STREAMFLOW, SEDIMENT DISCHARGE, AND STREAMBANK EROSION IN CACHE CREEK, YOLO COUNTY, CALIFORNIA, 1953-86

By *Jerry G. Harmon*

U.S. GEOLOGICAL SURVEY

Water-Resources Investigations Report 88-4188

Sacramento, California
1989

DEPARTMENT OF THE INTERIOR

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CONVERSION FACTORS

For readers who prefer to use metric and International System (SI) units rather than inch-pound units, the conversion factors for the terms used in this report are as follows:

Multiply	By	To obtain
acre	0.4047	hectare
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot	0.3048	meter
inch	25.40	millimeter
mile	1.609	kilometer
square foot (ft^2)	0.09294	square meter
square foot per foot (ft^2/ft)	0.3048	square meter per meter
square mile (mi^2)	2.590	square kilometer
ton, short	0.9072	megagram
ton per day (ton/d)	0.9072	megagram per day

DEFINITION OF TERMS

Water year: A water year is a 12-month period that begins October 1 and ends September 30 and is designated by the calendar year in which it ends. All references to years are to water years in this report unless otherwise noted.

Sea Level: Sea level in this report refers to the National Geodetic Vertical Datum 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.

TRADE NAMES

The use of trade names in this report is for identification purposes only and does not constitute endorsement by the Geological Survey.

STREAMFLOW, SEDIMENT DISCHARGE, AND STREAMBANK EROSION IN CACHE CREEK, YOLO COUNTY, CALIFORNIA, 1953-86

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ABSTRACT

Authorized enlargement of the outlet channel of Clear Lake is intended to control flooding of lakefront property by increasing the potential maximum flow release to Cache Creek, which flows through Capay Valley in Yolo County, California. Property owners in Capay Valley are concerned that streambank erosion rates will increase when flow releases from Clear Lake are increased. The purpose of this report is to define present channel characteristics and rates of flow related to streambank erosion. Between 1953 and 1984, about 300 acres of streambank have eroded along Cache Creek in Capay Valley. This streambank erosion was related to volumes of daily flow greater than 6,000 acre-feet. Areas of eroded streambanks were measured by comparing banklines shown in aerial photographs taken over several years.

Mean bed elevations at six cross sections during 1983-86 and at two cross sections over several years indicate general stability of elevations in the gravel-bed channel. The range of water-surface slope was from 0.13 percent to 0.51 percent in four reaches during two flood peaks. The Cache Creek channel in the study area is classified sinuous, and net lateral migration has been toward the right bank.

