys and deep canyons; except for erosion near Descanso, little damage occurred along the Sweetwater River. However, some tributaries east and upstream from Loveland Reservoir had large peak discharges that destroyed small bridges and grade-level crossings, thus isolating ranches. Downstream from Loveland Reservoir, roads and golf courses were damaged. Discharges in the lower 8 mi of the Sweetwater River are controlled by Sweetwater Dam, which was completed in 1888. The left side of the dam has always had a spillway; water has spilled on several prior occasions. The right end of the dam washed out in 1916 and was replaced by an overflow siphon system that was completed in 1921. During the February 1980 storms, water flowed through the siphons for the first time. Downstream from the reservoir, floodflows destroyed two grade-level crossings near Sunnyside.

SAN DIEGO RIVER BASIN

The San Diego River heads between the northern edge of the Laguna Mountains and the southern edge of the Volcan Mountains in central San Diego County and flows southwestward into El Capitan Reservoir. That reservoir, which has a capacity of 112,000 acre-ft and a drainage area of 188 mi^2, spilled for the first time since 1941. Boulder Creek, the major tributary from the east, joins the San Diego River 2 mi upstream from El Capitan Reservoir. The flow of Boulder Creek is regulated by Cuyamaca Reservoir, which is formed by an earthfill dam completed in 1887. The reservoir has a capacity of 12,150 acre-ft and a drainage area of 12 mi^2. Cuyamaca Reservoir spilled from February 23 to April 8, 1980 (M. Brown, Helix Water District, oral commun., 1982). The 1980 spill from San Vicente Reservoir on San Vicente Creek is the largest since the dam was finished in 1943. Crossings at Vigilante Road (immediately downstream) and Moreno Avenue (near the mouth of San Vicente Creek) were washed out; the floodflows inundated homes and stranded many residents. Figure 26 shows flooding in Moreno Valley. San Vicente Creek enters the San Diego River from the north near Lakeside, about 8 mi downstream from El Capitan Reservoir. Many small tributaries to the San Diego River have a major part of their drainage basin in residential communities of the San Diego metropolitan area. Figure 27 shows flooding along Los Coches Creek, which enters the San Diego River from the south at Lakeside and is typical of these streams.

In some reaches of the San Diego River, channel scour was extreme. The flood tore out a 20-ft-diameter steel culvert at Channel Road crossing near Lakeside and deepened the channel by 10 to 20 ft at Riverford Road.

The San Diego River caused havoc in San Diego, especially in Mission Valley between Interstate Highways 5 and 15. From State Highway 163 to Interstate Highway 5, commercial development has encroached on the several-hundred-foot-wide valley floor and narrowed the river channel to approximately 50 ft. Water reported to be 7 ft deep in places closed most secondary streets. Businesses, shopping centers, hotels, and golf courses were damaged (fig. 28). Thousands of individuals were evacuated. Pryde (1982) estimated a peak discharge at Mission Valley of 27,000 ft^3/s, which is much larger than the discharge of 3,420 ft^3/s 5 mi upstream at the gaging station near Santee (site 21). The rapid increase in discharge is attributed to the highly urbanized drainage area downstream from the station. The rapid increase occurred even though (1) the drainage area at the gaging station is nearly 90 percent of the area at Mission Valley, (2) the river flows through many small ponds enroute from the gaging station, and (3) only three tributaries of any significant size—Alvarado Canyon Creek from the

FIGURE 26.—Moreno Valley, Calif., looking northward up San Vicente Creek downstream from San Vicente Reservoir, February 21, 1980. (Photograph courtesy of San Diego Department of Public Works.)

east and Murphy Canyon and Murray Canyon Creeks from the north—enter the river between the gaging station and the downstream end of Mission Valley. The peak discharge at the gaging station, 3,420 ft^3/s, has a recurrence interval of approximately 9 years and is far less than the peak of 70,200 ft^3/s in 1916. The peak discharge in Mission Valley in 1916 was 75,000 ft^3/s.

After major floodflows had passed, the water level of El Capitan Reservoir was lowered about 30 ft for safety in case of a damaging earthquake. The water released in

FIGURE 27.—Lakeside, Calif., looking westward, February 21, 1980. Los Coches Creek flows from lower left and joins San Diego River in upper right. (Photograph courtesy of San Diego Department of Public Works.)

this safety effort and wasted to the ocean was valued at more than $4 million (San Diego County Flood Control District, 1980).

SAN DIEGUITO RIVER BASIN

Santa Ysabel Creek joins Santa Maria Creek to form the San Dieguito River, which enters Lake Hodges south of Escondido. Peaks of record occurred at Santa Maria Creek near Ramona (site 29) and at Guejito Creek near San Pasqual (site 28). Guejito Creek is tributary to Santa Ysabel Creek. Santa Maria Creek is one of the few streams that had a higher discharge in 1980 than in 1916. At Santa Ysabel Creek near Ramona (site 27), the 1980 discharge was slightly more than one-third of the 1916 discharge.

Sutherland Reservoir, located on the headwaters of Santa Ysabel Creek, spilled for the first time since it was completed in 1954 and contributed to an estimated spill of 22,000 ft^3/s at Hodges Dam (Lake Hodges); this was the largest spill since 1927, when an estimated 47,500 ft^3/s was spilled. Downstream from Hodges Dam, the San Dieguito River damaged two bridges near the mouth and inundated the Del Mar horse track and fairground (fig. 29) to a depth of 3 to 5 ft. Residents of the area and many valuable horses were evacuated.

SAN LUIS REY RIVER BASIN

The San Luis Rey River heads in the mountain area of north-central San Diego County and flows southwestward into Lake Henshaw above Henshaw Dam. Because

FIGURE 28.—San Diego River in lower Mission Valley, San Diego, Calif., looking westward, February 21, 1980. (Photograph courtesy of San Diego Department of Public Works.)

the reservoir has a large capacity relative to its drainage area of 205 mi^2, it contained all inflow during the flood period and was the only reservoir in San Diego County that did not spill during the February 1980 floods. The dam is near Elsinore fault, and because of the possibility of earthquake damage to the dam, the State Division of Safety of Dams has ordered that large volumes of water not be stored over prolonged periods. A controlled release that followed the flood was kept small enough to avoid damage downstream from the dam. Some damage was caused downstream from the dam by tributary inflow during the flood period.

The bridge at West Lilac Road near Pauma Valley and the grade-level crossing at Couser Canyon Road near Pala were washed out, and the new Interstate Highway 15 bridge near Pala was damaged. Near Oceanside, the Douglas Road bridge, the crossing at St. Francis Priory, and the Lorretta Road crossing just downstream from the gage (site 35) suffered flood damage. A large industrial-park complex, about 2 mi upstream from Interstate Highway 5 and 0.8 mi north of the San Luis Rey Mission, was inundated (fig. 30) on February 21 when a break occurred in the 3,000-ft levee along the San Luis Rey River.

At most gaging stations in the San Luis Rey River basin, peak discharges were probably the highest in the last 50 to 65 years. On the San Luis Rey River itself, the peak was small compared with those in 1891 and 1916. For example, at Oceanside (site 35) the 1980 peak discharge was 25,000 ft^3/s. A discharge of 95,600 ft^3/s occurred at Oceanside in 1916. Young and Cruff (1967, p. 60) show that a discharge of 128,000 ft^3/s occurred in 1891 at a site a few miles upstream.

FIGURE 29.—Racetrack and fairgrounds at Del Mar, Calif., looking eastward up the San Dieguito River, February 21, 1980. (Photograph courtesy of San Diego Department of Public Works.)

SANTA MARGARITA RIVER BASIN

Vail Lake, which is on Temecula Creek about 10 mi east of Temecula in Riverside County, spilled sometime between 0400 and 0900 hours on February 21, 1980, for the first time since the dam was completed in November 1948. Vail Lake has a drainage area of 320 mi^2, and the capacity of the reservoir at the spillway level is 49,370 acre-ft at an elevation of 1,470 ft. Data supplied by the Rancho California Water District (J. Schelege, written commun., 1981) indicate that the lake elevation was 1,466.8 ft when observed between 1400 and 1500 hours on February 20, 1980, and that the maximum elevation reached during spill was 1,473.00 ft. Contents at the time of maximum spill was approximately 52,000 acre-ft, and the maximum spill was estimated to be 8,000 ft^3/s.

Peak discharges at gaging stations in the Santa Margarita River basin also were generally the highest in the last 50 years, approaching the magnitudes of discharges during the 1927 floods. Murrieta Creek, which along with Temecula Creek forms the Santa Margarita River, experienced a peak flow of 21,800 ft^3/s at the gage at Temecula (site 37), the highest since records of peak discharges began in 1930. The daily discharge hydrograph for this station is shown in figure 31. On the Camp Joseph H. Pendleton Marine Corps Base, the Santa Margarita River eroded reaches of the left bank below Basilone Road and destroyed sections of a railroad spur. Sections of this railroad were also destroyed during the 1978 floods.

FIGURE 30.—Industrial-park complex near Oceanside, Calif., flooded by San Luis Rey River, looking northeastward from bluff behind San Luis Rey Mission, February 21, 1980. (Photograph courtesy of U.S. Army Corps of Engineers.)

SANTA ANA RIVER BASIN

The Santa Ana River is the largest coastal stream in southern California and has a drainage area of about 2,470 mi^2 at its mouth (fig. 32). The main stem and two of the major tributaries, Mill and Bear Creeks, originate in the San Bernardino Mountains (fig. 21). The river flows westward and debouches from a canyon onto an alluvial flood plain a few miles east of San Bernardino. Several other tributaries also originate on the western slope of the San Bernardino Mountains, flow southward, and enter the main river system. Lytle Creek, another major tributary, has its source in the San Gabriel Mountains (fig. 21) and flows southeastward to join the main stem near San Bernardino. Downstream from Lytle Creek, the river flows southwestward into Prado Reservoir, which is 31 mi upstream from the mouth. Below Prado Dam the river enters Santa Ana Canyon, which lies between the Chino Hills and the Santa Ana Mountains; those highlands physically separate the inland valleys of the upper basin from the coastal plain. Farther downstream, the river flows through large metropolitan areas and into the Pacific Ocean.

The flood of January 22, 1862, the largest in the history of the Santa Ana River basin, destroyed the former settlement of Agua Mansa (southwest of Colton), which had been 9.2 mi upstream from the gaging station of Riverside Narrows near Arlington (site 62). Computations based on old flood marks indicate a peak discharge of 320,000 ft^3/s. Discharges at the gaging station were 100,000 ft^3/s on March 2, 1938, and 19,500 ft^3/s on February 18, 1980.

The 1980 peak discharges in the Santa Ana River basin above Prado Dam were low compared with past floods. For example, the peak discharge of 5,930 ft^3/s at Santa Ana River near Mentone (site 46) was much less than the 1891 peak of 53,700 ft^3/s and the 1938 peak of 52,300 ft^3/s. Runoff volumes, however, were among the highest of this century.

The contents of the Prado Flood Control Reservoir on the Santa Ana River reached about 111,000 acre-ft on February 22, the second highest of record (fig. 33). The highest contents of record, 130,000 acre-ft, occurred on February 25, 1969. Figure 34 shows contents as a function of time for January through April 1980. Unusu-

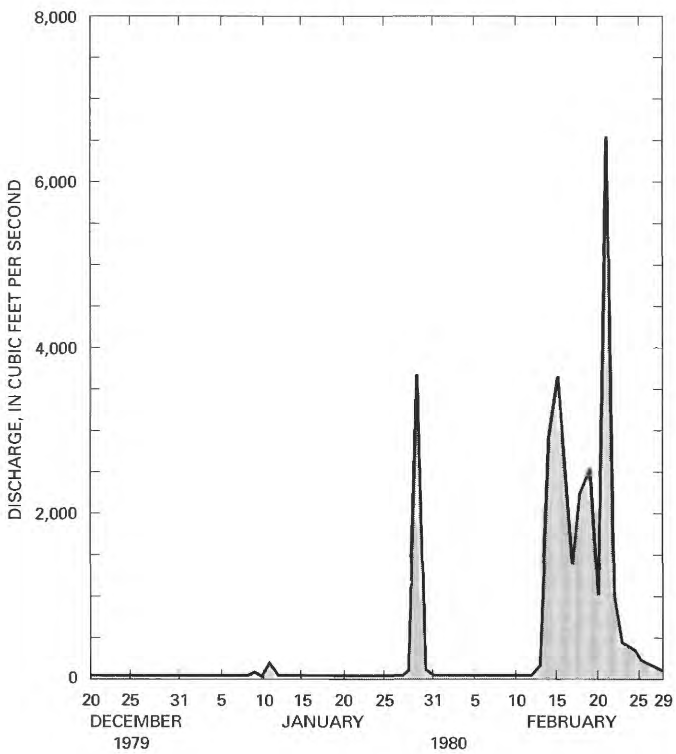


FIGURE 31.—Daily discharge for Murrieta Creek at Temecula, Calif. (station 11043000; site 37, pl. 1), December 1979–February 1980.

ally large releases from Prado Dam continued until mid-May.

Mudflows and slope failures due to saturated soils caused extensive property damage throughout the Santa Ana River basin. The Harrison Canyon debris basin at 40th Street and Harrison Street in San Bernardino was filled by mudflows after the storms of January 9, 14, and 28, February 16, and March 10 (K. Mashburn, San Bernardino County Flood Control District, oral commun., 1981). Levees were overtopped but did not fail. This 0.6-mi^2 drainage basin, which is tributary to East Twin Creek (see fig. 32), virtually had been made a big sand box by a fierce fire in September 1979 that burned most of the basin. The fire destroyed the root systems of vegetation and left a loose mantle. Attempts to seed the barren hillsides before the winter storm period had been unsuccessful. Large mudflows moved downstream at high velocities, and it was not uncommon for the Harrison Canyon debris basin to fill and spill within 20 minutes during these storms. Hampshire Avenue, immediately below the basin, was designed as an inverted "V" to carry floodwater, but it could not accommodate the large mudflows and debris flows. The mud reached depths of 6 to 7 ft on Hampshire Avenue, and more than 60 homes downstream from the debris basin were destroyed by the water and mudflows (fig. 35).

San Jacinto River and Lake Elsinore.—The San Jacinto River flows northwestward from its headwaters in the San Jacinto Mountains in Riverside County, passes near the town of San Jacinto into San Jacinto Valley, and turns southwestward toward Lake Elsinore, which is 30 mi downstream from San Jacinto (see fig. 32). Many years ago the course of the river was altered and the reach past San Jacinto and through the valley was leveed. Downstream from Bautista Creek, a leveed bypass channel was constructed to the east and north of the town. On the morning of February 21, 1980, the levee southeast of (upstream from) San Jacinto failed, and the floodwater reverted to the original river channel through the center of town. Figure 36 shows the destruction to the levees and the damage sustained from the floodwater in San Jacinto. Other levees to the north also failed, thus allowing floodwater to spread out across valley farmlands and into town. Detailed analyses of the failures are presented by Edwards (1982) and Sciandrone and others (1982).

One of the major disasters during the 1980 flood occurred at Lake Elsinore, the terminus of San Jacinto River. Historically, the lake was dry for many years in succession, but since 1965, when importation of Colorado River water began, a lake of about 6 mi^2 has been maintained. During wet periods the shallow lake expands. Prior to 1980, outflow is known to have occurred only in 1872, 1883–84, and 1916–17; there probably was outflow in 1862. During the rare occurrences of outflow, the direction of flow is northeastward to Temescal Wash (also called Temescal Creek). Large amounts of urbanization developed around the shores of the lake during the years of low lake levels. More history of the lake is published in Water-Supply Papers 441 and 961 (U.S. Geological Survey, 1918, 1943).

The Riverside County Parks and Recreation Department recorded a lake-surface elevation of 1,246.59 ft on February 13, 1980 (contents, 61,200 acre-ft). At that time, the lake was about 13 ft below the natural outlet and 20 ft below the tops of gravel piles that had been deposited in Temescal Wash by tributary inflow, mainly from Wasson Canyon, during the many years when there had been no outflow from the lake. During the major part of the flood, the lake surface rose several inches a day. By February 23, the surface had risen to 1,259 ft (contents, 124,000 acre-ft). At this time the Corps of Engineers let a contract for clearing the Temescal Wash channel to an elevation of 1,260 ft (White, 1982). Dredging progressed around the clock as the lake continued to rise. The dredging prevented about 1.5 to 2 ft of rise in the lake (White, 1982). Simultaneously with the dredging, homes and other developments were being protected with sandbags and levees, and residents were being evacuated.

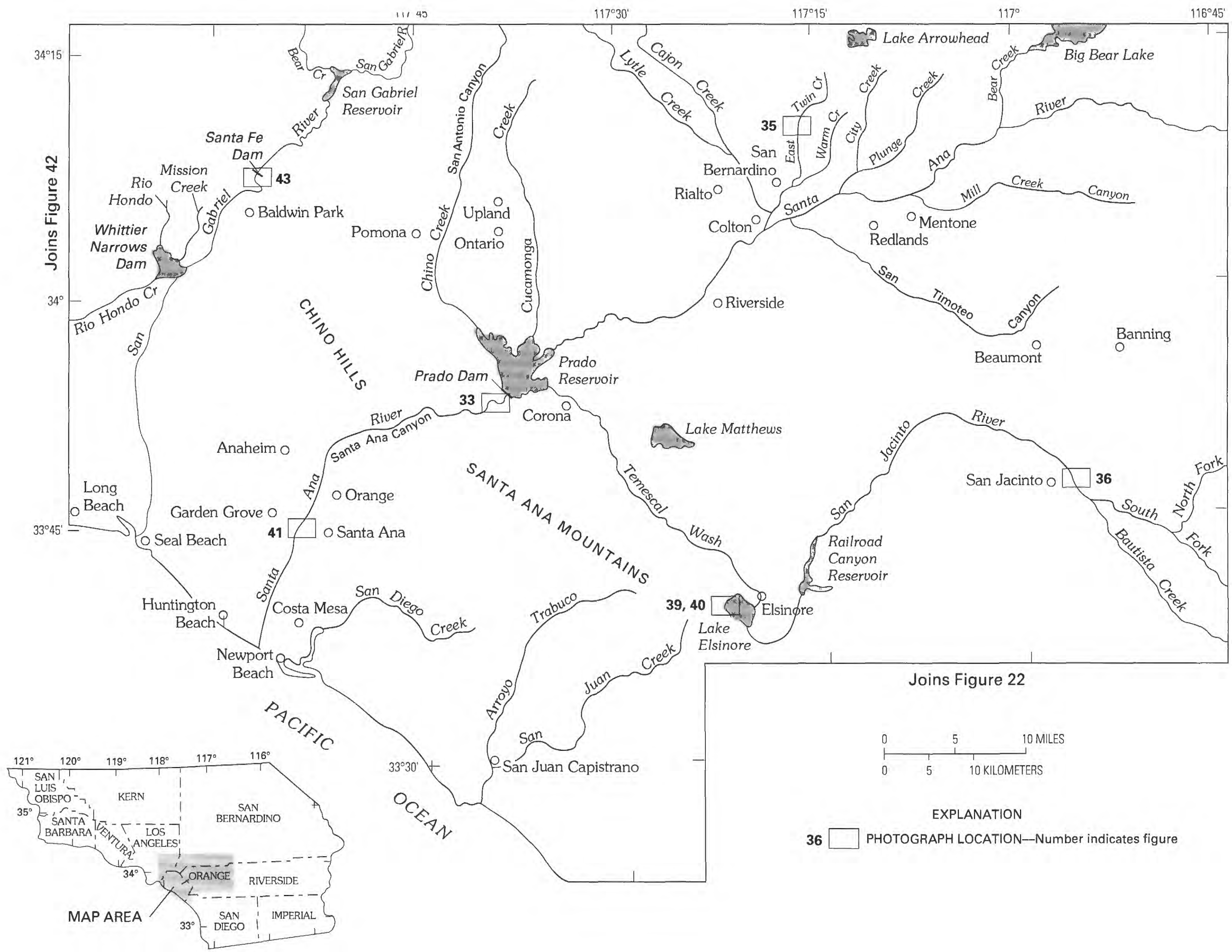


FIGURE 32.—Major reservoirs and streams in Orange, San Bernardino, and Riverside Counties, and in the San Gabriel River basin in Los Angeles County, Calif.

FIGURE 33.—Prado Dam and Flood Control Reservoir, Calif., looking northward from Santa Ana Canyon, February 1980, just after maximum storage had been obtained in the reservoir. (Photograph courtesy of San Bernardino County Flood Control District.)

Inflow reached a maximum of slightly more than 8,000 ft^3/s on February 22, and then decreased steadily, except for a slight increase in early March, to less than 100 ft^3/s in mid-April. Outflow started on March 7 and reached a maximum rate of almost 240 ft^3/s later in the month. The surface of Lake Elsinore reached a maximum elevation of 1,265.72 ft on March 20 (contents, 164,000 acre-ft), and the surface area was about 10 mi^2. Data from Riverside County indicate that inflow during the period when the lake was rising was about 103,000 acre-ft. Another 5,800 acre-ft flowed into the lake after the maximum lake level had been reached. The daily discharge hydrograph for the San Jacinto River near Elsinore (site 66), where inflow to Lake Elsinore is measured, is shown in figure 37. Figure 38 shows the changes in contents and stage of the lake from February 1 to September 30, 1980.

Flooding from Lake Elsinore damaged many homes and facilities in low-lying areas around the lake. The environmental assessment prepared by the Federal Emergency Management Agency (V. Thompson, written commun., 1981) lists 874 buildings and dwellings affected by the floodwater. Approximately 300 structures were

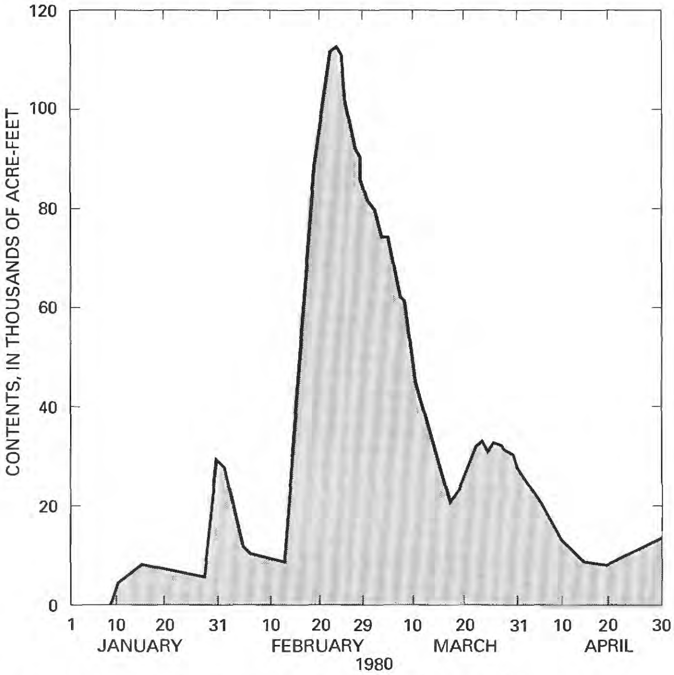


FIGURE 34.—Contents of Prado Flood Control Reservoir, Calif., January–April 1980.

damaged by the rising lake (figs. 39, 40). In addition, about 100 septic tanks serving undamaged structures were flooded and became unusable. Nearly all the approximately 400 mobile homes and travel trailers in the threatened area were relocated in time to prevent damage. An estimated 2,000 residents were displaced. Skylark Airport, at the southeastern end of the lake, and State and city parks and other recreational facilities were inundated.

Santa Ana River downstream from Prado Dam.—On the Santa Ana River below Prado Dam, the highest discharge since regulation began in 1941 occurred on February 21. Extensive damage occurred in Santa Ana between 17th Street and Harbor Boulevard. Daily mean discharges of more than 4,400 ft^3/s were recorded at Santa Ana (site 76) from February 17 to February 26, 1980, and daily mean discharges of 2,300 ft^3/s or larger occurred during the period March 2–16, 1980. Generally, a daily mean discharge of 2,300 ft^3/s is exceeded only one-half of 1 (0.5) percent of the time. The continuous high discharges scoured the riverbed to depths of up to 20 ft and undercut segments of the concrete lining along

FIGURE 35*A*.—Flooded homes along Hampshire Avenue below Harrison Canyon debris basin in San Bernardino, Calif., February 1980, showing debris basin with Hampshire Avenue in the foreground. (Photograph courtesy of San Bernardino County Flood Control District.)

the banks, thus causing it to break off. Repairs to the concrete linings and construction of grouted rock stabilizers are estimated to have cost the U.S. Army Corps of Engineers and local agencies about $4.5 million (R. Douglas, U.S. Army Corps of Engineers, oral commun., 1981).

Scour was severe at six major bridges and numerous minor bridges. The Fifth Street bridge was closed to traffic for almost a year. Part of the reason for the long closure was concern that a combination of heavy traffic and an earthquake, which might occur while the bridge was in a weakened condition, could collapse the bridge and result in loss of life. Keeping traffic off the bridge eliminated that possibility. Piers of this bridge are supported on piling, the tops of which were 1 to 2 ft below the streambed prior to the flood. After the flood, 10 to 15 ft of piling was exposed. Nelson (1982) states that up to 18 ft of scour occurred. The photograph in figure 41*A*, taken from the left downstream bank, shows the site on an unknown date prior to the February 1980 storm. The photograph in figure 41*B* was taken on March 3, 1980, from the right bank on the upstream side of the bridge at a discharge of about 5,000 ft^3/s. The photograph in figure 41*C*, taken from the left downstream bank after the high-water period, shows the amount of scour.

San Gabriel and Los Angeles River Basins

The San Gabriel River (fig. 32) heads in the San Gabriel Mountains north of Los Angeles and flows southward to the Pacific Ocean near Seal Beach. The many tributaries to the Los Angeles River head in the western part of the San Gabriel Mountains and flow south to the river (fig. 42). Part of the upper drainage is from the San Fernando Valley; the river flows eastward through the valley, then flows south through the coastal plain and enters the ocean near Long Beach (fig. 32).

The San Gabriel River is regulated by several reservoirs. The most downstream one is formed by Whittier Narrows Dam. The reservoir is fed by the San Gabriel River, Mission Creek, and Rio Hondo. Most of the inflow is from the San Gabriel River; most of the outflow is released to Rio Hondo, a tributary to the lower part of the Los Angeles River.

FIGURE 35*B*.—Flooded homes along Hampshire Avenue below Harrison Canyon debris basin in San Bernardino, Calif., February 1980, showing extent of sediment deposits. (Photograph courtesy of San Bernardino County Flood Control District.)

FIGURE 36A.—Flood damage in San Jacinto, Calif., February 1980: Aerial view looking northwestward just downstream from levee break on San Jacinto River, near trailer court at Mountain Avenue and Old Mountain Avenue, February 21, 1980. (Photograph courtesy of Riverside County Flood Control and Water Conservation District.)

Flood-control reservoirs in the San Gabriel River basin greatly reduced the peak discharge of the river and caused the discharge below Santa Fe Reservoir (site 77) during 1980 to be much less than the previous peak of record, which occurred in 1969. The discharge of the 1969 peak is 30,900 ft^3/s; that of the 1980 peak is 18,500 ft^3/s. Downstream from Santa Fe Dam (fig. 43), floodflows were contained within the flood-control channel.

The Los Angeles River is regulated by Sepulveda Dam (see fig. 42). Many tributaries that head in the mountains and join the river below the dam are also regulated by reservoirs. The peak discharge at the Los Angeles River at Sepulveda Dam (site 82) was the highest since 1929, but it was only sightly larger than the former peak of record in 1978. By contrast, the February 16 peak discharge at Long Beach (site 87) of 129,000 ft^3/s is 26

FIGURE 36*B*.—Flood damage in San Jacinto, Calif., February 1980: Aerial view looking northwestward near State Street and Ramona Boulevard, February 21, 1980. (Photograph courtesy of Riverside County Flood Control and Water Conservation District.)

percent greater than the previous high since recordkeeping began in 1928. The previous peak of record occurred in 1969.

COASTAL BASINS NORTH AND WEST OF LOS ANGELES

Flood damage was extensive in the small basins between the Los Angeles and Santa Clara Rivers. Homes were damaged by mudflows and floodwaters, and newspaper accounts of these events were daily occurrences. The Laurel Canyon area of Los Angeles sustained flood and mud damage to vehicles and homes, and a woman reportedly was hospitalized after her house slid off the foundation and into the street. In some areas, such as Mount Wilson, mud flowed easily and rapidly from slopes that had been denuded by brush fires of the previous summer. Wells (1982) and Davis (1982) detail amounts of movement and describe the impact of brush

FIGURE 36C.—Flood damage in San Jacinto, Calif., February 1980: Residential area near intersection of Camino Los Banos and First Street, February 21, 1980, shortly after levee break on San Jacinto River. (*Los Angeles Times* photograph.)

fires on the floods. Slosson and Krohn (1982) and Weber (1982) attribute well-administered building codes and improved methods of tract development with having prevented much additional damage.

Flooding and debris reportedly closed the Hollywood Freeway in downtown Los Angeles during morning rush hours of February 15; landslides closed four of the five westbound lanes of the Ventura Freeway near Los Angeles the same day. Mudslides closed the Pacific Coast Highway in Malibu, and Highway 101 was closed at many locations between Goleta (about 5 mi west of Santa Barbara) and the San Fernando Valley because of flooding on February 16. The Topanga Canyon area in the Santa Monica Mountains suffered awesome destruction (fig. 44) when the usually dry creek flooded after a week of rain.

Flooding, mudslides, and debris flows caused sufficient damage in Ventura and Santa Barbara Counties to cause those counties to be eligible for disaster aid. However, peak discharges on the major streams were not unusual. Much higher discharges have occurred several times (table 5) on the Santa Clara, Ventura, Santa Ynez, and Santa Maria Rivers. Records for most small streams are too short to provide a true comparison of the 1980 flood with earlier floods; however, many of the records show higher floods in 1969 and 1978 than in 1980. Such was not the case in Calleguas Creek basin—where Arroyo Simi and Conejo and Calleguas Creeks each had a higher discharge in 1980 than in 1969 or 1978. Taylor (1982) attributes the high discharge in Calleguas Creek to the fact that Arroyo Simi and Conejo Creek, the two major tributaries to Calleguas Creek, peaked almost simultaneously. She stated that concentration time on Arroyo Simi has decreased considerably in the last 46 years.

Parts of the Point Mugu, U.S. Naval Air Station, Pacific Missile Test Center, located about 50 mi west of Los Angeles on the coast, were flooded on February 17 when a dike along Calleguas Creek failed (fig. 45). About 60 percent of the low areas of the base reportedly were under 2 to 5 ft of water, causing about 3,000 residents of the housing area to be evacuated. There was no damage to the sophisticated missile-launching facilities. Taylor (1982) presents a chronology and analysis of the failure.

Floods in the Ventura River basin carried extreme amounts of sediment off 13 basins that had been denuded of vegetation by fires in 1979 (Taylor, 1982). Much more severe flooding probably would have occurred had flood-fighting equipment and personnel not been mobilized quickly because of information obtained from recently

FIGURE 36*D*.—Flood damage in San Jacinto, Calif., February 1980: Looking east toward Mountain Mobile Park and residential area from San Jacinto High School on Idyllwild Drive, just north of Tiger Lane, February 23, 1980. (Photograph courtesy of U.S. Army Corps of Engineers.)

installed flood-warning systems in the Sespe Creek and Santa Ynez River basins (Bartfield and Taylor, 1982; Stubchaer, 1982).

EFFECT OF FLOODS ON GROUND-WATER LEVELS

In southern California, sustained high streamflow constitutes an important source of recharge to the ground-water basins. Because of precipitation during the winter, followed by pumping during the summer, ground-water levels tend to show large seasonal fluctuation, rising in winter and early spring and falling in summer and autumn. In addition to this seasonal cycle, recharge varies greatly from year to year as a result of large variation in annual precipitation.

Figure 46 shows changes in the water level at an index well in Baldwin Park, about 15 mi east of central Los Angeles, from January 1977 to December 1980. This well is about 1.5 mi east of the San Gabriel River and 1 mi south of the Santa Fe Dam Flood Control Basin. The water level in this key observation well rose 33.7 ft between January and June 1980. Wells in many coastal basins indicated similar water-level changes as a result of recharge from the February 1980 flood.

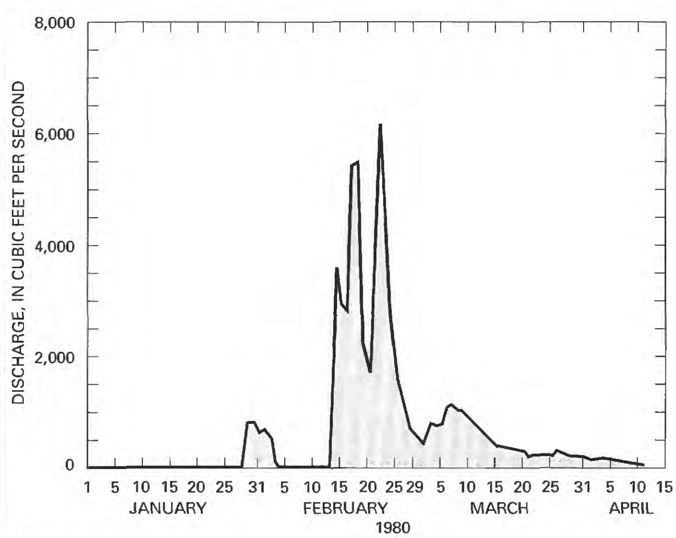


FIGURE 37.—Daily discharge for San Jacinto River near Elsinore, Calif. (station 11070500; site 66, pl. 2), January–April 1980.

COASTAL DAMAGE

The southern California coastline was hit hard by high winds and waves that damaged homes, marine facilities,

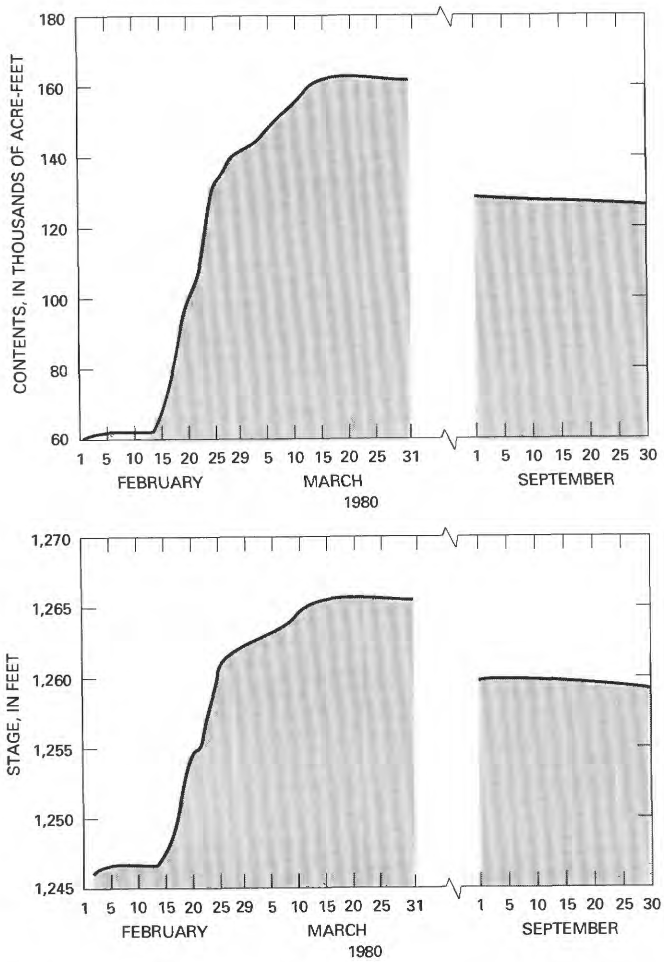


FIGURE 38.—Contents and stage of Lake Elsinore, Calif., February, March, September 1980.

and beaches. At Oceanside, several homes and small motels were almost destroyed by surf and wave action (fig. 47). The beach was reduced to a cobble pavement. At Santa Barbara, waves removed up to 2 ft of beach material from Leadbetter Beach (Shaw, 1982). Coastal residents northwest of Los Angeles suffered from heavy surf that ran as much as 8 to 9 ft above normal and threatened to erode their homes from the front, while flooding and mudslides from the rear threatened to push homes into the ocean.

A sewer line running into the Tapia Sewage-Treatment Plant in Agoura (fig. 42) was broken on February 16 when the plant was flooded, and raw sewage flowed down Malibu Creek and into the ocean. Approximately 65 mi of ocean beaches in Los Angeles County, extending from the Ventura County line to Los Angeles harbor, were closed to swimmers and surfers for more than 3 weeks because of a potential health hazard. Beaches in the city of Imperial Beach, San Diego County (fig. 22), were quarantined for almost 14 months because of sewage carried to the ocean by the Tijuana River. Beaches at San Diego were closed for about 2 months. The harbor patrol reported that many of the 6,000 boats moored at Marina Del Rey, in Los Angeles, had internal flooding and required pumping, and boats at numerous other marinas were damaged.

MONETARY DAMAGE AND FLOOD RELIEF

The large volumes and long durations of flow were as instrumental in causing high economic damage in southern California as were peak discharges. The February floods were more costly than any others that have occurred. The floods caused much damage because massive urban areas have developed since the last major flood. As stated earlier, San Diego, Riverside, Orange, San Bernardino, Los Angeles, Ventura, and Santa Barbara Counties were declared disaster areas. Eighteen lives were lost in these counties as a result of the January and February storms and floods.

Once the counties had been designated disaster areas, the Federal Emergency Management Agency (FEMA) designated the disaster declaration FEMA-615-DR-CA on February 21, 1980 (C. Smith, oral commun., 1981). This act enabled cities and other governmental agencies, as well as nonprofit institutions that have State and local jurisdiction, to file damage applications with FEMA for monetary support. Damage applications were received from 335 public entities for financial assistance totaling about $113 million; more than $60 million was obligated for this disaster through August 1981. The following table gives a breakdown of the project applications by type, as designated by FEMA (D. Taiclet, written commun., 1981), and the monies requested:

Class	Amount, in million dollars
A. Debris clearance	[1]43.9
B. Protective measures	10.7
C. Road systems	24.8
D. Water-control facilities	14.4
E. Public buildings and equipment	.4
F. Public utilities systems	13.9
G. Facilities under construction	.7
H. Private, nonprofit organizations	.2
I. Other	3.3
X. Miscellaneous	4.4

[1]Includes six applications totaling $1.4 million from agencies in Santa Cruz County (not covered in this report).

In addition, almost $6.6 million has been specified for the following FEMA programs: (1) individual family

FIGURE 39*A*.—Lake Elsinore, Calif., looking eastward, circa 1950.

FIGURE 39*B*.—Lake Elsinore, Calif., looking eastward, February 1980.

FIGURE 40.—Residential area along Lake Elsinore, Calif., February 1980. (Photograph courtesy of U.S. Army Corps of Engineers.)

grants to meet immediate needs ($4,275,000); (2) temporary housing (rental costs) ($551,500); and (3) mission assignment letters, which is FEMA's means of requesting other agencies to do work in connection with this disaster ($1,801,000). The first program is limited to $5,000 per family; 75 percent of the funds come from FEMA, and 25 percent come from the State. The second program is limited to rent for 1 year.

Damage estimates and costs associated with flood-related emergency activities have been compiled and published by the U.S. Army Corps of Engineers (1981b). That report states that flood, mudslide, and beachfront-erosion damage totaled about $500 million in southern California; according to the report, about $17 million was spent for emergency operations, repair, and restoration. In Riverside County, which experienced its most costly flood period on record, the report attributes 10 deaths and property damage of more than $70 million to the floods. In addition, about $4 million was spent for flood fighting and other emergency operations, and about $6 million for rehabilitation projects following the flood. This was the largest single expenditure of funds for flood fighting and rehabilitation in any southern California county during the 1980 floods.

The Corps' report further emphasizes the San Jacinto levee break as having the most serious consequence of all the effects of the 1980 floods in southern California. Many people were left homeless, residences were damaged and mobile homes destroyed, and many roads and streets were seriously damaged as a result of flooding. Damage was estimated at $29 million in urban areas and $1.5 million in agricultural areas.

SEDIMENT TRANSPORT

On several streams during the 1980 flood, channel scour, bank erosion, levee failure, channel migration, mudslides, debris-basin spills, and road overflow resulted in the transport of great quantities of sediment. Sediment transport during periods of high flow is especially important because at these times the river channels will try to obtain a state of equilibrium, either by aggradation or by degradation, to compensate for the many changes to the basin that have been induced, mainly by man. Streams that have gravel operations in the river bed, have infiltration ponds in the river channel, or have artificial controls or drop structures usually undergo drastic changes from sediment movement during floods. During high-flow periods, streams also carry great quantities of sediment to the sea and replenish the beaches. However, the large number of reservoirs that have been established during the past century serve as sediment traps, reducing the rate of replenishment. As a result, many beach areas have been replenished by man at considerable expense. Sediment movement also causes problems because of channel deposition.

Table 8 summarizes sediment data for the Santa Ana, Santa Clara, and Ventura Rivers (sites 76, 99, and 106) for storm periods of 25 days during the 1969 water year, 28 days during the 1978 water year, and 33 days during the 1980 water year. The percentages of annual load transported during the storm periods range from 64.3 to 76.2 for the Santa Ana River, 95.9 to 98.2 for the Santa Clara River, and 98.9 to 99.7 for the Ventura River.

The lower percentages for the Santa Ana River may have resulted in part from the presence of Prado Reservoir, which permits substantial regulation of the flow in the lower reaches of the Santa Ana River and acts as a sediment trap for upper basin flow. Also, when large quantities of water are released from the reservoir for prolonged periods of time, the released water transports large sediment loads obtained from the reservoir and from the stream channel. Large percentages of the total annual sediment load are transported during postflood releases. For example, the amount of sediment transported during the postflood period in 1980 is 19 percent of the yearly total and 25 percent of what was transported during the four storm periods during the 1980 water year. Table 9 shows annual sediment loads for water years 1969–80 and compares the movement during storm periods of 1969, 1978, and 1980 with the 12-year totals. The load of sediment transported, during 86 days, ranges from 66 to 94 percent of the 12-year total. Figure 48 relates the rate of sediment discharge to the combined water and sediment discharge rate at the Santa Clara River at Montalvo (site 99).

ARIZONA FLOODS

Although precipitation occurred throughout most of Arizona during the storms of February 13–22, 1980, large amounts of runoff occurred only in the mountains of central Arizona (fig. 1). Minor floods occurred in local areas within the Little Colorado River, Havasu Creek, and Bill Williams River basins. Moderate to severe floods occurred on unregulated streams in the basins of the Salt, Agua Fria, and Hassayampa Rivers, which are tributaries of the Gila River (pl. 2). The most severe floods occurred on the Salt and Agua Fria Rivers downstream from water-conservation reservoirs. Maricopa, Yavapai, and Gila Counties were declared disaster areas.

The peak discharge of 170,000 ft^3/s on the Salt River at Jointhead Dam at Phoenix (site 45, pl. 2) is the highest since 1905, when the Salt River carried an unregulated discharge of more than 200,000 ft^3/s. The highest discharge known for the Salt River since at least 1871 is 300,000 ft^3/s in 1891. The discharge of 66,600 ft^3/s of the Agua Fria River below Waddell Dam (site 51) on February 20 is the highest since November 1919, when the unregulated discharge exceeded 105,000 ft^3/s (site 51A). Discharges for sites 51A and 51B are computed from the same gage. Releases from the reservoirs on Salt, Verde, and Agua Fria Rivers in February 1980 came after large releases in March through May 1978 and December 1978 through May 1979. The 1978–80 period is the first period since regulation began in which large releases were made in three consecutive years and the first time since 1905 that floods had occurred so frequently. Regulation began in 1910 on the Salt River, in 1927 on the Agua Fria River, and in 1938 on the Verde River, the main tributary to the Salt River upstream from Phoenix.

Each of the six storms during February 13–21 caused distinct peaks on small streams. A peak occurred at one or more small streams on each day during the period except February 16 and 20. Each peak was followed by a recession to near base flow.

The larger streams had two distinct periods of flooding—one February 14–15 and the other February 19–20. During the first, the large streams began rising the morning of February 14 and peaked either late that night or early February 15. The second flood began late February 19, and streams peaked at various times between 2300 hours on February 19 and 1200 hours on February 20. The February 14–15 peak was higher in most of the Salt River basin; the February 19–20 peak was higher in the Little Colorado, Bill Williams, Agua Fria, and Hassayampa River basins and in parts of the Salt River basin.

GEOGRAPHIC SETTING

The central mountains of Arizona extend in an east-west direction across most of the State. (See pl. 2 for all geographic features named in this discussion.) The mountains make up parts of six counties (fig. 1): most of Gila and Yavapai Counties and small parts of Apache, Navajo, Coconino, and Maricopa Counties. The northern slopes of the mountains are drained by tributaries to the Little Colorado River and Havasu Creek. The southern slopes are drained by tributaries to the Salt, Agua Fria,

FIGURE 41*A*.—Santa Ana River at 5th Street bridge in Santa Ana, Calif.: Dry channel prior to February 1980. View from left downstream bank.

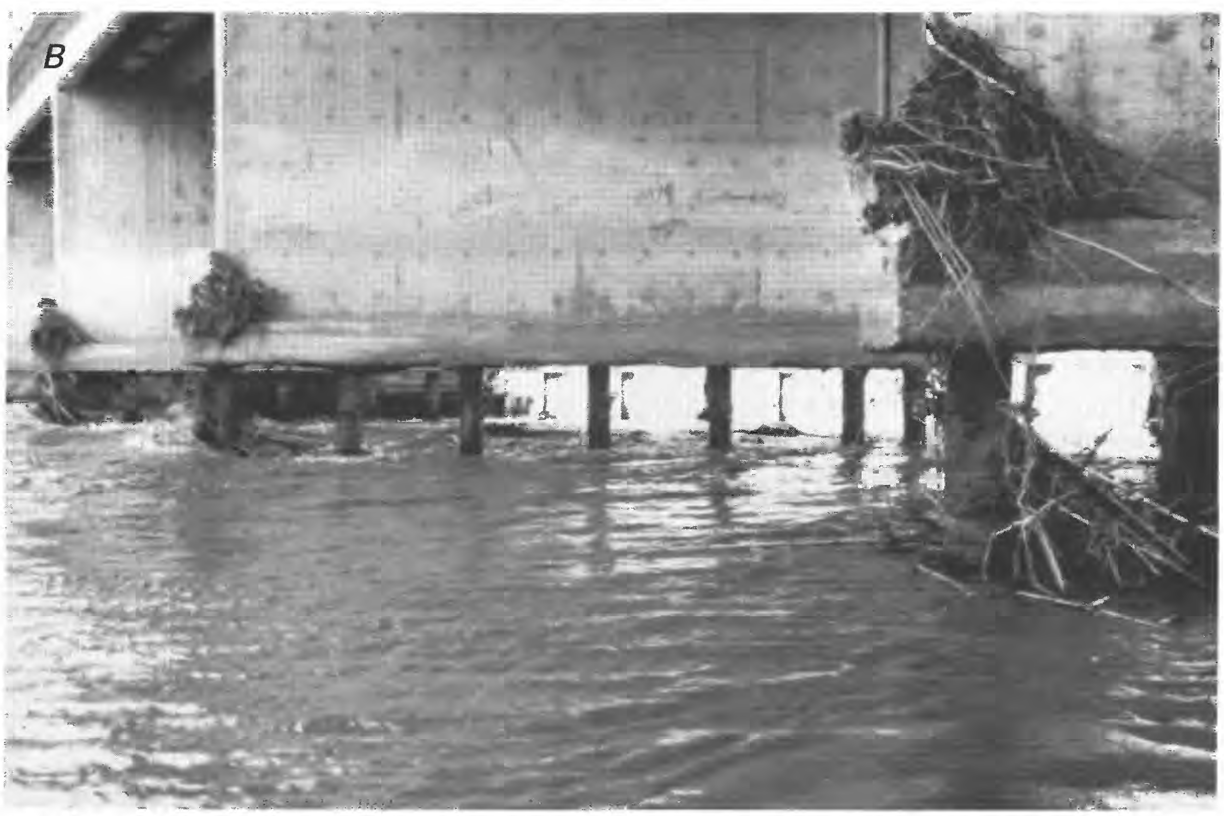


FIGURE 41*B*.—Santa Ana River at 5th Street bridge in Santa Ana, Calif., at discharge of about 5,000 cubic feet per second, March 3, 1980. View from right upstream bank. (Photograph courtesy of Orange County Environmental Management Agency.)

FIGURE 41C.—Santa Ana River at 5th Street bridge in Santa Ana, Calif.: Extent of damage in late spring 1980. View from left downstream bank.

and Hassayampa Rivers, all of which drain to the Gila River. The Bill Williams River heads in the western end of the mountains and drains to the Colorado River.

The Salt River, which is the principal stream in the Arizona part of the report area, is formed by the Black and White Rivers. Downstream from the confluence of the Black and White Rivers, five main tributaries—Carrizo, Cibecue, Canyon, Cherry, and Tonto Creeks—drain from the Mogollon Rim and enter the Salt River in a reach of 90 mi. Each tributary drains 200 to 1,100 mi^2. The largest tributary is Tonto Creek, which flows directly into Roosevelt Lake. These tributaries all head in or flow through Gila County. The five main tributaries are separated by steeply sloping, sparsely vegetated mountain ranges that extend southward from the Mogollon Rim and cause orographic uplift to the eastward-moving storms. The Salt River is joined by its major tributary, the Verde River, 25 mi upstream from Phoenix.

The Verde River drains from the low mountains west of Williams in Coconino County and flows southeastward through Yavapai and Maricopa Counties to the Salt River. As the Verde River flows through the Verde Valley, it is joined by several tributaries from the Mogollon Rim. These tributaries produce a major part of the runoff in the Verde River. At the confluence of the two rivers, the drainage areas of the Salt and Verde Rivers are about 6,300 and 6,600 mi^2, respectively. Downstream from the Verde River, the Salt River flows westward through the center of the highly urbanized part of Maricopa County and joins the Gila River west of Phoenix. The Salt River is the main source of flood runoff to the Gila River, which heads in New Mexico and flows across Arizona to join the Colorado River near Yuma.

Most of the streams in the mountains flow through well-defined canyons and short reaches of flood plain. The few flood plains are sparsely inhabited and are occupied by an occasional small town or community. Significant flood plains exist along the Verde River, East Verde River, and Tonto Creek and the lower reaches of the Hassayampa River. For some distance downstream from the Verde River, the Salt River flows in a broad braided channel about 0.5 to 1 mi wide, but through central Phoenix the river has a rather well defined channel. Much of that channel has been developed by manmade and natural causes during the past 15 years. Only a small part of the channel existed prior to the flood of December 1965 (Aldridge, 1970). The Salt River is crossed by many streets that connect the southern and northern parts of the metropolitan area.

The Agua Fria River heads between Prescott and Camp Verde in Yavapai County and flows southward to join the Gila River west of Phoenix 3 mi downstream from the Salt River. Principal tributaries are Black

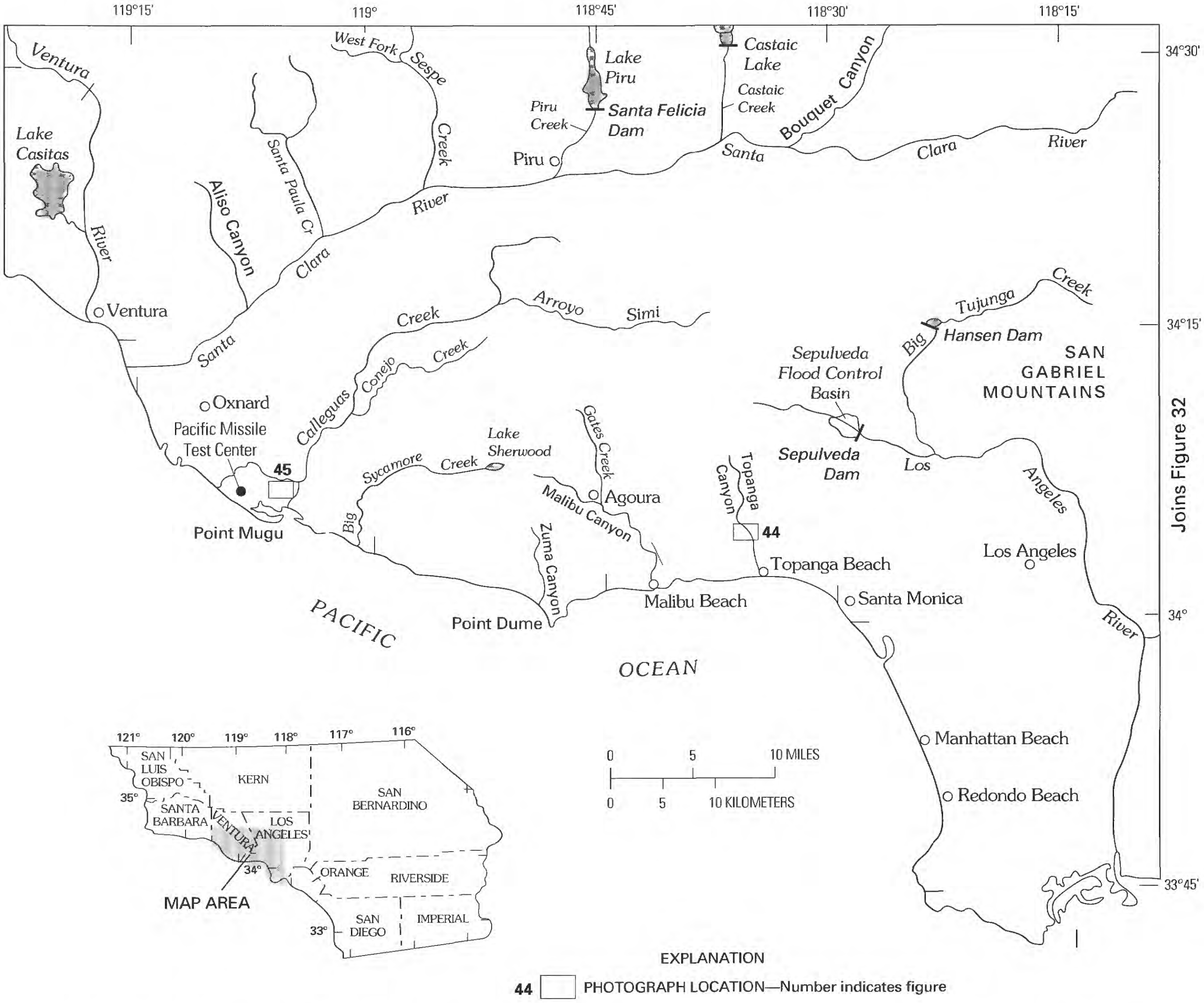


FIGURE 42.—Los Angeles River basin and other major coastal stream basins in Los Angeles and Ventura Counties, Calif.

Canyon Creek and the New River. Black Canyon Creek drains the Bradshaw Mountains and enters the Agua Fria River upstream from Lake Pleasant. The New River drains the New River Mountains and enters the Agua Fria River downstream from Lake Pleasant within the urban part of Maricopa County. The Agua Fria River flows through several cities west of Phoenix and separates much of the metropolitan residential area from downtown Phoenix.

From the time regulation began on the Agua Fria River in 1927 to 1978, the river carried a maximum of a few thousand cubic feet per second between Lake Pleasant and the New River. During these years of low flow, deposits of alluvium gradually accumulated along the river, and a narrow channel developed. The channel is incised only a few feet below a fairly wide, easily erodible flood plain.

Downstream from the Agua Fria River, the channel of the Gila River is overgrown with dense phreatophytes, and extensive flooding occurs during moderate discharges. The third major tributary to the Gila River in the study area is the Hassayampa River, which also heads near Prescott and flows southward through western Yavapai County and northwestern Maricopa County to join the Gila River west of Buckeye. The Hassayampa River is unregulated.

Four reservoirs on the Salt River and two reservoirs on the Verde River store water for irrigation. The principal reservoir is Roosevelt Lake—above Theodore Roosevelt Dam—on the Salt River just below Tonto

Creek. Roosevelt Lake has a capacity of 1,337,000 acre-ft. Three downstream reservoirs on the Salt River—Apache Lake above Horse Mesa Dam, Canyon Lake above Mormon Flat Dam, and Saguaro Lake above Stewart Mountain Dam—have a combined capacity of 373,000 acre-ft. Two reservoirs on the Verde River—Horseshoe and Bartlett—have a combined capacity of 309,600 acre-ft. Granite Reef Dam on the Salt River east of Phoenix and Gillespie Dam on the Gila River south of Buckeye—low-head diversion dams near the upstream and downstream limits of the metropolitan area—are the principal points where streamflow into and out of the metropolitan area is computed. Most of the flood damage in Maricopa County occurred between the two dams. Streamflow is also measured at Jointhead Dam, located in Phoenix 20 mi downstream from Granite Reef Dam. Jointhead Dam serves only as a low-flow control for the gaging station. There is no reservoir behind the dam. Lake Pleasant (another reservoir for storing irrigation water) on the Agua Fria River partially controls floodflows of the Agua Fria River. During most years, all inflow is stored. Water is released to the Agua Fria River only when the volume of water stored in the reservoir approaches the capacity of the reservoir and the inflow is greater than the amount needed for irrigation. Flood protection for the lower reaches of the Gila River is provided by Painted Rock Reservoir west of Gila Bend. The reservoir has a capacity of 2.5 million acre-ft. Alamo Reservoir on the Bill Williams River reduces floodflows into the Colorado River.

MINOR FLOODS IN LITTLE COLORADO, BILL WILLIAMS, AND UPPER GILA RIVER BASINS

Minor floods occurred near Show Low, Winslow, and a few other places in the Little Colorado River basin. Peak discharges occurred on February 15 and February 20, 1980. The second peak was generally higher except near the mouth of the Little Colorado River. At Winslow, the Little Colorado River was high enough on the dikes to cause concern about overtopping or failure, although the dikes held. Minor leakage caused a few inches of water to reach low-lying subdivisions. The peak discharge at Winslow was computed as 28,000 ft^3/s. By comparison, the peak in December 1978 was 57,600 ft^3/s. Several highways along the north side of the Mogollon Rim were closed because of the flood.

High flows occurred throughout the Bill Williams River basin. Large amounts of inflow to Alamo Lake caused the reservoir to reach a high level. An above-normal preflood level had resulted from large carryover storage caused by high flow in 1978 and 1979. The U.S. Bureau of Reclamation was concerned about a possible spill from Alamo Dam and a subsequent spill from Parker Dam on the Colorado River, and the water level in Lake Havasu (above Parker Dam) was lowered in order to provide additional flood control for the lower reaches of the Colorado River.

High water, but no outstanding floods, occurred in one or two tributaries to the Gila River upstream from the Salt River. The only significant damage was the washout of approaches to a State highway bridge near the mouth of the San Carlos River. Inflow to San Carlos Reservoir, when added to the high carryover storage from the preceding year, was sufficient to cause that reservoir to spill for the second consecutive year, but the spill did not occur until March 1980. The 1979 and 1980 spills are the first that occurred after the reservoir was constructed in 1929. The Gila River upstream from the Salt River peaked at less than 700 ft^3/s, several days after the flood on the Salt River. Peak discharges in the Little Colorado River, Bill Williams River, and upper Gila River basins were generally much less than those in past years; therefore, peak data have not been summarized in this report. Data are given in "Water Resources Data for Arizona, Water Year 1980" (U.S. Geological Survey, 1982).

MAJOR FLOODS IN LOWER GILA RIVER BASIN

ANTECEDENT CONDITIONS

To trace the development of conditions leading to the 1980 floods near Phoenix, it is necessary to start in March 1978, when extremely large volumes of runoff exceeded the unfilled capacity of reservoirs on the Salt, Verde, and Agua Fria Rivers. Water released from the reservoirs in March 1978 caused a severe flood in Phoenix, where the Salt River was the highest since 1920 (Aldridge and Eychaner, 1984). Large volumes of runoff during the spring of 1978 kept the reservoirs, which usually begin to drop in April or early May, essentially full until June 1978. The reservoirs on the Salt and Agua Fria Rivers were more than 70 percent full at the end of the 1978 irrigation season; the Verde River reservoirs were 50 percent full. Another period of high water began in November 1978. Runoff in December 1978 again exceeded the capacity of the reservoirs and caused another flood. The December 1978 flood was higher than the March 1978 flood at Phoenix (Aldridge and Hales, 1984). Reservoirs were essentially full in June 1979, and they retained a large volume of water after the irrigation season of 1979. Reservoirs on the Verde and Agua Fria Rivers remained 50 to 70 percent full, and those on the Salt River remained more than 80 percent full.

Storms in January 1980 caused above-average runoff that began to fill the reservoirs again. The January storms left large amounts of snow at altitudes above

FIGURE 43*A*.—San Gabriel River below Santa Fe Dam, Calif., looking upstream prior to the 1980 flood.

about 6,000 ft. Below about 8,000 ft, the snow was extremely dense; that is, a high percentage of the snow was water. Snow surveys on February 1 showed the water content of the snowpack of the Salt River basin to be 148 percent of normal. The soil under the snowpack was saturated. Above-average runoff that followed the January storms continued to increase the contents of reservoirs.

The unfilled capacities on February 13 were:

Reservoir system	Capacity (acre-ft)	Unfilled capacity, February 13 (acre-ft)
Salt River	1,755,000	194,000
Verde River	309,600	36,000
Lake Pleasant (Agua Fria River)	157,000	3,600

The potential for reservoirs to fill, spill, and cause flooding during any significant storm period was extremely high. The probabilities of the reservoirs filling during a single flood were 1.0 for the Verde and Agua Fria River reservoir systems and about 0.3 for the Salt River reservoir system.

SALT RIVER UPSTREAM FROM ROOSEVELT DAM

Runoff in the Salt River basin during the February 14–15 flood originated mainly below an altitude of 5,000 ft, although the snowline remained near 7,000 ft during most of the storm period and may have reached 10,000 ft early in the storm period. The high-altitude parts of the basin that had contributed heavily to the December 1978 flood (Aldridge and Hales, 1984) contributed little to the February 1980 flood. Peak discharges on streams draining less than 20 mi^2 were small relative to past floods from convective summer storms. The relative magnitude of the flood increased as the drainage area increased and flow from large areas concentrated (table 24). Large quantities of runoff came from tributaries to the Salt River between the confluence of the Black and White Rivers and Roosevelt Dam. The peak discharge of the Salt River near Roosevelt (site 11, pl. 2), 99,000 ft^3/s, is the third highest since records began in 1913. The high flow combined with a peak of record on Tonto Creek and

FIGURE 43B.—San Gabriel River below Santa Fe Dam, Calif., looking upstream during February 1980 release.

a large inflow from ungaged tributaries to produce a peak inflow to Roosevelt Lake of more than 150,000 ft^3/s. This is probably the second highest inflow to Roosevelt Lake since storage began in 1910. Most of the inflow to the system of reservoirs on the Salt River is measured at gaging stations on the Salt River near Roosevelt and Tonto Creek above Gun Creek, near Roosevelt (site 14; tables 10, 11).

This was the third time in 2 years that the inflow to Roosevelt Lake had exceeded 150,000 ft^3/s. To compare inflow rates during floods of March 1978, December 1978, and February 1980, the inflow to the reservoir during each flood was computed from hourly reports of lake levels and reservoir releases. Although 2-hour increments were used in the computation, the computed discharge fluctuated considerably because lake-level readings are affected by wind, gate openings, wedge storage, and observational error. Small variations in lake levels caused large variations in computed discharges. The fluctuations are great enough to make accurate determinations of inflow impossible. Peak inflows computed on the basis of 2-hour periods were 170,000 ft^3/s on March 2, 1978, 152,000 ft^3/s on December 18, 1978, and 167,000 ft^3/s on February 15, 1980. The computations do not account for traveltime that would have existed had tributaries been flowing into the Salt River rather than into the reservoir; therefore, they tend to overestimate the natural flow of the Salt River at Roosevelt Dam. Computations for the flood of March 1978 indicate that peak discharges that would have passed the damsite if the dam did not exist are probably about 10–15 percent less. Four floods of comparable magnitude occurred on the Salt River between 1890 and 1977. Aldridge (1970) reported discharges for the floods as follows:

Date	Estimated discharge, in cubic feet per second
February 1891	150,000
November 1905	145,000
March 1941	140,000
January 1951	140,000

The volume of water flowing into Roosevelt Lake from Salt River and Tonto Creek—that is, the gaged inflow—was 550,000 acre-ft during the 7 highest consecutive days

FIGURE 44.—House along Topanga Canyon, Santa Monica Mountains, near Santa Monica, Calif., February 20, 1980. (*Los Angeles Times* photograph.)

during the February 1980 flood period and is the third largest in 7 days since storage began in Roosevelt Lake in 1910 (table 12). Greater 7-day volumes of gaged inflow occurred in January 1916 and March 1978. The total volume of inflow (including ungaged flow) during the 7 highest days in February 1980 was about 740,000 acre-ft and may have exceeded the corresponding volumes in 1916 and 1978. The 7-day volume was particularly high because it encompassed the two periods of high runoff on February 15 and February 20, 1980. The 3-day volume was the fifth largest in the period of record.

Table 12 shows several additional periods between 1913 and 1980 when the gaged 7-day inflow to Roosevelt Lake exceeded 200,000 acre-ft. Inflows given in table 12 were computed by summing the daily discharges of the Salt River near Roosevelt and Tonto Creek near Roosevelt for 1913–40 or Tonto Creek above Gun Creek, near Roosevelt for 1941–80. On both streams, records prior to 1925 are from staff gages and have the normal uncertainties associated with staff-gage records. A water-stage recorder was installed on the Salt River in 1925, but the staff gage on Tonto Creek continued in use until December 1940. Thereafter, both streams were equipped with water-stage recorders. There is little likelihood that any inflows exceeded 200,000 acre-ft from 1906 to 1913, but several inflows of this magnitude occurred between the mid-1880's and 1905.

Large flows in 1980 from tributaries to the Salt River caused crests at downstream stations on the Salt River to occur before the crest at the upstream station, thereby masking the traveltime between gaging stations (fig. 49). The February 15 flood at the gaging station at Salt River near Roosevelt had one general crest with several minor fluctuations. The highest crest at Salt River near Roosevelt occurred before the single crest upstream at the gaging station at Chrysotile (site 8). The pattern is typical of most floods on the Salt River.

VERDE RIVER BASIN UPSTREAM FROM HORSESHOE DAM

Both the February 15 and February 20 floods were extremely high in the upper part of the Verde River basin. Some streams had the higher peak on February 15; others had the higher peak on February 20. Within any given geographical area, the date of the higher peak differed from stream to stream. An example is found among streams that drain to the Verde River from the north between Clarkdale and Camp Verde. Woods Can-

FIGURE 45.—Flooding at Point Mugu, U.S. Naval Air Station, Pacific Missile Test Center, Calif., February 18, 1980. (Photograph courtesy of U.S. Army Corps of Engineers.)

yon (site 29), Rattlesnake Canyon (site 31), and Dry Beaver Creek (site 32) had the higher peak on February 14–15; Oak Creek (site 25), Wet Beaver Creek (site 27), Bar M Canyon (site 30), and West Clear Creek (site 34) had the higher peak on February 19–20. Woods Canyon and Bar M Canyon are adjacent basins having similar drainage characteristics. The peak of February 14 on Rattlesnake Canyon is the peak of record. Peaks of February 15 and February 20 exceeded the previous peak of record since 1965 at Williamson Valley Wash near Paulden and since 1963 at Verde River near Paulden; the February 20 peak was the higher of the two peaks at those stations. The February 15 peak was the higher of the two peaks at all other stations on the Verde River. The peak of record occurred on February 19 or 20, 1980, at Oak Creek near Cornville and at Wet Beaver

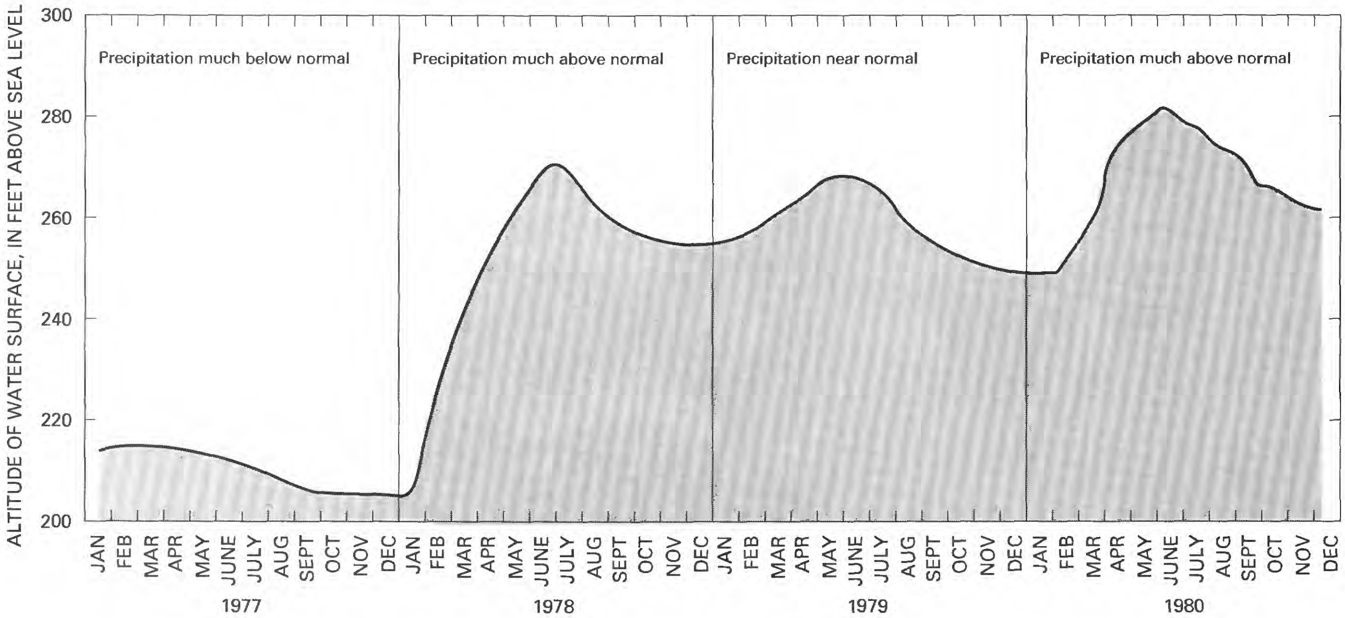


FIGURE 46.—Changes in ground-water level in well at Baldwin Park, Calif. (1S/10W-7R2), about 15 miles east of central Los Angeles, 1977–80.

FIGURE 47.—Damage to residential structures and severe erosion of beach from surf activity south of Oceanside Harbor breakwater at Oceanside, Calif., February 1980. (Photograph courtesy of U.S. Army Corps of Engineers.)

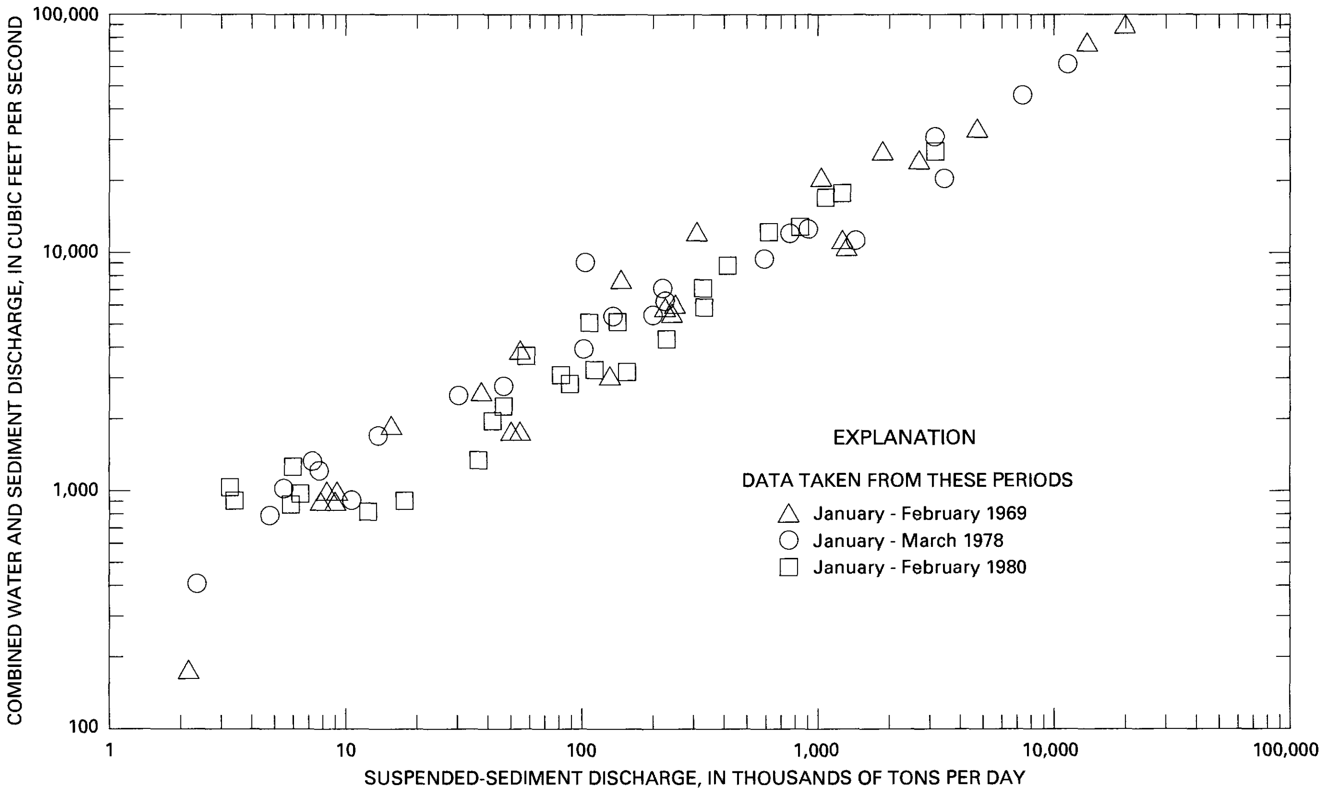


FIGURE 48.—Suspended-sediment discharge versus combined water and sediment discharge at Santa Clara River at Montalvo, Calif. (station 11114000; site 99, pl. 2), selected periods, 1969, 1978, 1980.

Creek near Rimrock. The record at Oak Creek started in 1940; the record at Wet Beaver Creek started in 1961. Two to five higher floods may have occurred in the Verde Valley since 1890. Years in which higher floods may have occurred are 1891, 1905, 1918, 1920, and 1938.

At the Oak Creek gage (site 25), the peak discharge is the highest or second highest since at least 1885. Upstream from the bridge on which the gage is located, the stage in 1938 exceeded that of February 1980, but the discharge of the 1938 flood is unknown. Channel changes since 1938 and possible collection of debris on the bridge preclude obtaining the discharge from any rating developed for the gage, which is on the downstream side of the bridge. The February 1980 flood wave was extremely sharp and was reportedly caused by a debris dam that formed and then broke several miles upstream from Sedona.

Granite Creek and Willow Creek near Prescott were high, but the discharges were not measured. Newspapers reported that on February 15 the stage of Granite Creek was the highest since 1963, being 3 ft over the Sixth Street bridge in downtown Prescott. A study of newspaper articles and reports on the 1963 flood (Aldridge, 1963; U.S. Army Corps of Engineers, 1963) indicates that the 1963 flood and the 1980 flood may have been approximately equal in Prescott, but that the 1980 flood was 1.3 ft lower than the 1963 flood at the discontinued gaging station on Granite Creek 2 mi north of Prescott.

The peak of February 15 at Verde River below Tangle Creek, above Horseshoe Dam (table 13, fig. 50) has been exceeded three or four times since 1890. The 7-day volume of 440,000 acre-ft, the second largest since 1906, was exceeded by the 7-day volume in March 1978.

Figure 50 shows the magnitude of inflow between the various gaging stations along the Verde River. Downstream from Clarkdale, crests occurred progressively later as the flood wave moved downstream. This is in contrast to what had frequently occurred during past floods, when downstream crests occurred earlier than upstream ones. Although crests occurred at downstream stations later than at upstream stations, the time between crests is not necessarily the true traveltime between stations because large tributary inflow affected the time of the crests.

FLOODING DOWNSTREAM FROM RESERVOIRS ON THE SALT AND VERDE RIVERS

The reservoir systems on the Salt and Verde Rivers became nearly full during the first day of the flood, and large volumes of water were released. Outflow from the

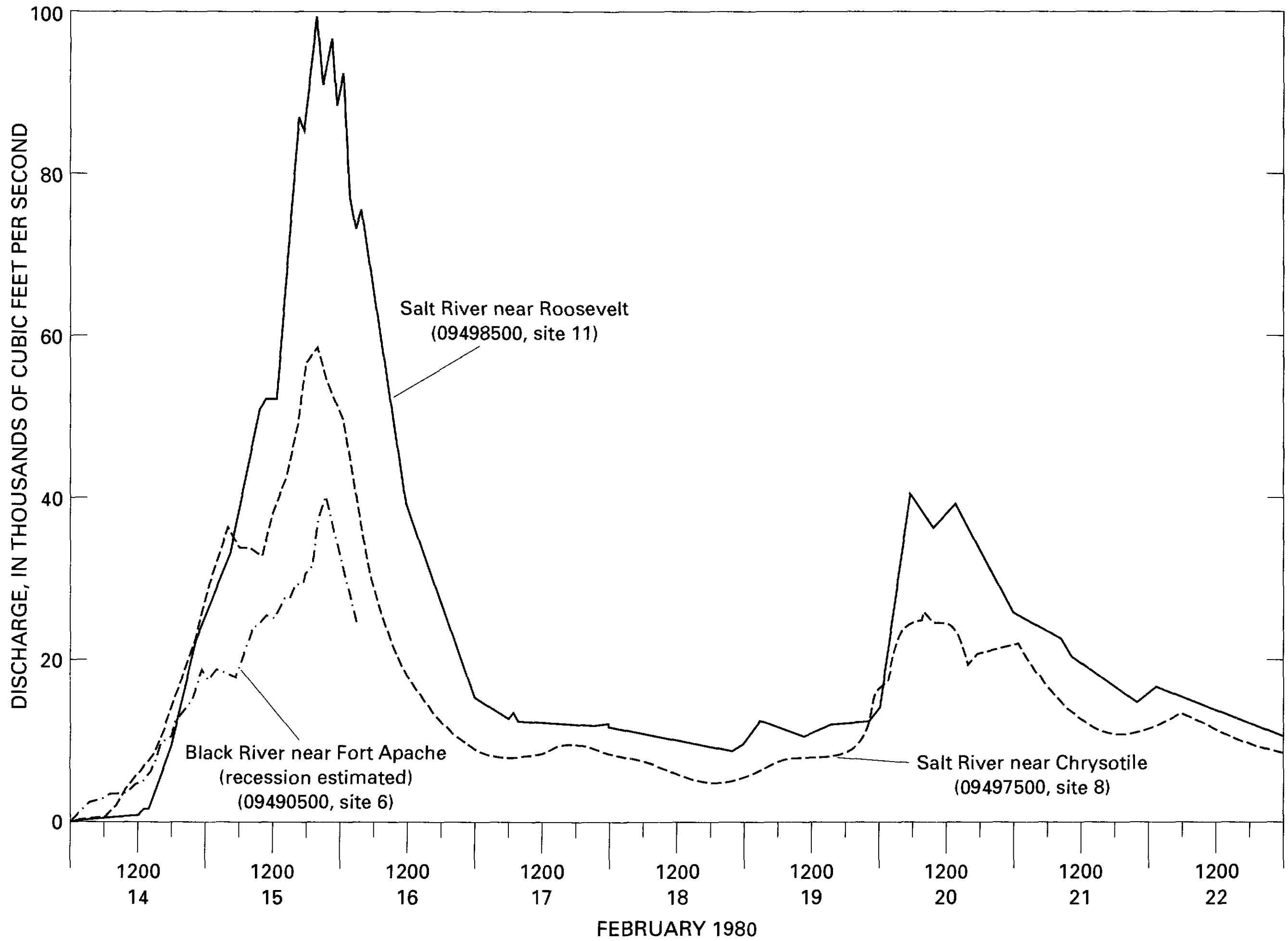


FIGURE 49.—Discharge of Black and Salt Rivers upstream from Roosevelt Dam, Ariz., February 14–22, 1980.

Salt River reservoir system is measured at the Salt River below Stewart Mountain Dam (table 14, fig. 51), where the peak discharge was 75,200 ft^3/s on February 15. Gaging stations downstream from the reservoirs are shown on plate 3. Outflow from the Verde River reservoir system is measured at the Verde River below Bartlett Dam (table 15). Peak discharge there on February 15 was 97,300 ft^3/s. The water released from the reservoirs combined with some tributary inflow to produce a peak discharge of 170,000 ft^3/s on the Salt River at Jointhead Dam, at Phoenix (table 16). Without the storage provided by the reservoirs, the peak discharge at Phoenix would have been about 250,000 ft^3/s.

When the February 13 storm began, water was being released from Stewart Mountain and Bartlett Dams at rates of 200 to 300 ft^3/s, but no water was flowing over Granite Reef Dam, a low diversion structure having no storage reservoir, because all flow was diverted into canals. Release rates from Bartlett and Stewart Mountain Dams were increased on February 13; water began flowing over Granite Reef Dam at 2000 hours. Downstream from Granite Reef Dam, water flowed in a channel that had not carried water for the preceding 2 or 3 days.

Plate 3 shows where damage was done by the flood and times when water released from Stewart Mountain and Bartlett Dams reached gaging stations between those dams and Gillespie Dam, another low structure having no appreciable reservoir storage. Data in the box at each gaging station indicate the time a particular part of the flood wave reached that station. Each identified part of the hydrograph is indicated by a single-digit number. Traveltimes can be determined for each part of the event by tracing its number downstream.

Number 1 gives the time when water first reached the station. At Granite Reef Dam the time is when water first began to flow over the dam. Releases large enough to cause overflow began at 1715 hours at Bartlett Dam and at 1800 hours at Stewart Mountain Dam. The first water reached Jointhead Dam in Phoenix at 0700 hours on February 14. Water reached Jointhead Dam faster in 1980 than it had in earlier years because the sandy

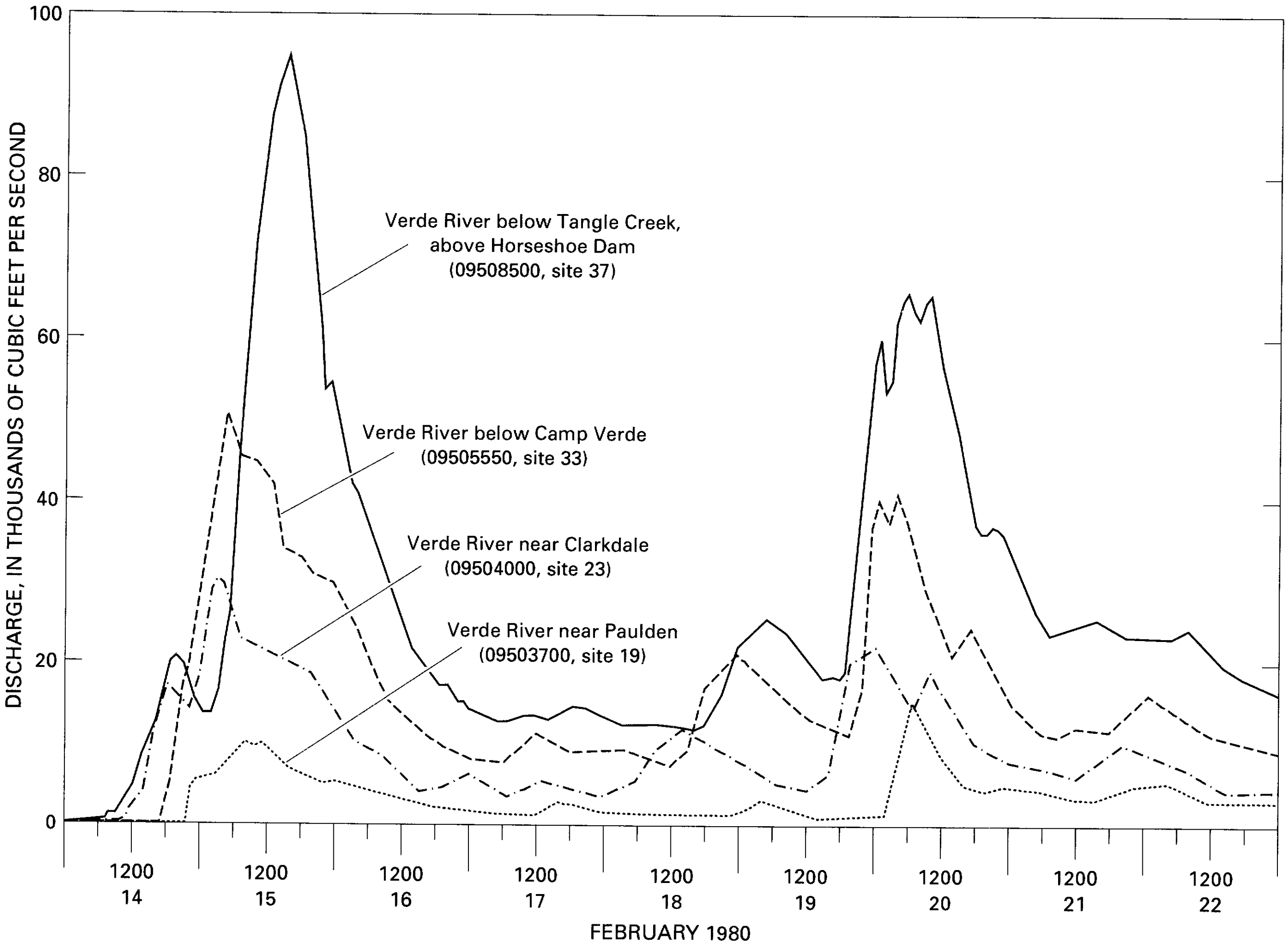


FIGURE 50.—Discharge of Verde River upstream from Horseshoe Dam, Ariz., February 14–22, 1980.

channel bottom had been wetted by flows in early February.

The rapid increase in the rate of release from Bartlett and Stewart Mountain Dams on February 15 at 0800 and 1000 hours, respectively, is the second part of the Salt-Verde flood wave identified on plate 3. Because of the greater traveltime from Bartlett Dam, releases from each of the upstream dams reached Granite Reef Dam at approximately the same time. The resultant rapid rise in the Salt River (times for which are given under number 2) reached Granite Reef Dam at 1000 hours on February 15 and Jointhead Dam at 1400 hours on the same day. This rise reached 35th Avenue at 1800 hours. The rise of Gila River below Gillespie Dam lagged the rise at Jointhead Dam by about 16 hours, but the exact time the Jointhead Dam rise reached Gillespie Dam was not determined, because the rise below Gillespie Dam was partly due to a large inflow from the Agua Fria River.

The crest of the flood wave is the third part for which times are given on plate 3. The crest, identified as number 3, is due to nearly concurrent maximum rates of release from Bartlett and Stewart Mountain Dams made on February 15, at 1800 hours from Bartlett Dam and at 2100 hours from Stewart Mountain Dam. The combined crest occurred at 2200 hours at Granite Reef Dam and at 0100 hours on February 16 at Jointhead Dam. The parts of the flood event can be seen on the hydrographs in figure 51, which also show several secondary rises after the major crest. These secondary crests provide additional information about traveltime.

The peak from the Salt River was supplemented by flow from the Agua Fria and Hassayampa Rivers; therefore, the peak discharge did not decrease greatly as the flood wave moved down the Salt and Gila Rivers. The peak discharge of the Gila River below Gillespie Dam was 178,000 ft^3/s, which is the highest since 1916 (table 17). Floodwater from the Salt River and tributaries to the Gila River between Salt River and Painted Rock Dam was stored in Painted Rock Reservoir and released at a rate of a few thousand cubic feet per second.

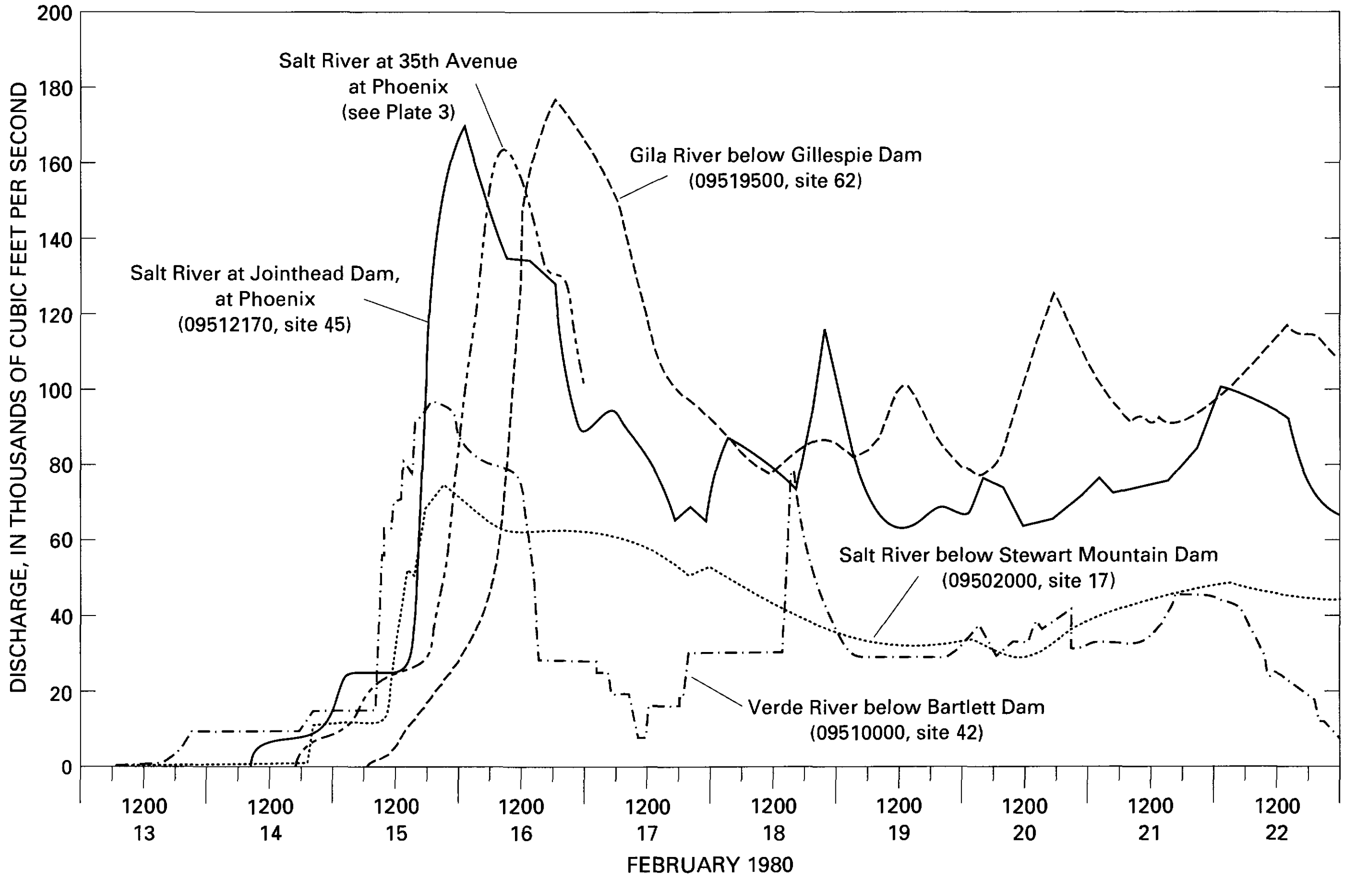


FIGURE 51.—Discharge of Salt, Verde, and Gila Rivers, Ariz., downstream from reservoirs, February 13–22, 1980.

AGUA FRIA AND HASSAYAMPA RIVERS

High discharges occurred on the Agua Fria and Hassayampa Rivers on February 14–15 and 19–20. The February 14–15 flow on the Agua Fria River caused Lake Pleasant to fill and necessitated release of large volumes of water from Waddell Dam (fig. 52). Water reached the mouth of the Agua Fria River about 12 hours after the major release began at Waddell Dam. From February 15 to February 20, outflow from Lake Pleasant was approximately equal to inflow.

The peak of record occurred on February 19, 1980, at stations on the Agua Fria River near Mayer (site 47, pl. 2) and Rock Springs (site 50, pl. 2). Data for these stations are given in tables 18 and 19. Inflow to Lake Pleasant was computed by the Maricopa County Metropolitan Water District no. 1 (written commun., 1981) from lake levels and gate openings. Inflow to the lake is equivalent to Agua Fria River above Waddell Dam (site 51A, pl. 2). Peak inflow to Lake Pleasant was 73,300 ft^3/s (table 20) and is less than the 79,500 ft^3/s computed for the December 1978 flood (Aldridge and Hales, 1984). The lower inflow occurred because Black Canyon Wash and streams tributary to Lake Pleasant had lower peak discharges in February 1980 than in December 1978 and did not peak simultaneously with the Agua Fria River as in 1978.

The peak discharges into Lake Pleasant in December 1978 and February 1980 are probably the highest since the reservoir was completed in 1927, but they are considerably less than the peaks of January 1916 and November 1919. The peak discharge in January 1916 was 105,000 ft^3/s. The 1919 flood was 3 ft higher than the 1916 flood; discharge was not determined. The volume of runoff into Lake Pleasant during the 7 highest days of the flood period in February 1980 was 220,000 acre-ft.

The peak discharge out of Lake Pleasant on February 20, 1980, was 66,600 ft^3/s, the highest since regulation began. The outflow is equivalent to Agua Fria River below Waddell Dam (pl. 3). The peak discharge decreased to 41,800 ft^3/s at El Mirage (Grand Avenue). The New River and other tributaries increased the peak to 44,200 ft^3/s at the gage near Avondale (table 21). The rise at Avondale occurred about 8 hours after the major release from Waddell Dam.

Locations where bridges were damaged by the Agua Fria River and times when the flood waves of February

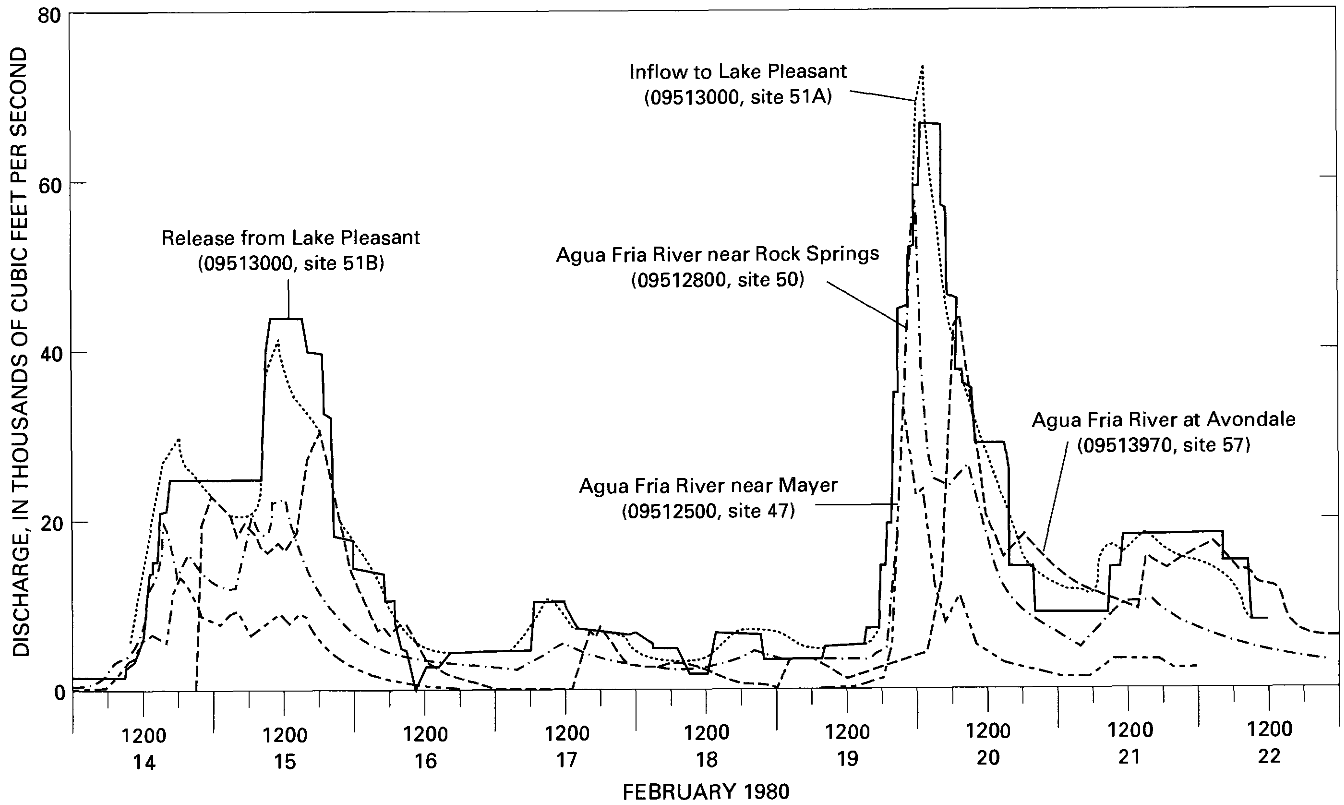


FIGURE 52.—Discharge of Agua Fria River, Ariz., February 14–22, 1980.

14–15 and February 19–20 reached gaging stations on the Agua Fria and Gila Rivers are shown on plate 3. Numbers 4 through 8 identify parts of the two flood events as follows:

4. When water was first released to the river at Waddell Dam or when water first reached the Avondale station,
5. The leveling off of the release rate on February 14,
6. The crest of the flood of February 15,
7. The beginning of the February 19 rise, and
8. The crest of the February 20 flood.

All of the above were identifiable at the Agua Fria River at Avondale gaging station, but only the crest on February 20 was identified on the Gila River downstream from the Agua Fria, because flow from the Agua Fria mingled with flow from the Salt River. Water was first released into the river downstream from Waddell Dam at 0900 hours on February 14. Small quantities of water released from the reservoir earlier were routed into irrigation canals. Number 4 identifies that release to the river or the time when the first water reached the Avondale station. At Waddell Dam, the release rates represented by numbers 5, 6, and 8 are constant for several hours. Times are for the beginning of that constant rate. These parts of the flood wave can be seen on the hydrograph of release from Lake Pleasant in figure 52.

Local residents in the upper part of the Hassayampa basin reported that the river was the highest it had been in many years, but they did not state a specific number of years. At the gaging station at Box damsite near Wickenburg (site 59, pl. 2), the peak discharge of 24,900 ft^3/s is the third highest since 1946. Higher discharges occurred in August 1951 and September 1970 (Roeske and others, 1978). The 1970 discharge of 58,000 ft^3/s is considered an extremely rare event.

FLOOD DAMAGE

The floods caused three deaths in Arizona. One person drowned trying to raft down Oak Creek when it was at flood stage. Two men drowned when their car was washed off a bridge over Granite Creek in Prescott.

Preliminary estimates of damage from the February 15 flood amounted to about $1 million each in Gila and Yavapai Counties. Damage in Gila County included destruction of 3,000 ft of sewer line in Miami, flooded boat ramps and campgrounds at Roosevelt Lake, and damage to many roads. All roads from Payson to Phoenix were closed. The estimated cost of repairs to streets in

Payson was $250,000. Several homes were isolated in the village of Pine.

In Yavapai County, about $400,000 damage occurred in Prescott, and more than $500,000 damage occurred in Verde Valley near Bridgeport and Cottonwood. In Sedona, a gasline was cut and the town was without gas for several days. Damage to the gasline was about $150,000. Residents were evacuated along the Verde River, Granite Creek, Oak Creek, Beaver Creek (downstream from the confluence of Wet Beaver and Dry Beaver Creeks), and West Clear Creek.

The flood of February 20 increased the damage in Yavapai County to about $6 million, mostly in the Verde Valley. At Bridgeport, the flood reportedly did less damage than did the March 1978 flood, although the stage was about 0.5 ft higher in 1980. About 15 to 20 rural highways were closed by one or both of the February floods.

The most severe damage occurred in the Phoenix area. About 25 streets and highways cross the Salt River between Granite Reef Dam and the mouth of the river; 6 streets cross the Gila River between the Salt River and Gillespie Dam (pl. 3). In February 1980, three of the crossings had large bridges; the remainder had grade-level crossings or small-capacity bridges. The small-capacity bridges were designed to handle a maximum of about 35,000 ft^3/s. The floods in March 1978, December 1978, and January 1979 damaged all but two crossings. Most crossings had been put back in service prior to the 1980 flood by replacing approaches or constructing grade-level crossings through the dry streambed. The flood on February 15, 1980, destroyed all grade-level crossings, damaged or destroyed small-capacity bridges and Interstate Highway 10, and brought crosstown traffic to a near standstill. Bridges at Mill and Central Avenues were the only ones crossing the Salt River that were kept open. Traffic jams several miles long and delays of 6 to 8 hours occurred as traffic was funneled across these two bridges. Cross-river traffic dropped from the normal volume of 400,000 vehicles per day to 187,400 per day. Special buses and a commuter train were put into service for 2 weeks until Interstate Highway 10 was reopened. Some bridges were repaired in March, but grade-level crossings were kept closed until flow ceased on June 2, 1980. Following the flood, a concrete pad and cutoff wall were constructed at Interstate Highway 10 to prevent further scour around piers of the bridges (McDermid and others, 1982). The Salt River flooded the eastern end of the runways at Sky Harbor Airport in Phoenix, washed out sewage-treatment and disposal facilities, destroyed several commercial buildings, and damaged gravel operations in the riverbed. Two thousand families were evacuated, and 155 homes reportedly sustained damage. Downstream from the Salt River, the Gila River flooded farmland and the two low-lying subdivisions of Holly Acres and Allenville, where an area as much as 2¾ mi wide was flooded (U.S. Army Corps of Engineers, 1981a).

The area flooded by the Agua Fria River on February 20 was as wide as 1¼ mi (Thomsen, 1980; U.S. Army Corps of Engineers, 1981a). The flood inundated two small subdivisions in the rural part of Maricopa County northwest of Phoenix and other residential areas. About 650 families were evacuated from along the Agua Fria River. The flood eroded extensive amounts of channel. Before the flood in February 1980, the river was crossed by 14 major streets and highways between Lake Pleasant and the mouth of the Agua Fria River (pl. 3). Six were bridges, and the rest were grade-level crossings. The flood of February 20 destroyed all grade-level crossings and three bridges and damaged road grades at the other three bridges. Two bridges—Grand Avenue and Glendale Avenue—remained open during the flood. About 5 mi above the mouth of the Agua Fria River, the bridge for the continuation of Interstate Highway 10 was under construction, but the embankments had not been constructed. The river cut a new channel about 4,000 ft to the east of the bridge and bypassed the bridge (fig. 53).

Damage in the Phoenix area from the flood amounted to $63.7 million (U.S. Army Corps of Engineers, 1981a). Damage to roads and bridges amounted to $22.0 million; damage to other public facilities amounted to $13.3 million. Other types of losses, in millions of dollars, were transportation delays, $8.4; business and income losses, $5.5; agricultural, $5.0; commercial, $3.1; industrial, $2.8; residential, $1.9; and emergency costs, $1.6 (table 22). The damage was a severe blow to an area that was recovering from damages of $39 million in March 1978 and $52 million in December 1978.

The floodwaters scoured most trout streams below an altitude of about 8,000 ft and removed aquatic insect life, moss-covered rocks, rubble, and the mud-covered bottoms where the trout lie (Avery, 1980). In places, streams were stripped to bedrock. Trees, shrubs, and other riparian vegetation were removed from flood terraces, and in many places the terraces were removed completely. The scouring caused severe shifting of high-water controls at many gaging stations.

POSTFLOOD RESERVOIR RELEASES

Several considerations influenced decisions about the magnitude and duration of postflood releases from the Salt and Verde River reservoirs. A need existed for reservoirs to be drawn down enough to allow operators to manage the release of possible subsequent high flows. A strong consideration was the amount that the reservoirs could be drawn down and still be filled by spring

FIGURE 53.—Agua Fria River at Interstate Highway 10 near Avondale, Ariz., February 20, 1980. (Photograph courtesy of Arizona Department of Transportation.)

runoff. Some local governmental agencies wanted floodwaters shut off so that flood damage could be repaired. Other agencies wanted the release kept high to dilute the raw sewage that was pouring into the Salt River from broken sewer lines. Sewer lines remained unusable until April 22, 1980. Releases from the reservoirs were held high enough to keep the discharge past Phoenix above 6,000 ft^3/s through February 22. The discharge was decreased gradually from February 23 to March 10. Flow was stopped temporarily on March 10 and was started again on March 27. Small discharges of 2,500 ft^3/s or less continued until June 2, when flow ceased.

Lake Pleasant, on the Agua Fria River, remained full, and water was released from the reservoir for several weeks after the flood. The release was approximately equal to the inflow. Part of the water released from Lake Pleasant was diverted into irrigation canals at a low-head dam 1 mi downstream from Waddell Dam; the remainder flowed over the diversion dam into the Agua Fria River channel. Water was released over the diversion dam from February 13 to April 13, but the flow reached the mouth of the Agua Fria River only during February 14–26. During the rest of the release period, all flow infiltrated into the streambed.

Between January 30 and May 15, 1980, 2.6 million acre-ft of water was released from the reservoirs on the Salt and Verde Rivers. One-half million acre-ft was diverted into canals at Granite Reef Dam, and 2.1 million acre-ft was released to the Salt River below Granite Reef Dam. Another 0.3 million acre-ft was released into the Agua Fria River at the diversion dam below Waddell Dam. About 2.3 million acre-ft reached Gillespie Dam, and 0.1 million acre-ft was lost to infiltration or evaporation. During past releases from the reservoirs, much larger quantities of water infiltrated into the ground. The low infiltration rate in 1980 is probably a result of the aquifers having been recharged by the floods in 1978 and 1979 (Mann and Rohne, 1983; Aldridge and Eychaner, 1984; Aldridge and Hales, 1984). In spite of the previous recharge, the water level in wells along the Salt River rose as much as 35 ft near Phoenix and 55 ft near Scottsdale during the 1980 flood.

The contents of Painted Rock Reservoir, a flood-control reservoir downstream from Gillespie Dam, reached an all-time high of 1.85 million acre-ft on March 6, 1980. Water was released to the Gila River at a rate that was generally less than 5,000 ft^3/s. Releases from the reservoir began on February 7, 1980, and continued through November 1980. Normally, several weeks pass before water released from Painted Rock Dam reaches the mouth of the Gila River, near Yuma. In February 1980, the discharge at the mouth began to increase 5 days after the release began at Painted Rock Dam, because the channel and adjacent land had been saturated by the large quantity of water released during the two preceding years. The last of the water stored from floods of December 1978 to March 1979 was released from the reservoir only 1 week before the 1980 release began. From February through November 1980, 2.1 million acre-ft of water was released from Painted Rock Dam; about 76 percent, or 1.6 million acre-ft, reached the mouth of the river. Streamflow losses were about 170,000 acre-ft between Painted Rock Dam and the Mohawk gaging station, 200,000 acre-ft from Mohawk to Dome, and 120,000 acre-ft from Dome to the mouth of the Gila River. Release of water from Painted Rock Reservoir for a long period caused flooding and waterlogging of extensive areas of farmland along the Gila River near Wellton and Mohawk. Water-level measurements in wells near the Gila River downstream from Painted Rock Dam show water-level increases of as much as 22 ft between January 1980 and January 1981.

The sustained flow from the Gila River was added to water released from reservoirs on the Colorado River and caused the Colorado River to incise a new connection to the Gulf of California through sandbars near the mouth in Mexico (Hodge, 1980). For the preceding two decades, water had rarely reached the gulf because storage in upstream reservoirs and many diversions along the Colorado River depleted the flow. In the early stages of the channel cutting that occurred in 1980, water flooded hundreds of acres of farmland and several villages that had developed on the Colorado River delta during the two decades of no flow.

RECURRENCE INTERVALS OF PEAK DISCHARGES

The probability of a given discharge being equaled or exceeded in any given year is frequently used as an indication of a flood's severity. The severity can also be expressed in terms of recurrence interval, which is the reciprocal of the probability. A discharge that will be equaled or exceeded on an average (over a long period of time) of once in 10 years and has a recurrence interval of 10 years is termed a "10-year flood" and has a probability of 0.1. A 100-year flood has a recurrence interval of 100 years and a probability of 0.01.

Recurrence intervals of floods of February 1980 in both California and Arizona differ greatly from site to site. The recurrence intervals for floods in southern California range from 2 to more than 100 years (table 23). Peak discharges with the highest recurrence intervals (lowest probabilities) occurred in the Salton Sea, Tijuana River, and San Luis Rey River basins. One small stream in the Santa Ana River basin—Bautista Creek (site 64, pl. 1)—also had a flood with a recurrence interval greater than 100 years. At most stations on principal streams in the Salt River basin, the recurrence interval for the February 1980 peak discharges ranges from 20 to 25 years; for the Agua Fria River near Mayer, the recurrence interval is greater than 100 years (table 24).

Part of the variation among stations can be explained by the nonuniform distribution of runoff, but there is also a large degree of uncertainty in the computed recurrence intervals. Values given in tables 23 and 24 have been computed mainly from records for the respective gaging stations rather than from any of the regional frequency relations that have been developed (Patterson and Somers, 1966; Young and Cruff, 1967; Arizona Water Commission, 1973; Waananen and Crippen, 1977; Roeske, 1978). The uncertainty is largely a function of the period over which the records were collected. Many of the records cover only the last 15–25 years. During this period, high flood peaks have occurred more frequently, especially in Arizona, than during the preceding 40 years.

Frequency estimates based on data collected mainly during this wet period indicate discharges for given recurrence intervals that are up to three times greater than those computed from long-term records that included many of the dry years. Also, many streams are regulated. Operational patterns are not adequately defined to permit recurrence intervals to be computed for peak discharges on most regulated streams.

SUMMARY OF FLOOD STAGES AND DISCHARGES

Maximum gage heights (stages) and discharges during the 1980 floods at continuous-recording stations, crest-stage stations, and miscellaneous sites are summarized in table 23 for California and table 24 for Arizona. The tables also show how these maximums compare with the previously known maximums.

The number in column 1 of each table identifies the site on plate 1 or 2. The second column is the U.S. Geological Survey downstream order number. The column headed "Period" shows the calendar years for which gage heights or discharges shown in the seventh and eighth columns are known to be a maximum. The period of record does not necessarily correspond to the period during which continuous records of discharge were obtained. Where available, records of historical floods are included, as are years when records may have been collected at other sites on the same stream. Years during which large floods may have occurred, but are not recorded, may be omitted even though some record of low to medium discharges may have been obtained during that year. For some sites, two or more periods are given. A comma between the periods indicates a break in the period of record. Peak discharges during the intervening period are unknown. It is possible that one or more peaks during that period exceed the maximums shown in the seventh and eighth columns. One maximum gage height and (or) discharge is given for the entire period. No comma is used where the first period represents unregulated discharges and the second, regulated. For this case, a maximum is given for each period. The sixth column shows the calendar year during which the maximum occurred. Separate listings are made when maximum discharge and gage height did not occur concurrently. Also, separate listings are given for periods having different degrees of regulation. The last four columns present data for the maximums in February 1980. The data include the day in February on which the maximum occurred, maximum gage height, maximum discharge, and the recurrence interval of the maximum discharge. More detailed information is given in "Water Resources Data for California, Water Year 1980" (U.S. Geological Survey, 1981) and "Water Resources Data for Arizona, Water Year 1980" (U.S. Geological Survey, 1982).

PHOTOGRAPHIC COVERAGE

Part of the U.S. Geological Survey's flood plan in its major offices in southern California is to coordinate photographic documentation of floods, and to communicate frequently with other Federal, State, and local agencies to increase coverage and reduce duplication of effort. During the February 1980 floods, communication and coordination activities were very successful and resulted in flights over a large number of rivers to obtain aerial photography. Most areas of significant flooding were photographed. The Geological Survey not only coordinated the activities for the flood photographic functions, but also contracted for aerial photography on several reaches of rivers in San Diego County. Agencies other than the Geological Survey handled coordination in Arizona. The Arizona Department of Transportation photographed flood areas in the metropolitan part of Maricopa County. Some photographs were taken by private companies. Large numbers of photographs from both ground and air were taken by newspapers, television stations, and government agencies.

Table 25 lists known aerial photographic coverage available from government agencies for the floods discussed in this report. Data were either furnished directly by the agency or made available for tabulation by U.S. Geological Survey personnel. All photography is in the files of the originating agency.

SUMMARY

Severe floods occurred in the coastal basins of southern California and in central Arizona after six Pacific storms struck the Southwestern United States during February 13–21, 1980. The storms were preceded by large amounts of precipitation in January, when many places received two to four times the average. The floods caused 18 deaths and more than $500 million damage in California. Seven southern California counties that were hard hit by floods, mudflows, slope failures, and beach erosion were declared eligible for Federal disaster aid. San Diego and Los Angeles Counties were hit especially hard. The floods caused three deaths and about $80 million damage in Arizona.

Outstandingly high discharges occurred spottily near and south of Los Angeles, Calif., and downstream from reservoirs on the Salt, Verde, and Agua Fria Rivers in Arizona. On many streams, the peaks were the highest in 40 to 60 years but less than the highest known. At least one stream had a higher discharge in 1980 than during the 1916 flood, which is the most widespread and highest known flood during the 20th century in southern California. Two streams that drain to the Salton Sea had extreme peaks. The peak discharge of San Felipe Creek near Julian is almost six times the former peak of record, and that of Palm Canyon Creek near Palm Springs is nearly twice the previous peak of record. The peak discharge on the Tijuana River near Nestor, Calif., was 89 percent greater than the peak of record between 1936 and 1979. In Arizona, peaks of record occurred at a few gaging stations on unregulated streams for which the period of record is relatively short. Floods that occurred upstream from Roosevelt Lake on the Salt River and Horseshoe Reservoir on the Verde River had been exceeded three to five times over the past 100 years and were of a magnitude that would occur on an average of about once every 20 to 30 years.

The meteorological circulation pattern immediately preceding the February storms was characterized by a strong 500-mb ridge over Alaska and a trough extending from about 50° N. latitude and 158° E. longitude to 30° N. and 143° W. Low pressure dominated the northeastern Pacific. A cold airmass moved into the Pacific from Siberia, and a strong temperature gradient developed between there and the tropics. Pacific subtropical westerly winds were strong enough to displace the Great Basin High and to divert storms into a path over southern California. Rapid increases in precipitable water, average relative humidity, and the K index, along with a decrease in the lifted index, indicated a very unstable weather structure. Short-wave perturbations moved through long-wave patterns as storm centers were continually generated to the north of the jetstream. On February 12 and 13, a subtropical jetstream formed and penetrated below the Alaskan ridge, and over a period of 9 days it brought six short-wave troughs, and the associated storm systems, to the Southwestern United States. As each storm moved through California another formed over the Pacific. Thunderstorms of high water content were embedded in the cloud systems and produced large amounts of rain. A ridge of high pressure had developed over the central Pacific by February 21 and diverted subsequent storms to a more northerly track.

The storms produced an average of 5 to 10 in of rain in the coastal plains and valleys of California and 15 to 30 in over the mountains. Most stations in the central mountains of Arizona received 3 to 12 in. In Arizona, the precipitation fell mostly as snow above an altitude of about 7,000 ft. In places, the water equivalent of the snowpack increased as much as 15 in during the February storms.

Precipitation amounts for periods of 24 hours or less had recurrence intervals of 5 to 10 years, but 10-day totals exceeded the 100-year rainfall at some stations. The large cumulative amount of precipitation was more instrumental in producing floods than was any short period of extreme rainfall. The volumes of runoff over 7 and 15 days in many streams south of Los Angeles in California are the highest ever recorded. The 7-day volumes on the Salt and Verde Rivers in Arizona are, respectively, the third and second highest since at least 1906.

The above-average volumes of runoff caused all reservoirs in San Diego County except Lake Henshaw to spill. The newer reservoirs spilled for the first time, and the older ones spilled for the first time in several decades. Seven conservation reservoirs on the Salt, Verde, and Agua Fria Rivers in Arizona filled and spilled for the third consecutive year. Inflows during the floods were several times greater than the unfilled capacities at the start of the floods. Releases from the Salt and Verde River reservoir systems on February 15 caused the Salt River at Phoenix to have the highest discharge since 1905. Releases from Lake Pleasant on February 20 caused the Agua Fria River to have the highest discharge since 1919.

The San Diego River flowed 7 ft deep through Mission Valley in San Diego. Thousands of individuals were evacuated as businesses, shopping centers, and hotels were flooded. The San Jacinto River, which in the past was diverted to the northeast around the city of San Jacinto in Riverside County, reverted to its former channel through the city.

Lake Elsinore, which is fed by the San Jacinto River, rose 19 ft after February 13, 1980, and reached a maximum level of 1,265.7 ft. The surface area of the lake increased from about 6 mi^2 before the floods to 10 mi^2

after them. Water flowed out into Temescal Wash for the first time since 1917. The lake flooded or otherwise affected 874 buildings; 300 permanent structures were damaged, and about 400 mobile homes and trailers were relocated.

A large industrial complex about 0.8 mi north of San Luis Rey Mission was inundated when a levee along the San Luis Rey River broke. The Santa Margarita River eroded long reaches of bank and destroyed sections of the railroad at Camp Joseph H. Pendleton Marine Corps Base. The Santa Ana River scoured its bed to depths of 20 ft and caused the concrete bank lining to give way. Severe scour occurred around the supports of six major bridges in the city of Santa Ana. Flood damage was extensive in small basins between the Los Angeles and Santa Clara Rivers. Parts of the Point Mugu, U.S. Naval Air Station, Pacific Missile Testing Center were flooded.

Mudflows and slope failures were prevalent in Los Angeles and San Bernardino and to the north of Los Angeles. Mudflows were especially severe in basins that had been denuded by intense fires during the preceding year.

High winds and wave action caused severe coastal damage, and broken sewer lines caused beach contamination. A number of homes and small hotels at Oceanside were damaged by surf and wave action, and the beach was reduced to a cobble pavement. Coastal residents near Marina Del Rey, in Los Angeles, suffered heavy damage from an 8- to 9-ft surf on one side of their property and flooding and mudslides on the other. About 150 ft of seawall was lost at Sea Cliff State Beach. Beaches near Imperial Beach, Calif., were quarantined for 14 months because of sewage carried to the ocean by the Tijuana River. Approximately 65 mi of beach in Los Angeles County was closed for 3 weeks because raw sewage from a broken line in Agoura was carried to the ocean by Malibu Creek.

Most of the flood damage in Arizona occurred in Maricopa County, where streets and roads that cross the Salt, Gila, and Agua Fria Rivers were destroyed. Only two bridges over the Salt River and two over the Agua Fria River remained open during and following the floods. More than 2,600 families were evacuated from along the Salt and Agua Fria Rivers. The floods severely damaged trout streams, and the Colorado River in Sonora, Mexico, cut a new channel through sand bars that had blocked the mouth of the river for two decades.

From February to May 1980, 2.6 million acre-ft of water was released from the Salt and Verde River reservoirs (of which 0.5 million acre-ft was diverted into canals at Granite Reef Dam) and 0.3 million acre-ft was released from Lake Pleasant; 2.3 million acre-ft reached Gillespie Dam. The storage in Painted Rock Reservoir (for flood control) reached an all-time maximum of 1.85 million acre-ft on March 6, 1980. Water was released from the reservoir for 10 months at a maximum discharge of about 5,000 ft^3/s. A total of 2.1 million acre-ft was released from Painted Rock Dam; 1.6 million acre-ft reached the mouth of the Gila River.

The prolonged high flows contributed to extreme amounts of recharge to aquifers, especially those within a few miles of major stream channels. Ground-water levels rose as much as 55 ft along the Salt River in Scottsdale, Ariz. In one well near the San Gabriel River east of Los Angeles the water level rose nearly 34 ft between January and June 1980.

SELECTED REFERENCES

Aldridge, B.N., 1963, Floods of August 1963 in Prescott, Arizona: U.S. Geological Survey open-file report, 12 p.

———1970, Flood of November 1965 to January 1966 in Gila River basin, Arizona and New Mexico, and adjacent basins in Arizona: U.S. Geological Survey Water-Supply Paper 1850-C, 176 p.

Aldridge, B.N., and Eychaner, J.H., 1984, Floods of October 1977 in southern Arizona and March 1978 in central Arizona: U.S. Geological Survey Water-Supply Paper 2223, 143 p.

Aldridge, B.N., and Hales, T.A., 1984, Floods of November 1978 to March 1979 in Arizona and west-central New Mexico: U.S. Geological Survey Water-Supply Paper 2241, 149 p.

Arizona Water Commission, 1973, Floodplain delineation criteria and proceedings: Arizona Water Commission Report 4, 12 p.

Avery, Ben, 1980, State flood damage severe, but trout streams surviving: The Arizona Republic, March 14, 1980, p. D7.

Bartfield, Ira, and Taylor, D.B., 1982, A case study of a real-time flood warning system on Sespe Creek, Ventura County, California, *in* National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980: Symposium, September 17–18, 1980, Proceedings, p. 165–176 [available from National Academy Press].

California Department of Natural Resources, 1954, Geology of southern California: California Department of Natural Resources Bulletin 170, Chapter 1, General Features, 53 p.

California Department of Water Resources, 1957, The California water plan: California Department of Water Resources Bulletin 3, 246 p. (reprint)

———1980, California flood management: An evaluation of flood damage and prevention programs: California Department of Water Resources Bulletin 199, 277 p.

Cooper, W.S., 1967, Coastal dunes of California: The Geological Society of America Memoir 104, 131 p.

Davis, J.D., 1982, Rare and unusual postfire flood events experienced in Los Angeles County during 1978 and 1980, *in* National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980: Symposium, September 17–18, 1980, Proceedings, p. 243–256 [available from National Academy Press].

Edwards, K.L., 1982, Failure of the San Jacinto River levees near San Jacinto, California, floods of February, 1980, *in* National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980:

Symposium, September 17–18, 1980, Proceedings, p. 347–356 [available from National Academy Press].

Evelyn, J.B., 1982, Operation and performance of Corps of Engineers flood control projects in southern California and Arizona during 1978–80, *in* National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980: Symposium, September 17–18, 1980, Proceedings, p. 131–150 [available from National Academy Press].

Franklin, E., Moreland, R., and Lao, P., 1981, Hydrologic data report 1979–1980 season: Orange County (Calif.) Environmental Management Agency, v. 16, 129 p.

Gray, T.I., Jr., Irwin, J.R., Krueger, A.F., and Varnador, M.S., 1976, Average circulation in the troposphere over the tropics, January 1968–August 1972: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, 110 p.

Hely, A.G., Hughes, G.H., and Irelan, Burdge, 1966, Hydrologic regimen of Salton Sea, California: U.S. Geological Survey Professional Paper 486–C, 32 p.

Hodge, Carle, 1980, Colorado River again pouring into gulf along ancient course: The Arizona Republic, March 30, 1980, p. C1–C2.

Mann, L.J., and Rohne, P.B., Jr., 1983, Streamflow losses and changes in ground-water levels along the Salt and Gila Rivers near Phoenix, Arizona, February 1978 to June 1980: U.S. Geological Survey Water-Resources Investigations Report 83–4043, 15 p.

McDermid, R.M., Geiser, G.J., Simons, D.B., and Li, Ruh-Ming, 1982, Flood control work on the Salt River in Phoenix, Arizona, *in* National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980: Symposium, September 17–18, 1980, Proceedings, p. 401–411 [available from National Academy Press].

McGlashan, H.D., and Ebert, F.C., 1918, Southern California floods of January 1916: U.S. Geological Survey Water-Supply Paper 426, 80 p.

Miller, J.F., 1964, Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States: U.S. Department of Commerce, Weather Bureau Technical Paper 49, 29 p.

Miller, J.F., Frederick, R.H., and Tracey, R.J., 1973, Precipitation-frequency atlas of the Western United States: U.S. Department of Commerce, National Oceanic and Atmospheric Administration Atlas 2, v. 8 for Arizona, 41 p., and v. 11 for California, 71 p.

National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, 1982, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980: Symposium, September 17–18, 1980, Proceedings, 487 p. [available from National Academy Press].

Nelson, C.R., 1982, The Santa Ana River in Orange County, California: A case study in sediment transport, *in* National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980: Symposium, September 17–18, 1980, Proceedings, p. 177–190 [available from National Academy Press].

Patterson, J.L., and Somers, W.P., 1966, Magnitude and frequency of floods in the United States, Part 9, Colorado River basin: U.S. Geological Survey Water-Supply Paper 1683, 475 p.

Pryde, P.R., 1982, Comment on peak floodflows in San Diego's Mission Valley, 1978–80, *in* National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980: Symposium, September 17–18, 1980, Proceedings, p. 205–206 [available from National Academy Press].

Roeske, R.H., 1978, Methods for estimating the magnitude and frequency of floods of Arizona: Arizona Department of Transportation Report ADOT-RS-15(121), 81 p.

Roeske, R.H., Cooley, M.E., and Aldridge, B.N., 1978, Floods of September 1970 in Arizona, Utah, Colorado, and New Mexico: U.S. Geological Survey Water-Supply Paper 2052, 135 p.

San Diego County Department of Sanitation and Flood Control, 1975, Storms in San Diego County: San Diego County (Calif.) Department of Sanitation and Flood Control, 19 p., 6 app.

San Diego County Flood Control District, 1980, Storm report February 1980: San Diego County (Calif.) Flood Control District report, 26 p.

Sciandrone, Joe, and others, 1982, Levee failures and distress, San Jacinto River levee and Bautista Creek channel, Riverside County, Santa Ana River basin, California, *in* National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980: Symposium, September 17–18, 1980, Proceedings, p. 357–386 [available from National Academy Press].

Scott, M.B., 1977, Development of water facilities in the Santa Ana River basin, California, 1810–1968: U.S. Geological Survey Open-File Report 77–398, 231 p.

Shaw, M.J., 1982, Coastal response of Leadbetter Beach, Santa Barbara, to southern California storms of February 16–21, 1980, *in* National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980: Symposium, September 17–18, 1980, Proceedings, p. 433–452 [available from National Academy Press].

Slosson, J.E., and Krohn, J.P., 1982, Southern California landslides of 1978 and 1980, *in* National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980: Symposium, September 17–18, 1980, Proceedings, p. 291–320 [available from National Academy Press].

Stubchaer, J.M., 1982, The Santa Barbara County flood experience in storms of 1978 and 1980, *in* National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980: Symposium, September 17–18, 1980, Proceedings, p. 257–270 [available from National Academy Press].

Taylor, D.V., 1982, Floodflows in major streams in Ventura County, *in* National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980: Symposium, September 17–18, 1980, Proceedings, p. 151–164 [available from National Academy Press].

Thomsen, B.W., 1980, Flood of February 1980 along the Agua Fria River, Maricopa County, Arizona: U.S. Geological Survey Open-File Report 80–767, 1 sheet.

Troxell, H.C., and others, 1942, Floods of March 1938 in southern California: U.S. Geological Survey Water-Supply Paper 844, 399 p.

U.S. Army Corps of Engineers, 1963, Flood damage report on storms and flood of August 1963, Granite Creek and tributaries, Prescott, Arizona: U.S. Army Corps of Engineers, Los Angeles District, 11 p.

———1981a, Flood damage survey, Phoenix, Arizona, February 1980: U.S. Army Corps of Engineers, Los Angeles District, 29 p.

———1981b, Water resources development by the U.S. Army Corps of Engineers in California (supp. to 1979 ed.): U.S. Army Corps of Engineers report, 64 p.

U.S. Geological Survey, 1918, Surface water supply of the United States, 1916, Part 11, Pacific slope basins in California: U.S. Geological Survey Water-Supply Paper 441, 330 p.

———1943, Surface water supply of the United States, 1942, Part 11, Pacific slope basins in California: U.S. Geological Survey Water-Supply Paper 961, 391 p.

———1981, Water resources data for California, Volume 1, Colorado River basin from Mexican border to Mono Lake basin, and Pacific slope basins from Tijuana River to Santa Maria River, water year 1980: U.S. Geological Survey Water-Data Report CA-80-1, 451 p.

———1982, Water resources data for Arizona, water year 1980, U.S. Geological Survey Water-Data Report AZ-80-1, 581 p.

U.S. Soil Conservation Service, 1980, Water-supply outlook for Arizona and Federal-State private snow surveys, February, March 1980: U.S. Department of Agriculture Water-Supply Outlook report, 12 p.

Waananen, A.O., 1969, Floods of January and February 1969 in central and southern California: U.S. Geological Survey open-file report, 233 p.

———1971, Floods of December, in central and southern California, *in* Rostvedt, J.O., and others, Summary of floods in the United States during 1966: U.S. Geological Survey Water-Supply Paper 1870-D, 14 p.

———1975, Floods of January–February in central and southern California, *in* Reid, J.K., and others, Summary of floods in the United States during 1969: U.S. Geological Survey Water-Supply Paper 2030, 15 p.

Waananen, A.O., and Crippen, J.R., 1977, Magnitude and frequency of floods in California: U.S. Geological Survey Water-Resources Investigations Report 77–21, 96 p.

Wahl, K.L., Crippen, J.R., and Knott, J.M., 1980, Floods of January and February 1980 in California: U.S. Geological Survey Open-File Report 80–1005, 52 p.

Weber, F.H., Jr., 1982, Landsliding and flooding in southern California during the winter of 1979–80, *in* National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980: Symposium, September 17–18, 1980, Proceedings, p. 321–332 [available from National Academy Press].

Wells, W.G. 2d, 1982, The storms of 1978 and 1980 and their effect on sediment movement in the eastern San Gabriel Front, *in* National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980: Symposium, September 17–18, 1980, Proceedings, p. 229–242 [available from National Academy Press].

White, C.R., 1982, Lake Elsinore flood disaster of March 1980, *in* National Research Council Committee on Natural Disasters and California Institute of Technology Environmental Quality Laboratory, Storms, floods, and debris flows in southern California and Arizona, 1978 and 1980: Symposium, September 17–18, 1980, Proceedings, p. 387–400 [available from National Academy Press].

Young, L.E., and Cruff, R.W., 1967, Magnitude and frequency of floods in the United States, Part 11, Pacific slope basins in California, Volume 1, Coastal basins south of Klamath River basin, and Central Valley drainage from the west: U.S. Geological Survey Water-Supply Paper 1685, 272 p.

TABLES 1–25

TABLE 1.—*Meridional-temperature gradient, per 10 degrees of latitude, observed at 0400 hours P.s.t., February 15, 1980, compared with long-term climatological averages for February (in parentheses) over the Pacific Ocean at various pressure levels*

[In degrees Celsius. mb, millibar]

Longitude ...	140° E.		160° E.		180° W.
Latitude.....	20-30° N.	30-40° N.	20-30° N.	30-40° N.	20-30° N.
850 mb	13 (9)	18 (13)	9 (7)	13 (8)	9 (5)
700 mb	12 (9)	20 (15)	9 (7)	18 (13)	7 (6)
500 mb	6 (6)	25 (17)	7 (6)	22 (12)	3 (7)

Longitude ...	180° W.	160° W.		140° W.	
Latitude.....	30-40° N.	20-30° N.	30-40° N.	20-30° N.	30-40° N.
850 mb	12 (7)	11 (4)	4 (5)	9 (4)	5 (4)
700 mb	19 (9)	12 (4)	6 (1)	9 (7)	6 (5)
500 mb	24 (9)	11 (6)	12 (6)	12 (6)	5 (5)

NOTE.--Climatological averages of meridional-temperature gradient, shown in parentheses, were derived from "Selected Level Heights, Temperatures and Dew Points for the Northern Hemisphere" NAVAIR-50-1C-52, published by direction of Commander, Naval Weather Service, for sale by Government Printing Office, Washington, D.C.

TABLE 2.—*Precipitation at selected stations in southern California and Arizona during January and February 1980*

[February maximum daily: Amount is for date (24-hour period) indicated by number in parentheses; for example, (17/0600) indicates rainfall during the 24-hour period ending at 0600 hours on February 17. Climatic divisions shown in fig. 13. California stations shown in fig. 14. Arizona stations shown in fig. 15. --, data not available]

Station	Latitude (deg min)	Longitude (deg min)	Elevation (ft)	January Total (in)	January Departure from normal (in)	February Total (in)	February Departure from normal (in)	February Maximum daily Amount (in)	February Maximum daily Date	Feb. 13-22 amount (in)
CALIFORNIA										
South Coast Drainage climatic division										
Burbank Valley pumping plant	34 11	118 21	655	7.43	4.28	14.45	11.36	5.60	(17/0600)	14.45
Campo	32 38	116 28	2,630	11.82	9.40	8.82	6.52	2.72	(18)	8.82
Chula Vista	32 36	117 05	9	4.72	3.11	2.24	.97	.60	(18)	2.24
Cuyamaca	32 59	116 35	4,640	22.37	16.78	22.90	17.49	5.90	(21/1200)	22.90
Henshaw Dam	33 14	116 46	2,700	18.77	14.54	21.40	17.67	3.85	(20)	21.40
La Mesa	32 14	117 01	530	9.70	7.49	7.43	5.51	1.87	(21)	7.43
Long Beach	33 49	118 09	34	7.17	4.91	9.40	7.24	2.37	(16)	9.37
Los Angeles Airport	33 56	118 23	100	9.97	4.45	9.13	6.81	2.63	(13)	9.13
Los Angeles Civic Center	34 03	118 14	257	7.50	4.50	12.75	9.98	3.03	(16)	12.75
Lytle Creek Ranger Station	34 14	117 29	2,730	26.12	18.70	30.89	24.82	6.60	(14/1100)	30.89
Mt. Wilson 2	34 14	118	5,709	21.01	14.66	30.71	24.65	5.42	(16)	30.71
Palomar Mt. Observatory	33 21	116 52	5,550	18.63	13.78	23.10	18.44	5.20	(21/1000)	23.10
Pasadena	34 09	118 09	864	11.10	7.09	19.70	15.87	3.53	(15)	19.70
San Diego	32 44	117 52	13	5.58	3.70	4.47	2.99	1.41	(20)	4.47
San Gabriel Dam	34 12	117 52	1,481	18.96	12.89	26.76	21.58	7.75	(17)	26.76
Topanga Patrol Station	34 05	118 36	745	12.30	6.50	17.00	12.37	8.30	(17)	17.00
Torrance	33 48	118 20	110	8.90	6.16	9.57	7.01	1.98	(18)	9.57
UCLA	34 04	118 27	430	7.35	3.49	18.37	14.74	4.14	(18)	18.37
Southeast Desert Basins climatic division										
Crestline Fire Station	34 14	117 18	4,900	14.40	--	30.10	--	6.80	(17/0600)	30.10
Lake Arrowhead	34 15	117 11	5,205	22.15	14.01	24.26	16.64	4.55	(21)	24.26
Palmdale	34 35	18 06	2,596	3.14	1.66	6.42	5.05	1.46	(14)	6.42
Palm Springs	33 50	116 30	425	4.14	3.01	5.41	4.75	1.14	(14)	5.41
ARIZONA										
Northwest climatic division										
Truxton Canyon	35 23	113 40	3,820	2.47	1.61	2.43	1.44	0.60	(14)	2.43
Tuweep	36 17	113 04	4,775	3.62	2.52	3.89	2.99	.70	(14, 19)	3.89
Northeast climatic division										
Flagstaff	35 08	111 40	7,006	6.52	4.63	7.81	6.34	2.37	(14)	7.81
Fort Valley	35 16	111 44	7,347	5.66	5.60	6.44	4.78	2.00	(14)	6.42
Junipine	34 58	111 45	5,134	10.13	7.34	13.94	11.67	2.90	(14)	13.94
Winslow	35 01	110 44	4,890	1.18	.76	1.36	.98	.57	(19)	1.36
North Central climatic division										
Childs	34 21	111 42	2,650	7.43	5.64	9.17	7.90	2.77	(20)	9.14
Crown King	34 12	112 20	5,920	13.54	10.56	16.63	14.38	3.71	(20)	16.53
Jerome	34 45	112 07	5,245	6.30	4.74	8.42	7.06	1.96	(15)	8.35
Prescott	34 34	112 28	5,510	5.91	4.21	6.59	5.23	2.35	(15)	6.59
Seligman	35 19	112 53	5,250	3.1	2.21	2.70	1.99	.70	(20)	2.70
Walnut Grove	34 56	112 49	5,090	5.51	4.16	5.30	4.19	2.31	(14)	5.30
East Central climatic division										
Miami	33 24	10 53	3,560	4.16	2.10	8.11	6.86	2.32	(15)	8.11
Pleasant Valley	34 06	110 56	5,050	5.60	3.65	7.20	5.93	2.01	(15)	7.20
Southwest climatic division										
Parker	34 10	114 17	425	1.78	1.25	2.36	2.04	0.66	(14)	2.36
South Central climatic division										
Bartlett Dam	33 49	111 38	1,650	5.39	4.00	8.57	7.60	2.61	(19)	8.57
Florence	33 02	111 23	1,505	2.46	1.53	2.46	1.65	.85	(15)	2.43
Mormon Flat	33 33	111 27	1,715	4.04	2.58	5.07	4.03	1.20	(16)	5.07
Phoenix Airport	33 26	112 01	1,110	1.58	.87	2.09	1.49	.79	(15)	2.09
Superior	33 18	111 06	2,995	4.10	1.95	6.04	4.64	1.23	(15)	6.01
Wikenburg	33 59	112 44	2,095	3.21	2.19	5.00	4.04	1.20	(14)	5.00
Southeast climatic division										
Ajo	32 22	112 52	1,800	0.64	-0.06	1.57	1.04	0.75	(16)	1.56
Clifton	33 03	109 17	3,460	1.15	.20	3.55	2.93	--	--	3.55
Duncan	32 45	109 07	3,660	.80	.01	3.12	2.53	1.36	(14)	1.96
Palisade Ranger Station	32 25	110 43	7,945	5.70	--	10.81	--	4.83	(14)	9.32
Sabino Canyon	32 18	110 49	2,640	1.65	.60	3.47	2.65	.99	(8)	2.31
Tucson Airport	32 08	110 57	2,584	.73	-.04	2.90	2.20	.86	(8)	2.04

TABLE 3.—*Average precipitation and departure from normal in California and Arizona during January and February 1980, by climatic division*

[Climatic divisions shown in fig. 13]

Climatic division	January			February		
	Mean (in)	Departure (in)	Percent of normal	Mean (in)	Departure (in)	Percent of normal
CALIFORNIA						
North Coast Drainage	7.38	-1.11	87	9.30	3.54	161
Sacramento Drainage	8.92	2.04	130	11.19	5.78	207
Northeast Interior Basins	8.61	4.79	225	7.01	4.26	255
Central Coast Drainage	5.54	1.26	129	7.13	3.83	178
San Joaquin Drainage	8.26	4.73	234	6.50	3.48	215
South Coast Drainage	9.21	6.12	298	11.82	8.96	413
Southeast Desert Basins	3.04	1.77	239	4.26	3.12	374
ARIZONA						
Northwest	3.19	2.34	375	2.98	2.09	335
Northeast	3.64	2.54	331	4.05	3.16	455
North Central	5.97	4.62	442	6.58	5.41	562
East Central	4.69	2.68	233	7.05	5.70	522
Southwest	1.12	0.65	238	1.56	1.20	433
South Central	2.33	1.38	245	3.11	2.34	404
Southeast	1.21	0.27	129	2.90	2.17	397

TABLE 4.—*Comparison of precipitation amounts observed during the storms of February 1980 with estimated 100-year amounts at selected stations in southern California and Arizona*

[In inches. Stations shown in figs. 14 and 15. --, data not available]

Station	24 hour		1 day		10 day	
	Observed	100 yr	Observed	100 yr	Observed	100 yr
CALIFORNIA						
Burbank Valley pumping plant	5.60	8.0	4.15	--	14.45	17.0
Crestline Fire Station	6.80	17.0	--	--	30.10	32.0
Cuyamaca	5.90	13.0	3.03	--	22.90	19.5
Henshaw Dam	--	--	3.85	7.1	21.40	20.0
Lake Arrowhead	--	--	4.55	15.9	24.26	30.0
Mt. Wilson 2	--	--	5.42	16.1	30.71	29.0
Palomar Mt. Observatory	5.20	11.0	4.09	--	23.10	20.0
San Gabriel Dam	--	--	7.75	12.8	26.76	30.0
Topanga Patrol Station	--	--	8.30	10.8	17.00	21.0
UCLA	--	--	4.14	--	--	--
ARIZONA						
Childs	--	--	2.77	--	4.2	9.14
Crown King	--	--	3.71	5.8	16.63	9.0
Junipine	--	--	2.90	4.9	13.94	8.0
Palisade Ranger Station	--	--	4.83	--	4.2	9.32

TABLE 5.—*Peak discharges at selected gaging stations during major floods in southern California*

[For peak discharges prior to 1916, year is indicated in parentheses. Sites shown on pl. 1. --, data not available]

Site	Station name	Drainage area, in square miles	Peak discharge in indicated year, in cubic feet per second						
			Prior to 1916	1916	1927	1938	1969	1978	1980
20	Sweetwater River near Descanso	45.4	--	9,870	11,200	--	1,750	1,150	6,750
21	San Diego River near Santee	377	--	70,200	45,400	7,350	1,830	3,010	3,420
27	Santa Ysabel Creek near Ramona	112	--	28,400	--	--	6,180	4,000	10,700
29	Santa Maria Creek near Ramona	57.6	--	7,140	--	--	1,400	2,850	15,200
	San Luis Rey River:								
33	at Monserate Narrows, near Pala	373	--	[1]75,000	--	--	3,250	4,340	15,500
35	at Oceanside	558	[2]128,000 (1891)	95,600	--	16,500	11,500	9,780	25,000
40	Santa Margarita River at Ysidora	740	--	--	33,600	31,000	19,200	21,200	24,000
41	San Juan Creek at San Juan Capistrano	117	--	--	--	13,000	22,400	14,700	11,400
	Santa Ana River:								
46	near Mentone	210	53,700 (1891)	29,100	24,000	52,300	15,300	2,170	5,930
62	at Riverside Narrows, near Arlington	855	320,000 (1862)	--	--	100,000	41,000	19,500	19,500
47	Mill Creek near Yucaipa	42.4	--	--	4,500	18,100	35,400	5,400	[3]5,550
49	City Creek near Highland	19.6	--	--	1,930	6,900	7,000	2,510	[3]3,630
52	East Twin Creek near Arrowhead Springs	8.8	--	--	480	3,360	2,300	1,480	[3]3,710
66	San Jacinto River near Elsinore	723	--	14,000	16,000	2,790	6,260	6,270	9,010
77	San Gabriel River below Santa Fe Dam, near Baldwin Park	236	--	[4]40,000	[4]18,200	[4]65,700	30,900	14,200	18,500
	Los Angeles River:								
82	at Sepulveda Dam	158	--	--	--	12,000	13,800	14,700	15,100
87	at Long Beach	827	--	--	--	99,000	102,000	94,800	129,000
84	Arroyo Seco near Pasadena	16.0	--	3,150	1,400	8,620	8,540	5,360	3,080
97	Sespe Creek near Fillmore	251	--	[5]18,600	--	56,000	60,000	73,000	40,700
98	Santa Paula Creek near Santa Pala	40.0	--	--	--	13,500	21,000	16,000	11,800
99	Santa Clara River at Montalvo	1,612	--	--	--	120,000	165,000	102,000	81,400
106	Ventura River near Ventura	188	--	--	--	39,200	58,000	63,600	37,900
126	Santa Ynez River at Narrows, near Lompoc	789	120,000 (1907)	--	--	45,000	80,000	63,200	16,300
133	Sisquoc River near Sisquoc	281	--	--	--	11,000	21,400	15,900	5,120

[1] Near Pala, drainage area 317 mi^2.
[2] Near Bonsall, drainage area 513 mi^2.
[3] Maximum in 1980 occurred January 29.
[4] Near Azuza, drainage area 214 mi^2.
[5] Near Sespe, drainage area 210 mi^2.

TABLE 6.—*Mean discharges for 7 and 15 consecutive days at selected sites in southern California during floods of 1980*

[Average flows for highest 7 and 15 consecutive days; rank of 1 indicates highest event during period of record, 2 indicates second highest, and so forth. Flows in 1980 began during the period February 13–19. Sites shown on pl. 1. Mean discharge in cubic feet per second]

Site	Station name	Period of daily discharge record (water years)	High 7 days				High 15 days			
			1980		Previous high		1980		Previous high	
			Mean discharge	Rank	Mean discharge	Year	Mean discharge	Rank	Mean discharge	Year
17	Campo Creek near Campo	1937–80	217	1	88	1941	149	1	67	1941
19	Tijuana River near Nestor	1937–80	16,300	1	5,670	1941	9,610	1	4,250	1941
20	Sweetwater River near Descanso	1907–27, 1956–80	1,120	2	1,260	1916	618	2	1,040	1916
37	Murrieta Creek at Temecula	1931–80	2,860	1	2,170	1969	1,610	1	1,030	1969
66	San Jacinto River near Elsinore	1917–80	5,560	1	4,490	1927	3,920	1	2,360	1927
70	Santa Ana River below Prado Dam	1941–80	5,910	1	5,320	1969	4,750	1	3,580	1969
84	Arroyo Seco near Pasadena	1914–80	549	4	1,230	1914	349	4	639	1914
97	Sespe Creek near Fillmore	1928–80	5,090	7	11,500	1969	2,850	8	7,220	1969
99	Santa Clara River at Montalvo	1950–80	14,200	3	25,400	1969	8,340	3	13,700	1969
106	Ventura River near Ventura	1930–80	4,770	4	6,970	1969	2,670	5	3,960	1969
125	Salsipuedes Creek near Lompoc	1942–80	523	3	925	1978	270	4	523	1962
133	Sisquoc River near Garey	1942–80	3,440	2	6,250	1969	1,990	2	3,780	1969

TABLE 7.—*Peak inflow and outflow from selected reservoirs in southern California, 1980*

[Discharges provided by Big Bear Municipal Water District; County of San Diego, Department of Public Works, Flood Control Division; International Boundary and Water Commission, United States Section (for Rodriquez); and U.S. Army Corps of Engineers, Los Angeles District. >, greater than. Locations of reservoirs shown in figs. 22, 32, and 42, and on pl. 2]

River basin	Reservoir	Inflow (ft^3/s)	Outflow (ft^3/s)	Date of peak outflow
Tijuana	Barrett	([1])	8,000	February 21
	Morena	([1])	2,900	February 21
	Rodriquez[2]	([1])	28,000	January 30
Sweetwater	Loveland	([1])	5,000	February 21
	Sweetwater	([1])	7,000	February 21
San Diego	El Capitan	40,000	1,080	February 24
	San Vicente	11,500	6,000	February 21
San Dieguito	Sutherland	([1])	6,100	February 21
	Lake Hodges	28,000	22,000	February 21
Santa Ana	Big Bear	1,160	1,270	February 19
	Prado	[3]42,200	7,440	February 21
San Gabriel-Los Angeles	Santa Fe	[3]15,000	18,500	February 17
	Whittier Narrows:			
	San Gabriel	[4]43,800	[5]11,000	February 17
	Rio Hondo	[6]18,200	23,700	February 14
	Sepulveda	[3]62,000	15,100	February 16
	Hansen	[3]9,300	5,020	February 17
Santa Clara	Piru	6,900	422	February 19
Ventura	Casitas	>9,000	643	February 21
Santa Ynez	Jamison	3,150	2,020	February 20
	Gibraltar	13,800	13,600	February 16
	Cachuma	20,900	17,900	February 20
Santa Maria	Twitchell	>4,000	391	June 27 (max. daily)

[1]No estimate made.
[2]In Mexico.
[3]From Evelyn (1982).
[4]February 17.
[5]From Joseph B. Evelyn, U.S. Army Corps of Engineers, oral communication, 1984.
[6]February 16.

TABLE 8.—*Sediment loads at selected stations in southern California during major storm periods, 1969, 1978, and 1980 water years*

[In tons. Sites shown on pl. 1]

Storm period	Santa Ana River at Santa Ana (site 76)	Santa Clara River at Montalvo (site 99)	Ventura River near Ventura (site 106)
1969 water year			
Jan. 19-29	1,172,793	22,154,200	3,650,975
Feb. 5-8	282,200	1,482,302	68,910
Feb. 18-27	5,994,780	25,941,870	2,864,371
Total	7,449,773	49,578,372	6,584,256
Percent of yearly total	64.3	98.2	98.9
1978 water year			
Dec. 25-29	9,165	55,384	536
Jan. 14-19	40,640	588,190	94,763
Feb. 5-15	579,480	9,738,297	2,084,444
Mar. 1-6	897,400	17,651,000	1,297,320
Total	1,526,685	28,032,871	3,477,063
Percent of yearly total	68.2	95.9	98.9
1980 water year			
Jan. 9-19	60,285	144,695	1,254
Jan. 28-Feb.1	152,530	237,262	266
Feb. 14-24	1,247,100	8,279,900	1,743,198
Mar. 2-7	550,000	769,500	13,990
Total	2,009,915	9,431,357	1,758,708
Percent of yearly total	76.2	96.1	99.7

TABLE 9.—*Annual sediment loads at selected stations in southern California for 1969–80 water years*

[In tons. Sites shown on pl. 1. --, data not available]

Water year	Santa Ana River at Santa Ana (site 76)	Santa Clara River at Montalvo (site 99)	Ventura River near Ventura (site 106)
1969	11,585,094	50,490,604	6,658,137
1970	22,470	664,220	32,768
1971	17,066	2,411,145	37,263
1972	--	476,051	7,094
1973	43,751	4,312,720	491,242
1974	74,824	493,457	--
1975	27,224	536,080	35,703
1976	6,934	67,601	1,605
1977	5,026	61,879	956
1978	2,238,835	29,218,506	3,514,054
1979	71,955	2,258,110	36,714
1980	2,636,012	9,810,441	1,764,103
Total	16,729,191	100,800,814	12,579,639
1969 as percent of total	69	50	53
1978 as percent of total	13	29	28
1980 as percent of total	16	10	14
Sum of 1969, 1978, and 1980 storm periods (from table 8) as percent of the 12-year total	66	86	94

TABLE 10.—*Gage height, in feet, and discharge, in cubic feet per second, February 14–22, 1980, at gaging station 09498500, Salt River near Roosevelt, Ariz. (site 11, pl. 2)*

Hour	Gage height	Discharge	Hour	Gage height	Discharge	Hour	Gage height	Discharge
Feb. 14			Feb. 16			Feb. 19--Con.		
0700	7.9	697	0100	26.7	87,400	1100	13.4	11,300
1000	8.1	841	0200	25.2	74,900	1400	13.7	12,500
1200	8.2	916	0300	24.8	71,800	1500	13.6	12,200
1400	8.7	1,370	0400	25.1	74,100	2300	14.2	14,300
1800	12.9	9,250	1200	20.2	40,800	2400	14.7	15,800
2200	16.7	20,600	2400	15.2	17,500	Feb. 20		
2400	17.8	28,300				0300	17.4	26,500
			Feb. 17			0600	21.1	46,100
Feb. 15			0600	14.2	12,500	1000	20.3	41,200
0400	18.9	33,700	0700	14.4	13,100	1400	20.9	45,000
1000	22.4	54,400	0800	14.1	12,200	2400	18.1	29,500
1100	22.6	55,800	2100	13.9	11,600	Feb. 21		
1300	22.6	55,800	2400	14.0	11,900	0900	17.2	25,600
1700	26.1	82,300				1000	18.8	33,100
1800	25.4	76,500	Feb. 18			1100	16.5	22,500
1900	27.2	91,800	2200	12.8	8,610	2200	15.0	16,800
1930	28.0	99,000	2400	13.1	9,450	2400	15.3	17,800
2000	27.2	91,800						
2100	26.7	87,400	Feb. 19			Feb. 22		
2200	27.1	90,900	0200	13.8	12,800	0100	15.5	18,500
2400	26.1	82,300	0300	14.1	13,700	2400	13.5	11,600

TABLE 11.—*Gage height, in feet, and discharge, in cubic feet per second, February 14–22, 1980, at gaging station 09499000, Tonto Creek above Gun Creek, near Roosevelt, Ariz. (site 14, pl. 2)*

Hour	Gage height	Discharge	Hour	Gage height	Discharge	Hour	Gage height	Discharge
Feb. 14			Feb. 16--Con.			Feb. 19--Con.		
0400	3.73	216	0400	7.50	7,430	1700	7.10	5,980
0600	4.00	357	0800	6.65	4,450	2000	9.50	15,600
0800	6.00	3,020	1600	5.80	2,610	2200	12.00	27,200
1100	7.00	5,390	2400	5.55	2,160	Feb. 20		
1400	10.00	17,800	Feb. 17			0030	16.50	57,200
1800	13.00	32,200	1200	5.65	2,330	0400	10.00	17,400
2300	11.30	23,900	2400	5.50	2,070	0600	9.80	16,400
2400	12.00	27,200	Feb. 18			1200	8.50	11,000
Feb. 15			0900	5.25	1,600	2400	7.90	8,800
0500	10.70	21,400	1300	5.30	1,680	Feb. 21		
0800	12.20	28,300	1600	6.00	3,120	0500	7.00	5,680
0900	12.20	28,300	1800	8.00	8,980	1200	8.80	12,100
1200	14.90	45,300	1930	9.00	13,400	1400	8.00	9,330
1500	17.00	61,400	1400	7.40	7,090	1700	10.00	17,800
1800	14.00	38,100	Feb. 19			1400	8.80	12,100
2200	10.00	17,800	0900	6.00	3,120	Feb. 22		
2400	9.00	13,400	1400	6.80	5,110	1100	7.20	5,680
Feb. 16			1500	6.60	4,450	1800	6.60	4,450
0300	7.10	5,980	1600	7.50	7,430	2400	6.50	4,140

TABLE 12.—*Gaged inflow to Roosevelt Lake and outflow from Stewart Mountain Dam, Ariz., for periods when the 7-day gaged inflow exceeded 200,000 acre-feet, 1913–80*

[Flow in thousands of acre-feet. Total 7-day inflows generally are 5 to 10 percent greater than gaged inflows. In March 1978, January 1979, and February 1980, total inflows were 18, 39, and 35 percent, respectively, greater than gaged inflow. Total inflow not available prior to 1941. Outflow not available prior to 1937. Locations shown on pl. 2]

Flood period	Gaged inflow to Roosevelt Lake			Outflow from Stewart Mountain Dam		
	Highest consecutive days			Highest consecutive days		
	1	3	7	1	3	7
January 30–February 5, 1915	96	159	224	--	--	--
January 16-22, 1916	212	502	693	--	--	--
January 25-31, 1916	155	302	383	--	--	--
March 23-29, 1916	57	129	206	--	--	--
December 5-11, 1919	118	201	241	--	--	--
February 21-27, 1920	131	292	394	--	--	--
December 27, 1923–January 2, 1924	104	191	285	--	--	--
February 15-21, 1927	81	216	280	--	--	--
February 9-15, 1932	84	212	290	--	--	--
February 7-13, 1937	97	190	210	0.05	0.1	0.2
March 13-19, 1941	152	328	404	.06	.08	.2
January 14-20, 1952	116	246	350	0	0	0
December 25-31, 1959	103	188	207	.2	.4	.5
December 22-28, 1965	111	196	229	7	19	26
December 30, 1965–January 5, 1966	80	171	207	77	171	[1]240
October 19-25, 1972	122	237	275	29	50	53
February 28–March 6, 1978	216	514	658	32	53	56
December 18-24, 1978	152	345	397	75	271	[1]408
January 17-23, 1979	95	190	228	[1]107	[1]291	[2]433
February 14-20, 1980	184	316	550	127	[1]326	[1]620

[1]Exceeds measured inflow but is less than total inflow.
[2]Exceeds total inflow because reservoirs were being drawn down to allow for additional runoff.

TABLE 13.—*Gage height, in feet, and discharge, in cubic feet per second, February 13–22, 1980, at gaging station 09508500, Verde River below Tangle Creek, above Horseshoe Dam, Ariz. (site 37, pl. 2)*

Hour	Gage height	Discharge	Hour	Gage height	Discharge	Hour	Gage height	Discharge
Feb. 13			Feb. 16			Feb. 19--Con.		
2400	4.07	547	0200	17.45	44,600	2300	17.77	47,700
Feb. 14			0400	16.98	40,300	2400	18.62	56,600
0400	4.23	612	0600	16.52	36,400	Feb. 20		
0700	4.78	846	0800	15.94	32,000	0100	18.91	60,000
1000	6.81	2,170	1000	15.40	28,200	0200	18.21	53,200
1200	9.08	4,780	1200	14.87	24,800	0300	18.41	43,300
1300	10.37	7,120	1600	14.00	19,900	0400	19.03	61,400
1400	11.18	9,070	2000	13.44	17,100	0500	19.28	64,400
1500	11.72	10,560	2400	12.86	14,500	0600	19.39	65,800
1700	13.10	15,600	Feb. 17			0700	19.20	63,400
1900	14.02	20,000	0500	12.46	13,000	0800	19.12	62,500
2000	14.14	20,580	0700	12.46	13,000	0900	19.26	64,200
2100	13.96	19,700	0900	12.62	13,600	1000	19.35	65,300
2300	13.07	15,400	1100	12.62	13,600	1100	19.08	62,000
2400	12.81	14300	1400	12.52	13,200	1200	18.64	56,900
			1900	12.92	14,800	1400	18.16	51,600
Feb. 15			2400	12.63	13,600	1600	17.33	43,500
0100	12.67	13,800				1800	16.65	37,500
0200	12.71	13,900	Feb. 18			2000	16.48	36,100
0300	13.27	16,300	0800	12.24	12,200	2100	16.59	37,000
0500	15.04	25,800	1200	12.32	12,500	2300	16.48	36,100
0700	17.48	44,900	1600	12.16	12,000	1400	16.33	34,900
0900	19.22	63,700	1800	12.39	12,800	Feb. 21		
1100	20.34	78,500	2100	13.29	16,400	0400	15.25	27,200
1300	21.04	88,900	2400	14.43	22,200	0700	14.73	23,900
1400	21.21	91,600				1600	14.97	25,400
1530	21.41	94,800	Feb. 19			2000	14.69	23,700
1700	21.08	89,600	0500	14.99	25,500	2400	14.67	23,600
1800	20.81	85,400	0900	14.70	23,700	Feb. 22		
2000	19.82	71,300	1500	13.69	18,300	0400	14.66	23,500
2200	18.36	53,800	1800	13.66	18,100	0800	14.78	24,200
2300	18.39	54,100	1900	13.85	19,100	1600	13.84	19,000
2400	18.06	50,600	2100	16.10	33,200	2400	13.29	16,400

TABLE 14.—*Gage height, in feet, and discharge, in cubic feet per second, February 13–25, 1980, at gaging station 09502000, Salt River below Stewart Mountain Dam, Ariz. (site 17, pl. 2)*

[Outflow from Salt River reservoir system]

Hour	Gage height	Discharge	Hour	Gage height	Discharge	Hour	Gage height	Discharge
Feb. 13			Feb. 16--Con.			Feb. 22		
1000	3.34	938	2400	22.9	62,000	0200	20.5	48,600
1600	3.35	947	Feb. 17			1500	20.0	46,000
1800	4.01	1,620	0600	22.7	60,800	2400	19.6	44,000
1900	4.24	1,880	1330	22.0	56,800			
2400	4.27	1,910	1600	21.9	56,200	Feb. 23		
Feb. 14			2030	20.9	50,700	0600	19.3	42,500
1800	4.27	1,910	2400	21.3	52,900	1200	18.9	40,600
1900	4.60	2,290	Feb. 18			1800	18.1	36,900
2000	10.85	12,600	0800	20.0	46,000	2100	17.6	34,600
2100	11.08	13,200	2000	18.4	38,200	2400	17.5	34,200
2200	11.06	13,100	2200	16.4	29,600			
2300	10.95	12,900	2300	18.0	36,400	Feb. 24		
2400	10.81	12,500	2400	17.9	36,000	0600	16.99	32,010
Feb. 15			Feb. 19			1200	15.79	27,300
0100	10.7	12,300	0800	17.3	33,300	1400	15.59	26,600
0200	10.9	12,700	1900	17.0	32,100	2400	15.59	26,600
0900	10.5	11,900	2400	17.3	33,300	Feb. 25		
1000	11.3	13,700	Feb. 20			0500	15.39	25,800
1200	18.4	38,200	0200	17.4	33,800	0900	14.59	23,000
1300	20.0	46,000	1100	16.45	29,800	1200	14.29	22,000
1400	21.2	52,300	1600	16.8	31,200	1600	18.89	20,720
1500	20.9	50,700	2100	18.0	36,400	1800	9.99	10,880
1800	24.0	68,800	2400	18.5	38,700	1900	6.99	5,400
2100	25.0	75,200				1915	9.99	10,900
2400	24.4	71,200	Feb. 21			2000	13.09	18,300
Feb. 16			1200	19.6	44,000	2100	13.29	18,800
0700	23.2	63,800	1900	20	46,000	2300	12.99	18,000
1100	23.0	62,600	2400	20.4	48,000	2400	12.39	16,400

TABLE 15.—*Gage height, in feet, and discharge, in cubic feet per second, February 13–25, 1980, at gaging station 09510000, Verde River below Bartlett Dam, Ariz. (site 42, pl. 2)*

Hour	Gage height	Discharge
Feb. 13		
0600	2.82	780
1230	3.5	1,520
1500	3.87	1,970
1715	5.1	3,950
1815	6.25	5,800
1915	7.40	8,090
2145	8.5	10,600
Feb. 14		
0900	8.58	10,800
1815	10.25	15,200
2145	10.36	15,500
2400	10.39	15,600
Feb. 15		
0800	10.45	15,800
0830	14.20	28,800
0900	16.80	41,070
0930	19.40	55,600
1000	20.83	64,100
1100	20.81	64,000
1200	21.92	71,300
1300	21.90	71,200
1330	23.25	80,600
1500	22.90	78,100
1530	24.50	89,900
1600	24.88	92,900
1700	24.95	93,400
1830	25.40	97,300
2030	25.36	96,600
2230	25.09	94,500
2400	24.10	86,900
Feb. 16		
0030	23.80	84,700
0430	23.40	81,700
1100	22.80	77,400
1200	22.00	71,900
1300	21.00	65,200
1400	19.00	53,200
1500	14.13	28,400
1900	14.19	28,700
2400	14.20	28,000
Feb. 17		
0200	13.94	27,600
0230	13.13	24,300
Feb. 17--Con.		
0430	13.07	24,100
0530	11.58	19,000
0830	11.47	18,600
0900	9.20	12,400
1000	7.33	8,000
1130	7.24	7,760
1200	10.30	15,400
1230	10.68	16,400
1800	10.69	16,400
1830	11.30	18,200
1900	11.40	18,400
1930	14.30	29,200
2000	14.60	30,500
2100	14.67	30,800
2400	14.52	30,100
Feb. 18		
1330	14.30	29,200
1400	16.50	39,500
1430	19.30	55,000
1530	23.00	78,900
1700	21.20	66,500
1900	19.00	53,200
2100	17.30	43,700
2400	15.75	35,800
Feb. 19		
0100	15.30	33,700
0300	14.70	31,000
0500	14.38	29,500
0830	14.30	29,200
1130	14.43	29,800
1545	14.34	29,400
2100	14.29	29,100
2315	14.65	30,700
2400	14.83	31,500
Feb. 20		
0330	16.20	38,000
0430	15.15	33,000
0500	15.25	33,500
0530	14.60	30,500
0600	14.63	30,600
0630	14.25	28,000
0800	14.92	31,900
1000	15.20	33,200
1230	15.03	32,400
1400	16.40	39,000
Feb. 20--Con.		
1500	15.60	35,100
1700	16.30	38,500
2030	16.80	41,100
2100	14.87	31,700
2200	14.81	31,400
2400	14.96	32,100
Feb. 21		
0100	15.03	32,400
0415	15.16	33,000
1045	15.20	33,200
1515	16.50	39,500
1615	17.60	45,300
1845	17.60	45,300
2215	17.57	45,100
2400	17.50	44,500
Feb. 22		
0430	17.15	42,900
0915	14.60	30,500
1030	12.75	22,800
1200	13.15	24,400
1245	12.90	23,400
1430	12.39	21,500
1700	11.85	19,800
1845	10.95	17,200
2000	9.00	11,900
2115	8.75	11,300
2300	7.07	7,420
Feb. 23		
0300	7.10	7,460
0800	7.87	7,130
1100	8.30	10,100
1600	9.12	12,200
2100	9.78	13,900
2300	10.88	17,100
Feb. 24		
0500	10.74	16,700
1300	10.93	17,300
2000	11.93	20,200
Feb. 25		
0430	11.45	18,700
0915	12.30	21,300
1230	12.95	23,800
1545	12.00	20,400
1630	8.50	10,630
1715	6.15	5,590
2045	6.12	5,530

TABLE 16.—*Gage height, in feet, and discharge, in cubic feet per second, February 14–24, 1980, at gaging station 09512170, Salt River at Jointhead Dam, at Phoenix, Ariz. (site 45, pl. 2)*

[For 2400 February 20 to 2400 February 24, stage-discharge relation is undefined. Discharge values given for that period are estimated from summation of Salt River below Stewart Mountain Dam and Verde River below Bartlett Dam and shape of recorder trace at Jointhead Dam. --, data not available]

Hour	Gage height	Discharge	Hour	Gage height	Discharge	Hour	Gage height	Discharge
Feb. 14			Feb. 16--Con.			Feb. 20--Con.		
0700	--	0	2400	6.30	90,000	1200	5.01	63,000
0800	2.75	5,000	Feb. 17			1700	5.10	65,000
0900	3.07	6,600	0300	6.46	92,000	2400	5.77	72,000
1000	3.13	6,940	0600	6.56	94,000	Feb. 21		
1400	3.26	8,000	1400	5.75	78,000	0200	5.92	76,000
1800	3.33	8,580	1700	5.00	63,000	0500	5.75	72,000
2000	3.40	9,200	2000	5.28	69,000	1500	6.17	75,000
2300	3.70	12,000	2300	5.08	65,000	1900	6.25	76,000
2400	4.20	17,300	2400	5.15	66,000	2100	6.45	85,000
Feb. 15			Feb. 18			2400	6.95	95,000
0200	--	24,000	0200	6.00	83,000	Feb. 22		
0400	4.84	25,800	0400	6.17	87,000	0200	7.36	100,000
0900	4.78	25,000	0800	6.05	84,000	0800	7.20	97,000
1400	4.87	26,200	1700	5.50	73,000	1400	6.93	92,000
1500	5.50	35,900	2000	6.60	95,000	1800	5.95	75,000
1600	7.00	63,100	2200	7.60	115,000	2400	5.42	67,000
1800	9.50	113,100	2400	7.00	103,000	Feb. 23		
2000	10.60	144,000	Feb. 19			0400	4.85	58,000
2200	11.15	160,000	0600	5.50	73,000	0600	4.50	54,000
2400	11.3	165,000	0900	5.10	65,000	1000	4.17	49,000
Feb. 16			1200	4.98	63,200	1400	4.03	49,000
0100	11.45	170,000	1400	4.97	63,000	1600	4.02	50,000
0400	10.75	148,000	2000	5.27	69,000	2200	4.12	52,000
0800	9.30	135,000	2400	5.13	66,000	2400	4.12	52,000
1400	9.30	135,000	Feb. 20			Feb. 24		
1600	9.10	129,000	0200	5.30	69,000	0400	4.02	50,000
1800	8.90	123,000	0400	5.75	78,000	1200	4.09	52,000
2200	6.30	90,000	0700	5.75	74,000	2100	3.77	46,000
2300	6.20	87,000	0800	5.58	75,000	2400	3.83	47,000

TABLE 17.—*Gage height, in feet, and discharge, in cubic feet per second, February 15–23, 1980, at gaging station 09519500, Gila River below Gillespie Dam, Ariz. (site 62, pl. 2)*

Hour	Gage height	Discharge	Hour	Gage height	Discharge	Hour	Gage height	Discharge
Feb. 15			Feb. 18--Con.			Feb. 21--Con.		
0000	10.20	332	1100	15.10	73,700	0800	15.71	91,300
0400	10.20	332	1400	15.23	79,700	1000	15.75	92,300
0800	10.41	1,050	1800	15.45	85,000	1200	15.70	91,000
1200	11.07	4,820	2000	15.51	86,400	1400	15.73	91,800
1600	12.04	14,900	2200	15.51	86,400	1600	15.66	90,000
2000	12.54	21,900	2400	15.49	89,900	2000	15.70	91,000
2400	13.00	29,300	Feb. 19			2400	15.88	95,500
Feb. 16			0400	15.31	81,600			
0400	13.56	39,200	0800	15.49	85,900	Feb. 22		
0600	13.96	47,100	1230	16.12	102,000	0400	16.08	100,500
0800	14.71	63,000	1400	16.11	101,000	0800	16.28	105,700
1000	16.08	95,400	1600	15.95	97,200	1200	16.55	113,000
1200	17.32	134,000	2000	15.45	85,000	1445	16.72	117,000
1300	17.86	149,000	1400	15.18	78,600	1600	16.63	115,000
1500	18.38	165,000	Feb. 20			2000	16.58	114,000
1830	18.81	178,000	0400	15.09	76,500	2400	16.36	108,000
2400	18.36	164,000	0800	15.31	81,600			
Feb. 17			1200	16.08	100,000	Feb. 23		
0600	17.92	151,000	1600	16.78	119,000	0400	15.89	95,700
1200	16.72	117,000	1800	17.05	126,000	0800	15.48	85,700
1600	16.16	103,000	2000	16.85	121,000	1200	15.11	76,900
2400	15.74	92,000	2400	16.33	107,000	1600	14.74	68,500
Feb. 18			Feb. 21			2000	14.54	64,100
0600	15.34	82,300	0400	15.94	97,000	2400	14.47	62,600

TABLE 18.—*Gage height, in feet, and discharge, in cubic feet per second, February 13–21, 1980, at gaging station 09512500, Agua Fria River near Mayer, Ariz. (site 47, pl. 2)*

Hour	Gage height	Discharge	Hour	Gage height	Discharge	Hour	Gage height	Discharge
Feb. 13			Feb. 15--Con.			Feb. 19--Con.		
2400	3.23	16.3	0400	9.27	9,580	2230	15.56	32,200
Feb. 14			0700	7.90	6,310	2300	14.96	29,500
0330	3.30	24.3	1000	8.80	8,390	2400	13.41	23,100
0400	3.68	111	1100	9.19	9,370	Feb. 20		
0430	3.70	118	1300	8.55	7,780	0130	13.61	23,900
0600	3.95	239	1430	9.17	9,320	0200	12.66	20,300
0630	4.60	830	1600	9.00	8,880	0300	10.80	14,000
0730	5.20	1,620	1800	8.00	6,530	0500	8.60	7,900
0900	6.18	3,110	2100	6.65	3,880	0730	9.86	11,200
1000	6.40	3,460	2400	5.87	2,630	1000	7.66	5,800
1130	7.70	5,890	Feb. 16			1300	6.72	4,000
1230	7.82	6,140	0600	5.03	1,380	1500	6.29	3,280
1330	8.13	6,810	1200	4.51	728	1800	5.93	2,720
1600	7.68	5,840	1800	4.19	414	2000	5.77	2,480
1700	10.00	11,600	2400	4.02	285	2400	5.30	1,760
1730	10.00	11,600	Feb. 19			Feb. 21		
1830	10.79	13,900	1300	3.40	41	0530	4.93	1,240
2000	10.10	11,800	1830	4.91	1,220	0700	5.48	2,030
2030	10.10	11,800	1900	6.10	2,990	0930	6.48	3,590
2200	8.80	8,380	1930	7.40	5,270	1030	6.55	3,710
2300	8.95	8,750	2000	10.20	12,140	1300	6.36	3,400
2400	8.80	8,380	2030	12.26	18,300	1700	6.49	3,610
Feb. 15			2100	13.98	25,400	2100	5.82	2,550
0130	8.6	7,900	2130	15.36	31,300	2300	5.80	2,520
0230	9.15	9,270	2200	15.76	33,100	2400	5.65	2,290

TABLE 19.—*Gage height, in feet, and discharge, in cubic feet per second, February 14–22, 1980, at gaging station 09512800, Agua Fria River near Rock Springs, Ariz. (site 49, pl. 2)*

[Gage height: Recorded gage height by manometer; large amounts of drawdown at high stages. Peak outside stages are 19.79 ft February 15 and 28.15 ft February 19]

Hour	Gage height	Discharge	Hour	Gage height	Discharge	Hour	Gage height	Discharge
Feb. 14			Feb. 16			Feb. 19--Con.		
0000	7.62	628	0400	12.0	4,970	2400	21.08	59,500
0300	7.79	698	1100	10.81	3,640	Feb. 20		
0700	11.19	3,190	1900	10.15	2,950	0200	20.12	27,800
0930	11.99	4,150	2400	9.84	2,630	0300	19.82	25,000
1200	14.66	8,360	Feb. 17			0600	19.71	24,300
1500	17.76	15,700	0400	10.16	2,780	0900	20.01	26,800
1530	18.88	19,800	0800	11.42	4,500	1200	18.55	18,400
1730	16.66	12,700	1145	12.21	5,210	1500	16.35	12,000
2000	18.01	16,400	1800	10.84	3,550	1800	15.04	9,000
2130	17.01	13,600	Feb. 18			2400	13.45	6,040
2400	16.27	11,800	0100	10.11	2,920			
Feb. 15			0600	9.80	2,600	Feb. 21		
0100	16.66	12,700	1200	9.85	2,650	0400	12.80	5,030
0330	16.36	12,000	1300	10.08	2,890	0800	14.57	8,060
0430	17.16	14,000	1800	10.85	3,680	1200	15.54	10,100
0630	19.18	21,100	1945	11.70	4,620	1600	15.83	10,800
0830	18.48	18,100	2100	11.42	4,280	2000	14.88	8,670
0930	18.70	19,000	2400	11.04	3,890	2400	14.48	7,890
1030	19.38	22,200	Feb. 19					
1230	19.44	22,600	0400	10.66	3,500	Feb. 22		
1400	18.64	18,700	1400	10.48	3,320	0600	13.37	5,910
1800	16.26	11,800	1900	12.01	4,970	1200	12.61	4,760
2100	14.34	8,230	2000	14.99	9,300	1800	11.76	3,640
2400	13.12	6,390	2200	20.54	36,800	2400	11.42	3,220

TABLE 20.—*Inflow and outflow, in cubic feet per second, February 14–22, 1980, Lake Pleasant, Agua Fria River at Waddell Dam, Ariz. (sites 51A and 51B, pl. 2)*

[Furnished by Maricopa County Municipal Water Conservation District no. 1. --, data not available]

Hour	Inflow	Outflow
Feb. 14		
0200	697	1,550
0600	1,550	1,550
0800	3,730	1,550
1000	5,280	3,100
1200	12,400	9,600
1400	20,500	15,600
1600	27,700	23,400
1800	25,200	25,200
2000	26,100	25,200
2200	25,200	25,200
2400	23,900	25,200
Feb. 15		
0400	20,300	25,200
0600	21,100	25,200
0800	24,300	25,200
1000	41,400	44,000
1130	42,300	44,000
1400	36,200	44,000
1600	33,500	40,000
1700	30,600	40,000
1800	33,200	40,000
2000	17,500	25,200
2200	20,500	18,000
Feb. 15--Con.		
2400	18,000	18,000
Feb. 16		
0200	--	14,400
0400	--	14,400
0500	12,900	14,400
0700	9,950	10,800
0800	5,850	5,000
1000	7,620	0
1200	--	2,950
--	([1])	([1])
Feb. 19		
1600	--	7,200
1800	9,320	14,400
2000	--	25,200
2200	41,500	44,000
2400	59,600	52,000
Feb. 20		
0100	73,300	--
0200	71,700	66,600
0400	58,100	66,600
0600	43,700	46,200
0800	37,700	36,000
1000	--	28,800
1200	31,300	28,800
Feb. 20--Con.		
1400	25,400	28,800
1600	--	14,400
1800	16,100	14,400
2000	14,800	14,400
2200	--	9,000
2400	--	9,000
Feb. 21		
0200	--	9,000
0330	11,500	9,000
0600	--	9,000
0800	16,000	9,000
1000	17,000	14,400
1200	16,300	18,000
1400	18,000	18,000
1600	--	18,000
1800	17,600	18,000
2000	16,300	18,000
2400	--	18,000
Feb. 22		
0400	--	18,000
0600	--	14,400
0800	8,470	14,400
1000	8,890	7,200
1200	8,470	7,200

[1] From 1200 February 16 to 1500 February 19, inflow ranged from 3,920 to 11,600 ft^3/s, and outflow ranged from 1,800 to 10,600 ft^3/s. See figure 52.

TABLE 21.—*Gage height, in feet, and discharge, in cubic feet per second, February 14–22, 1980, at gaging station 09513970, Agua Fria River at Avondale, Ariz. (site 57, pl. 2)*

Hour	Gage height	Discharge	Hour	Gage height	Discharge	Hour	Gage height	Discharge
Feb. 14			Feb. 16--Con.			Feb. 19--Con.		
0000	0.32	0	0700	2.38	7,100	2400	0.65	380
2100	.32	0	0800	2.46	7,600	Feb. 20		
2200	4.50	19,500	0900	2.48	7,700	0200	1.90	4,520
2330	5.09	23,500	1000	2.20	6,100	0400	3.00	11,400
2400	5.00	23,000	1200	1.70	3,550	0600	4.85	26,700
			1800	1.2	1,500	0700	6.65	43,500
Feb. 15			2400	.7	430	0800	6.77	44,200
0200	4.77	21,400				1000	5.20	32,000
0300	4.63	20,500	Feb. 17			1200	3.55	20,500
0400	4.31	18,500	1400	.1	150	1400	3.05	17,300
0500	4.60	20,100	1500	1.90	4,550	1500	2.75	15,400
0600	4.43	19,000	1600	2.33	6,800	1800	3.25	18,500
0800	4.07	16,800	1700	2.25	6,400	2400	2.40	13,300
0900	3.95	16,300	1800	2.38	7,100	Feb. 21		
1000	4.04	16,700	1900	2.32	6,700	1400	1.80	9,800
1100	4.12	17,100	2000	2.10	5,600	1500	2.85	16,000
1200	4.02	16,600	2200	1.60	3,100	1900	2.60	14,500
1400	4.35	18,600	2400	1.57	2,950	2400	2.95	16,700
1600	5.62	27,300				Feb. 22		
1800	6.15	31,000	Feb. 18			0300	3.10	17,600
2000	5.60	27,000	0800	1.68	3,450	0600	2.65	14,800
2200	4.45	19,300	1200	1.40	2,210	0800	2.55	14,200
2400	3.50	13,500	1800	.95	840	1000	2.28	12,600
			2400	.70	430	1200	2.25	12,400
Feb. 16			Feb. 19			1400	2.13	11,700
0200	2.80	9,400	0200	1.64	3,240	1600	1.38	7,500
0400	2.40	7,200	0500	1.74	3,700	1800	1.25	6,700
0500	2.42	7,300	0700	1.67	3,400	2000	1.25	6,700
0600	2.35	6,900	1200	1.17	1,400	2400	1.18	6,400

TABLE 22.—*Summary of flood damage in the Phoenix, Ariz., area, February 1980*
[Modified from U.S. Army Corps of Engineers, 1981a]

Type of damage	Damage, in dollars			
	Salt River	Gila River	Agua Fria River	Total
Residential	873,000	769,000	248,000	1,890,000
Commercial	2,806,000	284,000	31,000	3,121,000
Industrial:				
Sand and gravel . .	1,710,000	23,000	62,000	1,795,000
Other.	1,012,000	0	0	1,012,000
Public:				
Roads and bridges .	16,399,000	1,360,000	4,242,000	22,001,000
Other.	11,639,000	619,000	1,053,000	13,311,000
Agricultural:				
Soil restoration. . .	33,000	1,925,000	195,000	2,153,000
Income losses. . . .	--	75,000	195,000	270,000
Other.	108,000	1,361,000	1,113,000	2,582,000
Business and income:				
Losses	5,282,000	11,000	239,000	5,532,000
Emergency costs:				
Public	615,000	8,000	2,000	625,000
Other.	694,000	64,000	231,000	989,000
Transportation delays:[1]				
Additional driver time.	6,500,000	--	--	--
Additional distance traveled	1,600,000	--	--	--
Additional operating costs	280,000	--	--	--
Total, transportation delays .	8,380,000	--	--	8,380,000
Grand total . . .	49,551,000	6,499,000	7,611,000	63,661,000

[1]Transportation delays were not computed for Gila and Agua Fria Rivers.

TABLE 23.—*Summary of flood stages and discharges*
[Sites shown

Site	Permanent station number	Stream and place of determination	Drainage area (mi^2)
		Salton Sea basin	
1	10254050	Salt Creek near Mecca	269
2	10255700	San Felipe Creek near Julian	89.2
3	10255800	Coyote Creek near Borrego Springs	144
4	10255810	Borrego Palm Creek near Borrego Springs	21.8
5	10255850	Vallecito Creek near Julian	39.7
6	10255885	San Felipe Creek near Westmorland	1,693
7	10256500	Snow Creek near White Water	10.8
8	10257600	Mission Creek near Desert Hot Springs	35.7
9	10257710	Chino Canyon Creek near Palm Springs	3.88
10	10258000	Tahquitz Creek near Palm Springs	16.8
11	10258500	Palm Canyon Creek near Palm Springs	93.3
12	10259000	Andreas Creek near Palm Springs	8.61
13	10259200	Deep Creek near Palm Desert	30.6
14	10259300	Whitewater River at Indio	1,073
15	10259540	Whitewater River near Mecca	1,495
		Tijuana River basin	
16	11012000	Cottonwood Creek above Tecate Creek, near Dulzura	310
17	11012500	Campo Creek near Campo	85.0
18	11013000	Tijuana River near Dulzura	481
19	11013500	Tijuana River near Nestor	1,695

See footnotes at end of table.

at selected gaging stations in southern California
on pl. 1]

Period	Maximum prior to February 1980			Maximum in February 1980			
	Year	Gage height (ft)	Discharge (ft^3/s)	Day	Gage height (ft)	Discharge (ft^3/s)	Recurrence interval (years)
Salton Sea basin							
1961-80	1976	14.3	9,900	21	9.44	1,290	6
1958-80	1967	4.08	1,050	21	7.85	6,150	>100
1950-80	1977	---	3,840	21	7.50	3,890	18
1950-80	1979	9.8	2,640	21	5.42	279	8
1963-80	1976	6.30	1,160	18	[1]6.22	231	5
1960-80	1976	19.0	100,000	21	8.65	3,440	2
1921-31, 1959-80	1969	[2]13.8	13,000	16	5.64	1,040	4
1967-80	1969	6.40	1,660	19	3.30	749	8
1974-80	1977	5.93	247	21	5.38	95	---
1947-80	1965 1969	12.34	2,900	21	---	1,690	15
1930-42, 1947-80	1979	6.38	4,400	21	7.29	7,000	30
1948-80	1954	7.11	1,960	18	4.38	411	6
1962-80	1976	7.84	7,100	21	5.08	1,170	6
1938, 1965-80	1938	---	29,000	17	4.12	6,100	7
1960-80	1969	---	[3]2,500	21	---	[1 3]2,100	---
Tijuana River basin							
[4]1936-80	1980	9.70	5,980	21	11.15	11,700	>100
1936-56 [4]1957-80	1937 1958	4.80 3.70	880 367	20	4.36	652	14
[4]1936-80	1980	10.20	6,780	18 21	11.19 ---	--- [1]12,200	--- 100
1914-15, [4]1936-80	1980	11.50	[1]32,000	21	8.70	33,500	---

TABLE 23.—*Summary of flood stages and discharges at*
[Sites shown

Site	Permanent station number	Stream and place of determination	Drainage area (mi²)
		Sweetwater River basin	
20	11015000	Sweetwater River near Descanso	45.4
		San Diego River basin	
21	11022500	San Diego River near Santee	377
		Los Penasquitos Creek basin	
22	11023250	Poway Creek near Poway	7.92
23	11023310	Rattlesnake Creek at Poway	8.13
24	11023325	Beeler Creek at Pomerado Road, near Poway	5.46
25	11023330	Los Penasquitos Creek below Poway Creek, near Poway	31.2
26	11023340	Los Penasquitos Creek near Poway	42.1
		San Dieguito River basin	
27	11025500	Santa Ysabel Creek near Ramona	112
28	11027000	Guejito Creek near San Pasqual	22.5
29	11028500	Santa Maria Creek near Ramona	57.6
		San Luis Rey River basin	
30	11031500	Agua Caliente Creek near Warner Springs	19.0
31	11033000	West Fork San Luis Rey River near Warner Springs	25.5
32	11037700	Pauma Creek near Pauma Valley	11.0
33	11040000	San Luis Rey River at Monserate Narrows, near Pala	373
34	11040200	Keys Creek tributary at Valley Center	7.65
35	11042000	San Luis Rey River at Oceanside	558

See footnotes at end of table.

selected gaging stations in southern California—Continued
on pl. 1]

Period	Maximum prior to February 1980 Year	Gage height (ft)	Discharge (ft³/s)	Maximum in February 1980 Day	Gage height (ft)	Discharge (ft³/s)	Recurrence interval (years)
			Sweetwater River basin				
1905-27, 1956-80	1927	[2]13.2	11,200	20	12.31	6,750	25
			San Diego River basin				
1863-1932 [4]1933-80	1916 1937	[2]25.1 [2]9.4	70,200 14,200	21	12.82	3,420	9
			Los Penasquitos Creek basin				
[4]1977-80	1978	6.15	375	21	7.26	755	---
1970-80	1980	1.74	567	21	2.88	1,430	---
[4]1977-80	1980	9.20	1,410	21	9.00	1,240	---
[4]1970-80	1978	9.85	3,530	21	11.11	4,990	---
[4]1964-80	1978	---	[1]4,700	21	10.26	4,750	30
			San Dieguito River basin				
1863-1953 [4]1954-80	1916 1969	[2]14.0 11.55	28,400 6,180	21	14.25	10,700	27
1946-80	1980	7.11	3,710	20	7.22	3,940	50
1885-1946 [4]1946-80	1916 1958	14.1 5.42	7,140 5,220	21	14.39	15,200	65
			San Luis Rey River basin				
1961-80	1966	5.18	1,200	21	4.80	1,440	40
1913-15, 1956-80	1966 1978	--- 14.35	4,200 ---	21	15.60	6,200	33
1964-80	1980 1966	--- 8.60	2,320 ---	20	8.51	3,170	65
[4]1935-41, [4]1946-80	1980	9.97	12,100	21	9.68	15,500	---
1969-80	1980	8.59	1,580	21	8.80	1,680	---
1891-1929 [4]1929-80	1891 1980	--- 15.83	128,000 21,000	21	14.00	25,000	---

TABLE 23.—*Summary of flood stages and discharges at*
[Sites shown

Site	Permanent station number	Stream and place of determination	Drainage area (mi^2)
		Santa Margarita River basin	
36	11042400	Temecula Creek near Aguanga	131
37	11043000	Murrieta Creek at Temecula	222
38	11044000	Santa Margarita River near Temecula	588
39	11044500	Santa Margarita River near Fallbrook	644
40	11046000	Santa Margarita River at Ysidora	740
		San Juan Creek basin	
41	11046550	San Juan Creek at San Juan Capistrano	117
42	11047000	Arroyo Trabuco near San Juan Capistrano	35.7
43	11047200	Oso Creek at Crown Valley Parkway, near Mission Viejo	14.0
		Aliso Creek basin	
44	11047500	Aliso Creek at El Toro	7.91
		San Diego Creek basin	
45	11048500	San Diego Creek at Sand Canyon Avenue, near Irvine	40.5
		Santa Ana River basin	
46	11051500	Santa Ana River near Mentone	210
47	11054000	Mill Creek near Yucaipa	42.4

See footnotes at end of table.

selected gaging stations in southern California—Continued
on pl. 1]

Period	Maximum prior to February 1980			Maximum in February 1980			
	Year	Gage height (ft)	Discharge (ft³/s)	Day	Gage height (ft)	Discharge (ft³/s)	Recurrence interval (years)
			Santa Margarita River basin				
1957-80	1958	---	3,540	21	12.0	3,420	27
	1969	10.6	---				
[4]1930-80	1943	13.82	17,500	21	13.70	21,800	23
1923-47	1927	14.6	25,000	21	16.5	22,000	15
[4]1948-80	1969	15.32	14,600				
1924-47	1927	[2]15.6	33,100	21	14.4	21,000	12
[4]1948-80	1969	14.18	20,000				
1923-47	1927	[2]18.00	33,600	18	[5]18.80	[1]24,000	10
[4]1948-80	1969	15.89	19,200				
			San Juan Creek basin				
1928-80	1969	[2]5.6	22,400	18	17.8	---	---
				20	---	11,400	---
1930-65	1937	6.80	9,240	18	3.18	3,140	12
[4]1966-77	1969	5.42	8,000				
1970-80	1973	[5]7.67	---	16	7.60	5,150	23
	1979	---	2,400				
			Aliso Creek basin				
1930-80	1969	[2]11.00	2,500	16	---	1,870	12
				18	[5]3.82	---	
			San Diego Creek basin				
1949-80	1969	---	6,700	16	21.17	7,720	70
	1978	18.41	---				
			Santa Ana River basin				
[4]1891-1980	1891	---	53,700	21	7.85	5,930	6
1919-80	1969	16.8	35,400	16	9.85	---	---
				18	---	2,480	6

TABLE 23.—*Summary of flood stages and discharges at*
[Sites shown

Site	Permanent station number	Stream and place of determination	Drainage area (mi^2)
		Santa Ana River basin--Continued	
48	11055500	Plunge Creek near East Highlands	16.9
49	11055800	City Creek near Highland	19.6
50	11056500	Little San Gorgonio Creek near Beaumont	1.74
51	11057500	San Timoteo Creek near Loma Linda	125
52	11058500	East Twin Creek near Arrowhead Springs	8.80
53	11058600	Waterman Canyon Creek near Arrowhead Springs	4.65
54	11059000	Warm Creek Floodway at San Bernardino	47.8
55	11059300	Santa Ana River at E Street, near San Bernardino	532
56	11060400	Warm Creek near San Bernardino	15.0
57	11062000	Lytle Creek near Fontana	46.3
58	11063000	Cajon Creek near Keenbrook	40.6
59	11063500	Lone Pine Creek near Keenbrook	15.1
60	11063680	Devil Canyon Creek near San Bernardino	5.49
61	11065000	Lytle Creek at Colton	172
62	11066500	Santa Ana River at Riverside Narrows, near Arlington	855
63	11069500	San Jacinto River near San Jacinto	141
64	11070050	Bautista Creek at Valle Vista	47.2
65	11070375	San Jacinto River at Railroad Canyon Weir, near Elsinore	562
66	11070500	San Jacinto River near Elsinore	723
67	11072000	Temescal Creek near Corona	[6]164
68	11073200	San Antonio Creek below San Antonio Dam	26.9
69	11073360	Chino Creek at Schaefer Avenue, near Chino	48.9
70	11074000	Santa Ana River below Prado Dam	[6]1,490

See footnotes at end of table.

selected gaging stations in southern California—Continued
on pl. 1]

Period	Maximum prior to February 1980			Maximum in February 1980			
	Year	Gage height (ft)	Discharge (ft^3/s)	Day	Gage height (ft)	Discharge (ft^3/s)	Recurrence interval (years)
Santa Ana River basin--Continued							
1919-80	1938	---	5,340	16	5.65	1,200	5
1919-80	1969	9.39	7,000	16	8.44	2,790	15
1948-80	1969	8.50	5,900	16	3.46	65	3
1927-80	1969	[2]8.2	15,000	16	8.50	3,400	27
1919-80	1980	8.35	3,710	16	5.30	919	2
1911-14, 1919-80	1938	---	2,350	16	4.41	545	2
[4]1961-80	1969	6.75	9,600	16	5.65	4,510	8
[4]1939-80	1969	[2]11.9	28,000	18	13.40	14,500	---
1964-80	1978	---	[1]12,000	16	2.88	2,330	6
1918-80	1969	15.0	35,900	16	9.22	10,300	30
1919-80	1938	[2]26.0	14,500	16	9.59	4,240	9
1919-38, 1949-80	1938	---	6,180	16	5.91	713	7
1911-14, 1919-80	1969	[2]5.40	3,720	19	6.70	672	12
[4]1957-80	1978	14.8	17,500	16	8.90	8,070	8
1862-1926 [4]1927-80	1862 1938	--- ---	320,000 100,000	18	10.40	19,500	---
[4]1920-80	1927	---	45,000	21	12.70	17,300	48
[4]1969-80	1979	3.30	1,390	21	6.40	8,320	>100
[4]1951-80	1969	---	5,330	22	7.27	5,700	34
[4]1916-80	1927	11.8	16,000	22	9.53	9,010	30
[4]1927-80	1938	---	14,900	18	---	3,500	---
[4]1962-80	1969	11.22	8,420	20	---	[1]470	---
[4]1969-80	1969 1978	--- 9.66	[7]9,200 ---	16	7.07	1,260	---
1920-40 [4]1941-80	1938 1969	--- 5.75	[8]100,000 5,800	21	6.88	7,440	---

TABLE 23.—*Summary of flood stages and discharges at*
[Sites shown

Site	Permanent station number	Stream and place of determination	Drainage area (mi^2)
		Santa Ana River basin--Continued	
71	11075600	Santa Ana River at Imperial Highway, near Anaheim	[6]1,544
72	11075720	Carbon Creek below Carbon Canyon Dam	19.5
73	11075755	Santa Ana River at Ball Road, at Anaheim	[6]1,587
74	11075800	Santiago Creek at Modjeska	12.5
75	11077500	Santiago Creek at Santa Ana	98.6
76	11078000	Santa Ana River at Santa Ana	[6]1,700
		San Gabriel River basin	
77	11085000	San Gabriel River below Santa Fe Dam, near Baldwin Park	236
78	11087020	San Gabriel River above Whittier Narrows Dam	353
79	11088500	Brea Creek below Brea Dam, near Fullerton	21.6
80	11089500	Fullerton Creek below Fullerton Dam, near Brea	4.94
81	11090200	Fullerton Creek at Richman Avenue, at Fullerton	12.1
		Los Angeles River basin	
82	11092450	Los Angeles River at Sepulveda Dam	158
83	11097000	Big Tujunga Creek below Hansen Dam	153
84	11098000	Arroyo Seco near Pasadena	16.0
85	11101250	Rio Hondo above Whittier Narrows Dam	91.2
86	11102300	Rio Hondo below Whittier Narrows Dam	124
87	11103000	Los Angeles River at Long Beach	827
		Calleguas Creek basin	
88	11105850	Arroyo Simi near Simi	70.6
89	11106400	Conejo Creek above Highway 101, near Camarillo	64.2
90	11106550	Calleguas Creek at Camarillo State Hospital	248

See footnotes at end of table

selected gaging stations in southern California—Continued
on pl. 1]

Period	Maximum prior to February 1980			Maximum in February 1980			
	Year	Gage height (ft)	Discharge (ft^3/s)	Day	Gage height (ft)	Discharge (ft^3/s)	Recurrence interval (years)
			Santa Ana River basin--Continued				
[4]1973-80	1978	---	[1]4,000	19	4.80	10,600	---
1927-72	1927	---	2,500	17	4.44	407	---
[4]1973-80	1978	4.38	394				
[4]1976-80	1979	5.40	8,380	16	5.08	11,100	---
[4]1961-80	1969	10.50	6,520	18	9.03	1,810	9
[4]1928-80	1969	[2]9.10	6,600	16	5.82	1,560	---
1923-40	1938	[2]10.20	46,300	16	9.62	---	---
[4]1941-80	1969	6.90	19,100	18	9.10	17,800	---
			San Gabriel River basin				
[4]1942-80	1969	22.20	30,900	17	19.51	18,500	---
[4]1955-80	1969	10.90	46,600	17	10.70	43,800	---
[4]1942-80	1979	---	1,190	18	---	[3]1,700	---
[4]1941-80	1969	7.32	313	18	7.69	299	---
[4]1959-80	1980	6.70	2,050	16	6.50	1,950	25
			Los Angeles River basin				
[4]1929-80	1978	12.04	14,700	16	---	15,100	25
[4]1932-80	1938	---	[1]54,000	17	4.75	5,020	---
[4]1910-80	1938	9.42	8,620	16	6.06	3,080	10
[4]1956-80	1969	7.23	17,700	16	7.35	18,200	---
[4]1966-80	1969	13.82	38,800	14	10.50	23,700	---
[4]1928-80	1969	16.00	102,000	16	17.99	129,000	---
			Calleguas Creek basin				
1969-80	1978	7.5	7,730	16	8.80	9,310	34
1972-80	1978	20.44	9,830	16	21.67	11,800	10
1968-80	1969	8.50	---	16	10.54	25,300	32
	1978	---	18,700				

TABLE 23.—*Summary of flood stages and discharges at*
[Sites shown

Site	Permanent station number	Stream and place of determination	Drainage area (mi²)
		Santa Clara River basin	
91	11108500	Santa Clara River at Los Angeles-Ventura County line	625
92	11109250	Lockwood Creek at Gorge, near Stauffer	58.7
93	11109600	Piru Creek above Lake Piru	372
94	11109800	Piru Creek below Santa Felicia Dam	425
95	11110500	Hopper Creek near Piru	23.6
96	11111500	Sespe Creek near Wheeler Springs	49.5
97	11113000	Sespe Creek near Fillmore	251
98	11113500	Santa Paula Creek near Santa Paula	40.0
99	11114000	Santa Clara River at Montalvo	1,612
		Ventura River basin	
100	11115500	Matilija Creek at Matilija Hot Springs	54.6
101	11116000	North Fork Matilija Creek at Matilija Hot Springs	15.6
102	11117500	San Antonio Creek at Casitas Springs	51.2
103	11117600	Coyote Creek near Oak View	13.2
104	11117800	Santa Ana Creek near Oak View	9.11
105	11118000	Coyote Creek near Ventura	41.2
106	11118500	Ventura River near Ventura	188
		Carpenteria Creek basin	
107	11119500	Carpenteria Creek near Carpenteria	13.1
		San Ysidro Creek basin	
108	11119660	San Ysidro Creek at Montecito	3.07

See footnotes at end of table

selected gaging stations in southern California—Continued
on pl. 1]

Period	Maximum prior to February 1980: Year	Gage height (ft)	Discharge (ft³/s)	Maximum in February 1980: Day	Gage height (ft)	Discharge (ft³/s)	Recurrence interval (years)
Santa Clara River basin							
[4]1952-80	1969	19.01	68,800	16	6.50	13,900	8
1971-80	1978	7.32	1,070	16	5.45	2,490	---
[4]1939-80	1938	---	35,000	16	7.92	6,900	4
[4]1955-68, 1973-80	1958	3.66	544	19	---	[3]422	---
1930-80	1969	12.72	8,400	16	11.60	8,120	32
1947-80	1978	14.18	10,700	16	10.82	6,780	12
1911-80	1969 1978	[9]24.95 ---	--- 73,000	16	19.53	40,700	13
1927-80	1969	18.18	21,000	16	12.59	11,800	14
[4]1927-80	1969	17.41	165,000	16	10.38	81,400	---
Ventura River basin							
[4]1927-80	1969	16.5	20,000	16	11.19	10,600	10
1928-80	1969	11.0	9,440	16	7.51	3,720	10
1949-80	1969	14.30	16,200	16	10.65	7,380	12
1958-80	1969	12.00	8,000	16	[5]13.72	5,100	10
1938, 1958-80	1969 1978	10.70 ---	--- 5,330	16	9.49	3,830	12
1927-58 [4]1967-80	1938 1978	--- 11.63	11,500 420	16 21	9.69 ---	--- 643	--- ---
1911-14, [4]1929-80	1969 1978	24.3 ---	--- 63,600	16	14.60	37,900	19
Carpenteria Creek basin							
1941-80	1971	14.10	8,880	16	8.50	2,000	8
San Ysidro Creek basin							
[4]1969, 1972-80	1969	---	5,620	16	2.85	332	---

TABLE 23.—*Summary of flood stages and discharges at*
[Sites shown

Site	Permanent station number	Stream and place of determination	Drainage area (mi^2)
		Sycamore Creek basin	
109	11119700	Sycamore Creek at Santa Barbara	3.41
		Mission Creek basin	
110	11119750	Mission Creek near Mission Street, at Santa Barbara	8.38
		Arroyo Burro Creek basin	
111	11119780	Arroyo Burro Creek at Santa Barbara	6.65
		Atascadero Creek basin	
112	11119940	Maria Ygnacio Creek at University Drive, near Goleta	6.35
113	11120000	Atascadero Creek near Goleta	18.9
		San Jose Creek basin	
114	11120500	San Jose Creek near Goleta	5.51
115	11120510	San Jose Creek at Goleta	9.42
		Carneros Creek basin	
116	11120530	Tecolotito Creek near Goleta	4.42
		Gaviota Creek basin	
117	11120550	Gaviota Creek near Gaviota	18.8
		Jalama Creek basin	
118	11120600	Jalama Creek near Lompoc	20.5
		Santa Ynez River basin	
119	11123000	Santa Ynez River below Gibraltar Dam, near Santa Barbara	216
120	11123500	Santa Ynez River below Los Laureles Canyon, near Santa Ynez.	277

See footnotes at end of table

selected gaging stations in southern California—Continued
on pl. 1]

Period	Maximum prior to February 1980 Year	Gage height (ft)	Discharge (ft³/s)	Maximum in February 1980 Day	Gage height (ft)	Discharge (ft³/s)	Recurrence interval (years)
			Sycamore Creek basin				
1970-80	1978	4.65	1,120	16	4.83	582	---
			Mission Creek basin				
1970-80	1973	4.97	2,580	16	5.45	1,300	---
			Arroyo Burro Creek basin				
[4]1970-80	1978	5.67	1,850	16	5.66	1,850	---
			Atascadero Creek basin				
1970-80	1978	5.87	1,650	16	3.69	765	---
1941-80	1973	---	5,380	16	10.27	4,600	13
	1974	[2]13.3	---				
			San Jose Creek basin				
1941-80	1943	12.74	---	16	7.39	1,370	9
	1969	---	2,000				
1970-80	1978	5.65	2,330	16	4.44	1,330	---
			Carneros Creek basin				
1970-72	1971	3.14	397	16	4.47	1,610	5
			Gaviota Creek basin				
1966-80	1967	---	4,000	19	8.13	2,560	5
	1978	9.09	---				
			Jalama Creek basin				
1965-80	1978	11.34	4,020	16	8.36	2,480	7
			Santa Ynez River basin				
[4]1920-80	1969	25.8	54,200	16	[10]16.63	13,600	---
[4]1947-80	1969	18.88	67,500	16	11.84	17,800	---

TABLE 23.—*Summary of flood stages and discharges at*
[Sites shown

Site	Permanent station number	Stream and place of determination	Drainage area (mi²)
		Santa Ynez River basin--Continued	
121	11124500	Santa Cruz Creek near Santa Ynez	74.0
122	11128250	Alamo Pintado Creek near Solvang	29.4
123	11128500	Santa Ynez River at Solvang	579
124	11129800	Zaca Creek near Buellton	32.8
125	11132500	Salsipuedes Creek near Lompoc	47.1
126	11133000	Santa Ynez River at Narrows, near Lompoc	789
127	11134800	Miguelito Creek at Lompoc	11.6
128	11135000	Santa Ynez River at Pine Canyon, near Lompoc	844
		San Antonio Creek basin	
129	11135800	San Antonio Creek at Los Alamos	34.9
130	11136100	San Antonio Creek near Casmalia	135
		Santa Maria River basin	
131	11136800	Cuyama River below Buckhorn Canyon, near Santa Maria	886
132	11137900	Huasna River near Arroyo Grande	103
133	11138500	Sisquoc River near Sisquoc	281
134	11139500	Tepusquet Creek near Sisquoc	28.7
135	11140000	Sisquoc River near Garey	471
136	11141000	Santa Maria River at Guadalupe	1,741

[1]Estimated.
[2]Datum then in use.
[3]Maximum daily.
[4]Regulated.
[5]Backwater or tide affected.

selected gaging stations in southern California—Continued
on pl. 1]

Period	Maximum prior to February 1980			Maximum in February 1980			
	Year	Gage height (ft)	Discharge (ft^3/s)	Day	Gage height (ft)	Discharge (ft^3/s)	Recurrence interval (years)
			Santa Ynez River basin--Continued				
1941-80	1969	14.45	7,050	16	11.15	2,620	6
1969-80	1969	10.32	---	19	5.34	397	---
1970-80	1978	6.80	724				
[4]1928-80	1969	17.1	[1]82,000	19	7.16	21,600	---
1963-80	1969	---	1,390	19	3.83	96	4
	1978	9.66	---				
1941-80	1952	20.8	11,400	16	8.77	4,890	6
[4]1947-80	1969	24.20	80,000	19	11.35	16,300	---
1969-80	1969	5.83	680	16	6.30	787	---
[4]1941-80	1969	24.91	[1]78,000	20	9.66	16,200	---
			San Antonio Creek basin				
1970-80	1978	9.58	1,270	19	3.42	228	---
1955-80	1978	13.22	3,440	16	8.98	967	7
			Santa Maria River basin				
1929-80	1969	---	17,800	17	9.42	---	---
	1978	14.74	---	19	8.97	3,130	5
1929-80	1969	15.90	21,000	18	7.66	2,560	5
1929-80	1966	15.75	23,200	19	7.57	5,120	4
1943-80	1966	5.48	788	18	6.05	301	8
1940-80	1966	13.50	---	19	7.80	7,980	7
	1969	---	24,500				
[4]1940-80	1952	---	32,800	20	7.40	9,700	10
	1969	10.00	---				

[6]Excludes 768 mi^2 above Lake Elsinore.
[7]At site 6.1 mi downstream.
[8]At site 2.5 mi downstream.
[9]From debris wave.
[10]Recorded gage height; gage height from flood marks is 18.5 ft.

TABLE 24.—*Summary of flood stages and dis-*
[Sites shown

Site	Permanent station number	Stream and place of determination	Drainage area (mi²)
1	09479500	Gila River near Laveen	[1]20,615
2	09489000	Santa Cruz River near Laveen	8,581
3	09489100	Black River near Maverick	315
4	09489500	Black River below pumping plant, near Point of Pines	560
5	09489700	Big Bonito Creek near Fort Apache	119
6	09490500	Black River near Fort Apache	1,232
7	09494000	White River near Fort Apache	632
8	09497500	Salt River near Chrysotile	2,849
9	09497800	Cibecue Creek near Chrysotile	295
10	09497980	Cherry Creek near Globe	200
11	09498500	Salt River near Roosevelt	4,306
12	09498508	Upper Parker Creek near Roosevelt[3]	1.09
13	09498870	Rye Creek near Gisela	122
14	09499000	Tonto Creek above Gun Creek, near Roosevelt	675
15	--------	Fish Creek above Lewis and Pranty Creek, near Tortilla Flat.	32.2
16	09501300	Tortilla Creek at Tortilla Flat	24.3
17	09502000	Salt River below Stewart Mountain Dam	6,232
18	09502800	Williamson Valley Wash near Paulden	255
19	09503700	Verde River near Paulden	[5]2,530
20	09503740	Hell Canyon tributary near Ashfork	.75
21	09503750	Limestone Canyon near Paulden	14.50
22	09503800	Volunteer Wash near Bellemont	131
23	09504000	Verde River near Clarkdale	[5]3,520
24	09504400	Munds Canyon tributary near Sedona	1.19

See footnotes at end of table.

charges in the Gila River basin of Arizona
on pl. 2]

Period	Maximum prior to February 1980			Maximum in February 1980			
	Year	Gage height (ft)	Discharge (ft^3/s)	Day	Gage height (ft)	Discharge (ft^3/s)	Recurrence interval (years)
1940-80	1941 1978	--- 10.20	11,900 ---	23	7.49	545	1
1940-80	1962	17.50	9,200	20	9.36	115	1
1962-80	1972	8.99	11,100	19	3.46	856	1
1953-80	1972	18.0	17,900	15	10.65	6,640	7
1957-80	1978 1978	9.09 ---	--- 4,510	15	8.19	3,440	25
1912-80	1916	---	[2]50,000	15	24.0	40,000	25
1957-80	1978	15.71	14,600	15	12.07	8,160	11
1906-80	1916	18	74,000	15	16.06	58,300	25
1959-80	1977	17.3	22,200	15	11.67	10,600	8
1965-80	1979	---	15,700	15	13.8	13,500	16
1906-80	1941 1978	--- 29.35	117,000 ---	15	28.0	99,000	25
1934-80	1945	---	270	15	3.86	68.8	8
1963-80	1970	14.1	44,400	19	5.75	4,550	3
1940-80	1979	17.0	61,400	15	17.0	61,400	25
1978-80	1978	---	2,650	15	---	2,450	8
1942-80	1971	13.23	7,500	15	9.9	4,250	4
[4]1930-80	1979	23.3	65,000	15	25.0	75,200	---
1965-80	1980	8.23	7,520	20	8.93	10,100	20
1963-80	1980	10.24	8,870	20	12.72	15,700	33
1964-80	1969	7.60	84	([6])	5.78	20	---
1969-80	1971	16.51	4,100	15	5.11	500	3
1966-80	1978	6.55	2,300	([6])	5.42	1,150	---
1915-21, 1965-80	1920	[7]19.1	50,600	15	17.92	30,100	---
1964-80	1970	11.10	705	([6])	6.61	180	---

TABLE 24.—*Summary of flood stages and discharges*
[Sites shown

Site	Permanent station number	Stream and place of determination	Drainage area (mi^2)
25	09504500	Oak Creek near Cornville	357
26	09504800	Oak Creek tributary near Cornville	.048
27	09505200	Wet Beaver Creek near Rimrock	111
28	09505250	Red Tank Draw near Rimrock	49.4
29	09505255	Woods Canyon near Munds Park[3]	18.9
30	09505260	Bar M Canyon near Munds Park[3]	25.6
31	09505300	Rattlesnake Canyon near Rimrock	24.6
32	09505350	Dry Beaver Creek near Rimrock	142
33	09505550	Verde Creek below Camp Verde	[5]4,670
34	09505800	West Clear Creek near Camp Verde	241
35	09507980	East Verde River near Childs	328
36	09508300	Wet Bottom Creek near Childs	36.4
37	09508500	Verde River below Tangle Creek, above Horseshoe Dam	[5]5,872
38	--------	Deadman Creek near Horseshoe Dam	36.3
39	--------	Lime Creek near Horseshoe Dam, near Carefree	41.9
40	--------	Davenport Creek near Horseshoe Dam	25.5
41	--------	Sheep Creek near Horseshoe Dam	34.2
42	09510000	Verde River below Bartlett Dam	[5]6,185
43	09510100	East Fork Sycamore Creek near Sunflower	4.49
44	09510200	Sycamore Creek near Fort McDowell	164
45	09512170	Salt River at Jointhead Dam, at Phoenix	13,500
46	09512280	Cave Creek below Cottonwood Creek, near Cave Creek	82.7
47	09512500	Agua Fria River near Mayer	588

See footnotes at end of table.

in the Gila River basin of Arizona—Continued
on pl. 2]

Period	Maximum prior to February 1980			Maximum in February 1980			
	Year	Gage height (ft)	Discharge (ft^3/s)	Day	Gage height (ft)	Discharge (ft^3/s)	Recurrence interval (years)
1885-1980	1938	[8]23	---	20	16.30	26,400	25
1940-80	1970	16.48	---				
	1978	---	25,100				
1963-80	1969	6.51	53	([6])	4.54	24	7
1961-80	1970	12.41	7,670	19	13.96	10,900	14
1957-80	1970	13.3	10,500	([6])	10.73	6,000	12
1961-80	1970	7.9	3,990	14	5.24	1,720	---
1961-80	1970	9.35	---	19	4.88	1,530	---
	1978	---	4,210				
1957-80	1970	11.50	3,590	14	11.90	4,000	---
1960-80	1970	14.35	26,600	14	12.53	18,600	9
1970-80	1978	21.27	55,000	15	19.30	50,900	6
1964-80	1978	11.6	22,400	19	10.42	15,100	7
1961-80	1970	20.5	23,500	20	15.10	14,100	7
1967-80	1978	15.72	6,680	19	16	6,830	11
1924-80	1938	19.0	100,000	15	21.41	94,800	20
1978-80	1978	---	6,620	([6])	---	3,220	12
1978-80	1978	---	5,180	([6])	---	7,860	33
1978-80	1978	---	5,500	([6])	---	2,670	9
1978-80	1978	---	6,660	([6])	---	2,640	8
1888-1939	1891	---	[9]150,000	15	25.4	97,300	---
[4]1939-80	1978	25.9	101,000				
1959-80	1970	9.50	1,940	19	4.82	300	6
1959-80	1970	19.7	24,200	15	11.42	10,400	6
1871-1938	1891	---	300,000	16	[10]11.45	170,000	---
[4]1939-80	1978	---	126,000				
1980	---	---	---	19	9.5	7,020	---
1940-80	1970	14.90	---	19	15.76	33,100	>100
	1978	---	[10]26,700				

TABLE 24.—*Summary of flood stages and discharges*
[Sites shown

Site	Permanent station number	Stream and place of determination	Drainage area (mi²)
48	09512600	Turkey Creek near Cletor	89.4
49	09512700	Agua Fria River tributary No. 2 near Rock Springs	1.11
50	09512800	Agua Fria River near Rock Springs	1,130
51A	09513000	Agua Fria River at (above) Waddell Dam	1,459
51B	09513000	Agua Fria River at (below) Waddell Dam	1,459
52	09513650	Agua Fria River at El Mirage	1,637
53	09513780	New River near Rock Springs	67.3
54	09513800	New River at New River	83.3
55	09513835	New River at Bell Road, near Peoria	187
56	09513860	Skunk Creek near Phoenix	64.6
57	09513970	Agua Fria River at Avondale	2,018
58	09515000	Hassayampa River at Walnut Grove, near Wagoner	90.9
59	09515500	Hassayampa River at Box damsite, near Wickenburg	417
60	09516500	Hassayampa River near Morristown	774
61	09517000	Hassayampa River near Arlington	1,470
62	09519500	Gila River below Gillespie Dam	49,650
63	09519800	Gila River below Painted Rock Dam	50,910
64	09520360	Gila River near Mohawk	55,430
65	09520500	Gila River near Dome	57,850
66	09520700	Gila River near mouth, near Yuma	59,950

[1]Of which 7,729 mi² is downstream from Coolidge Dam.
[2]Estimated on basis of records for Salt River near Chrysotile.
[3]Part of a U.S. Forest Service small watershed project. Several nearby stations are not included.
[4]Regulated.
[5]Includes 373 mi² in Aubrey Valley Playa, a closed basin.
[6]Date unknown.

in the Gila River basin of Arizona—Continued
on pl. 2]

Period	Maximum prior to February 1980			Maximum in February 1980			
	Year	Gage height (ft)	Discharge (ft^3/s)	Day	Gage height (ft)	Discharge (ft^3/s)	Recurrence interval (years)
1970-80	1970	16.0	9,000	19	11.51	5,230	---
1963-80	1964	19.54	1,200	([6])	6.32	405	4
1970-80	1978	27.2	52,800	19	28.15	59,500	---
1891-1980	1919	[7]33.0	<105,000	20	---	73,300	---
[4]1927-80	1978	---	59,500	20	---	66,600	---
[4]1963-80	1978	11.70	58,400	20	10.14	41,800	---
1960-80	1970	13.5	18,600	19	8.13	9,350	6
1960-80	1970	9.98	19,500	19	11.44	14,900	10
1960-80	1967	13.5	14,600	20	8.91	21,100	8
1959-80	1964 1970	--- 12.24	11,500 ---	20	7.60	1,210	3
[4]1959-80	1970 1978	11.21 6.08	--- 29,200	20	6.77	44,200	---
1980	---	---	---	19	5.08	3,760	---
1891-1978	1970	34.6	58,000	19	18.9	24,900	25
1916-80	1970	19.0	47,500	20	14.32	17,000	10
1961-80	1970	8.40	39,000	20	2.76	11,000	7
1891-1920 1921-80	1891 1978	- 17.06	250,000 125,000	17	18.81	178,000	---
[4]1959-80	1979	10.57	3,340	([11])	10.02	5,060	---
[4]1966-80	1979	11.12	3,080	([11]) ([11])	12.0 ---	--- 4,070	---
1903-58 [4]1959-80	1916 1979	--- 12.17	[12]200,000 3,330	([11])	6.94	4,080	---
[4]1975-80	1979	---	2,580	([11])	---	[12]3,720	---

[7]Site and datum then in use.
[8]Upstream from bridge; gage is on downstream side of bridge.
[9]Estimated on basis of records for Salt River above and below Verde River.
[10]Revised.
[11]After February.
[12]Maximum daily.

TABLE 25.—*Known aerial photographic coverage of southern California available from government agencies for the floods of January and February 1980*

Area of photography	Date
Coachella Valley Water District, Coachella, California	
Whitewater River from Salton Sea to Windy Point; approximately 55 miles	Feb. 24 and Feb. 25, 1980
International Boundary and Water Commission, United States and Mexico, United States Section, El Paso, Texas	
Tijuana River from international boundary to the Pacific Ocean	Jan. 31, 1980 Mar. 20, 1980
Los Angeles County Flood Control District, Los Angeles, California	
Van Tassel Canyon	Feb. 20, 1980
Santa Anita Canyon-Wilderness Park	Do.
Lannan debris basin and debris disposal area	Do.
Sturtevant debris basin	Do.
Sierra Madre Dam	Do.
Carter debris basin and Carter Crib Dam	Do.
Auburn debris basin and Floral debris basin	Do.
Bailey debris basin and Sunnyside debris basin	Do.
Sunnyside debris basin and Carriage House debris basin	Do.
Hastings debris disposal area and Sierra Madre Villa debris basin	Do.
Kinneloa debris disposal area and Eaton debris disposal area	Do.
Eaton Reservoir above New York Dr.	Do.
West of Eaton Reservoir	Do.
Santa Anita debris basin	Do.
Sturtevant debris basin	Do.
Yucca Canyon	Do.
Carter Canyon West debris basin	Do.
Eaton Dam and Reservoir	Do.
Kinneloa East and Kinneloa West debris basins	Do.
Gooseberry debris basin	Do.
Rubio debris basin	Do.
Las Flores debris basin	Do.
Devonwood debris basin	Do.
Eaton Canyon and Allen Reservoir	Do.
Allen Reservoir	Do.
Tanoble Crib Dam	Do.
Gooseberry Creek	Do.

TABLE 25.—*Known aerial photographic coverage of southern California available from government agencies for the floods of January and February 1980*—Continued

Area of photography	Date
Los Angeles County Flood Control District, Los Angeles, California--Continued	
Las Flores debris basin and private drain 331	Feb. 20, 1980
Tujunga Wash--Foothill Blvd. to 1,500 ft ± upstream Mt. Gleason Ave.	Do.
Mandeville Canyon--Sunset Blvd. to Mulholland Dr.	Do.
Rustic Canyon--Pacific Ocean to 4 miles + above Sunset Blvd.	Do.
Topanga Canyon--Pacific Ocean to Glenview "Community"	Do.
Malibu Canyon--Pacific Ocean to Piuma Rd.	Do.
Zuma Canyon--Pacific Ocean upstream 2.4 miles ±	Do.
Trancas Canyon--Pacific Ocean upstream	Do.
Dry Canyon--Ventura Freeway to Calabasas Highlands	Do.
Arroyo Seco--Slide area	Do.
Santa Clara River--Ventura County line to San Martinez Chiquito Canyon	Do.
Santa Clara River--San Martinez Chiquito Canyon to Castaic Junction	Do.
Santa Clara River--Castaic Junction to Bouquet Junction	Do.
Santa Clara River--Bouquet Junction to Sierra Highway (Mint Canyon)	Do.
Santa Clara River--Sierra Highway to Bee Canyon	Do.
Santa Clara River--Bee Canyon to Mill Canyon	Do.
Santa Clara River--Mill Canyon to Aliso Canyon	Do.
Big Tujunga Reservoir and debris disposal area	Do.
Cogswell Reservoir	Do.
Cogswell Reservoir-Devil's Canyon	Do.
San Gabriel River West Fork-North Fork to Big Mermaids Canyon	Do.
Morris Reservoir--Morris Dam to San Gabriel Dam	Do.
San Dimas Canyon--Puddingstone Diversion Dam to San Dimas debris deposal area	Do.
Thompson Creek--Live Oak debris basin to Thompson Reservoir	Do.
Monterey County Flood Control and Water Conservation District, Monterey, California	
Carmel River from Carmel Village west to Pacific Ocean, about 12 miles (River meanders caused by flood)	June 1980

TABLE 25.—*Known aerial photographic coverage of southern California available from government agencies for the floods of January and February 1980*—Continued

Area of photography	Date
Riverside County Flood Control and Water Conservation District, Riverside, California	
San Jacinto River from just above Bautista Creek, the city of San Jacinto and area downstream that was underwater, to 1 mile southwest of Perris Valley Airport	Feb. 21, 1980
Salt Creek from Railroad Canyon Reservoir upstream to just west of Hemet	Feb. 23, 1980
Day Creek from Santa Ana River upstream to [illegible] mile south of Route 10	Feb. 27, 1980
Temescal Creek from Prado Flood Control basin upstream to just beyond Magnolia Ave. in Home Gardens	Feb. 22, 1980
Murrieta Creek from confluence with Temecula Creek upstream to Wildomar	Feb. 26, 1980
Temecula Creek from confluence with Murrieta Creek upstream about 4.0 miles, including Pechanga Creek and other smaller tributaries from the south on the Pechanga Indian Reservation	Feb. 26, 1980
Lake Elsinore--Entire lake and peripheral area, extending southeasterly toward Wildomar	Mar. 13, 1980
Palm Canyon Creek from just upstream from Highway 111 in Palm Springs, upstream to about Hermits Beach in the Agua Caliente Indian Reservation. (Also, see Tahquitz Creek.)	Feb. 22, 1980
Tahquitz Creek from upstream from Highway 111 in Palm Springs downstream to mouth; includes Palm Canyon Creek downstream from Highway 111 to mouth	Feb. 27, 1980
San Bernardino County Flood Control District, San Bernardino, California	
Harrison Canyon debris basin located at 40th St. and Harrison Ave. in San Bernardino and area about 0.5 mile wide by 2.0 miles long lying in a northeasterly direction above the basin	Jan. 19, 1980 Feb. 1, 1980 Feb. 23, 1980 Mar. 13, 1980 Apr. 9, 1980
Prado Dam Reservoir on Santa Ana River just after maximum storage occurred; consists of five verticals and four obliques, in color	Feb. 24, 1980

TABLE 25.—*Known aerial photographic coverage of southern California available from government agencies for the floods of January and February 1980*—Continued

Area of photography	Date
U.S. Army Corps of Engineers, South Pacific Division, Los Angeles District, Los Angeles, California	
Lake Elsinore, perimeter of lake defined by high-water marks	Feb. 27, 1980
U.S. Geological Survey, California District, San Diego Project Office, San Diego, California	
San Diego River from Pacific Ocean upstream to Route 67 just east of Lakeside	Feb. 22, 1980
Cottonwood Creek from Barrett Junction (below Barrett Reservoir) to confluence with Tecate Creek; then Tijuana River to international boundary	Feb. 22, 1980
Tijuana River from international boundary at Interstate 5 to Pacific Ocean	Feb. 22, 1980
Ventura County Public Works Agency, Ventura, California	
Conejo Creek--Calleguas Creek to Hill Canyon	Feb. 23, 1980
San Antonio Creek--Ventura River to the East Ojai Valley	Feb. 24, 1980
Sespe Creek--Santa Clara River to Devils Gate	Feb. 26, 1980
Canada Larga Creek--Ventura River to 5,000 ft upstream	Feb. 24, 1980
Ventura River from mouth to Matilija Dam	Feb. 24, 1980
Santa Clara River from mouth to Los Angeles County line	Feb. 24, 1980
Calleguas Creek from Hueneme Rd. to Seminary Rd.	Feb. 22, 1980
Arroyo Las Posas from Seminary Rd. to Hitch Blvd.	Feb. 23, 1980
Arroyo Simi--Hitch Blvd. to Yosemite Ave. (Simi Valley)	Feb. 23, 1980
Real Canyon (Piru)--Santa Clara River debris basin	Mar. 31, 1980
Harmon Barranca (Ventura)--Santa Clara River to Santa Paula Freeway	Feb. 24, 1980
Santa Paula Creek--Santa Clara River to Steckel Park	Feb. 24, 1980
Arundell Barranca Flood Plain--Ventura	Feb. 26, 1980
Revolon Slough--Pleasant Valley Rd. to Ventura Freeway	Feb. 22, 1980
Beardsley Wash--Ventura Freeway through Wright Rd.	Feb. 22, 1980
Nyeland Acres--Vicinity of Santa Clara Ave. and the Ventura Freeway	Feb. 22, 1980
Pleasant Valley Rd.--Highway 1 to Camarillo Airport	Feb. 22, 1980
Camarillo Airport--Vicinity of Camarillo Airport	Feb. 22, 1980
Rice Rd.--Vicinity of Highway 1 and Rice Rd., Oxnard	Feb. 22, 1980
Brown Barranca--Santa Clara River to Santa Paula Freeway	Feb. 24, 1980

TABLE 25.—*Known aerial photographic coverage of southern California available from government agencies for the floods of January and February 1980*—Continued

Area of photography	Date
Ventura County Public Works Agency, Ventura, California--Continued	
Franklin Barranca--Santa Clara River to Telegraph Rd.	Feb. 24, 1980
Arundell Barranca--Pacific Ocean debris basin	Feb. 26, 1980
Piru Creek--Santa Clara River to Southern Pacific railroad tracks	Feb. 26, 1980
Grimes Canyon (Bardsdale)--Santa Clara River to 10,000 ft southerly	Feb. 26, 1980
Thacher Creek--Highway 150 to Thacher School	Feb. 24, 1980
Reeves Creek--Sieta Robles Tract to end of Reeves Rd.	Feb. 24, 1980
McNell Creek--Santa Antonio Creek to Los Padres National Forest	Feb. 24, 1980
Orcuit Canyon--Santa Clara River to headwaters	Feb. 26, 1980