INTRODUCTION

Background

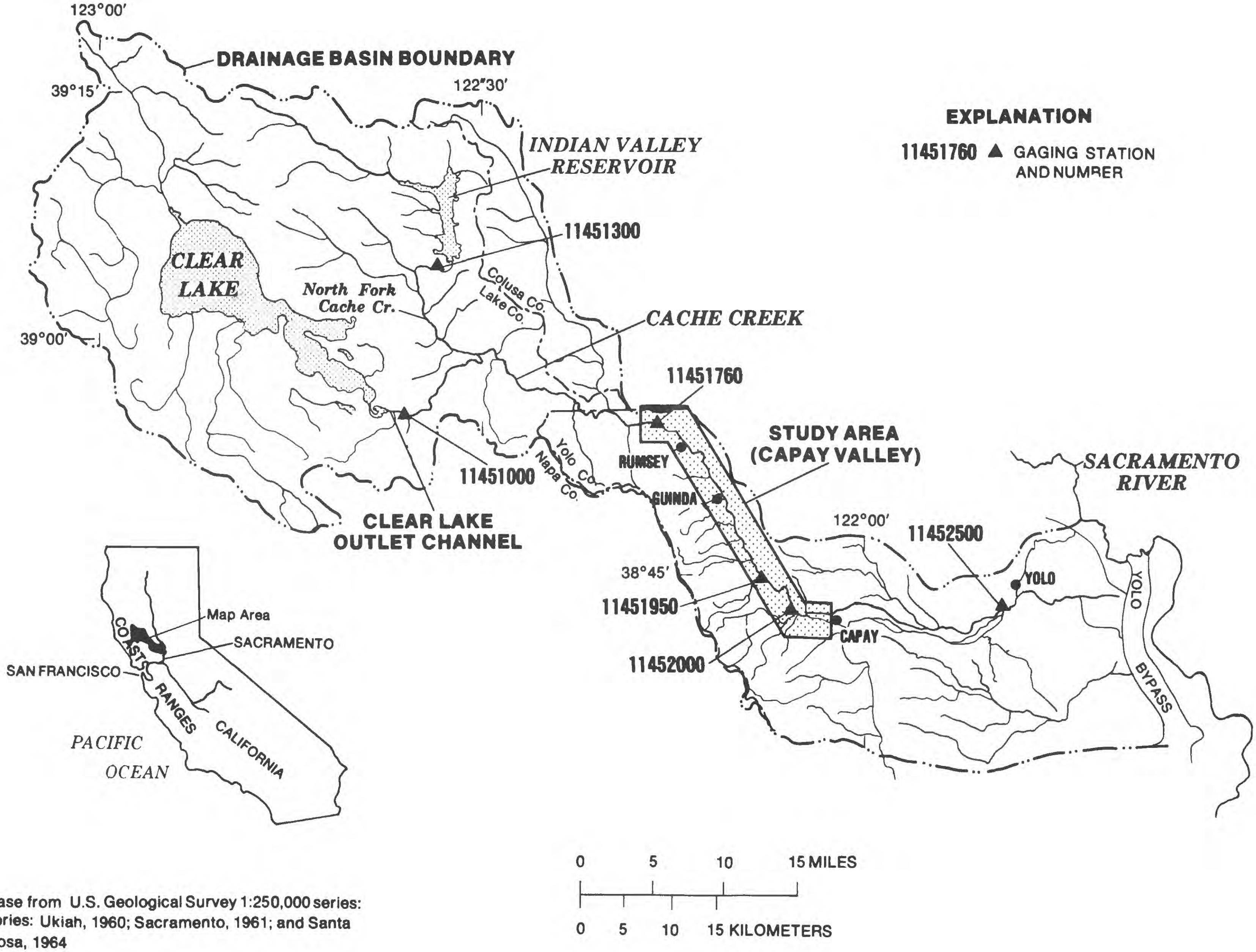
Cache Creek flows from the outlet channel of Clear Lake in Lake County, California (fig. 1). This channel is small enough to restrict outflow from the lake, and flooding of residential and commercial property bordering Clear Lake resulted in 1938, 1958, 1970, 1983, and 1986. Flooding before 1983 is described by the U.S. Army Corps of Engineers (1975). During 1983, rainfall in Lake County exceeded 200 percent of normal (Fogelman and others, 1984). Storm runoff caused Clear Lake to rise to its highest recorded level, and the town of Lakeport was inundated. During a public meeting after the 1983 flood, a plan to enlarge the outlet channel of Clear Lake was presented. The increase in flow-release capability provided by a larger outlet channel would control flooding at Clear Lake. At the meeting, owners of property near Cache Creek in Capay Valley, Yolo County, California, (fig. 1) expressed concern that an increase in streamflow rates from Clear Lake would increase streambank erosion rates in Capay Valley. In October 1983, the U.S. Geological Survey began a study of streamflow, sediment discharge, channel geometry, and streambank erosion in Capay Valley to establish base data and to relate streamflow to streambank erosion.

Purpose and Scope

The purpose of this report is to present data that can be used to determine the effect of increased streamflow releases on streambank erosion in Capay Valley. The data collected and assembled during 1983-86 include streamflow (1953-86), sediment discharge (1960-63 and 1984-86), size analyses of bed and bank material (1984-86), cross sections of the channel (1984-86), water-surface profiles (1984-86), and measured areas of eroded streambanks (1953-84). Streamflow and sediment discharges were measured at stage-recording gages above Rumsey and near Brooks. Cross sections of the channel of Cache Creek were surveyed at 49 sites in the study area (fig. 2). Elevations of highwater marks at selected cross sections after peak flows of December 1983, February 1985, and February 1986 were documented by level surveys. Cross sections monumented for future recovery and elevations of highwater marks were referenced to sea level. Samples of bed and bank material were collected at most of the cross sections. Daily streamflow records were used to compute volumes of high flows in Cache Creek between 1953 and 1984. Areas of eroded streambanks were measured for each interval between dates when aerial photographs were taken.

Approach

Streamflow ratings were developed from a series of measurements made over a range of flows to provide continuous records of streamflow at stage-recording gages (fig. 2). Samples of bed and bank material and of suspended sediment were analyzed to define the distribution of clay, silt, sand, gravel, cobbles, and boulders in the channel and in the water. Data from bed-material size analyses, level surveys, and streamflow measurements were used to compute bedload discharges; bedload discharges also were measured directly with a Helley-Smith bedload sampler. Concentrations of suspended sediment in periodic samples of water and sediment were plotted to provide points for a daily concentration curve for the months of November through May each water year from 1984 to 1986. Coordinate points and elevations of highwater marks at selected cross sections were referenced to local bench marks that are related to sea level. Cross sections at five sites were surveyed in November 1983, June 1984, September 1985, and September 1986 to verify changes in streambank locations shown in aerial photographs. Water-surface slopes were computed by dividing differences in elevations of highwater marks at cross sections by channel distances between cross



Base from U.S. Geological Survey 1:250,000 series: series: Ukiah, 1960; Sacramento, 1961; and Santa Rosa, 1964

FIGURE 1.— Location of study area.

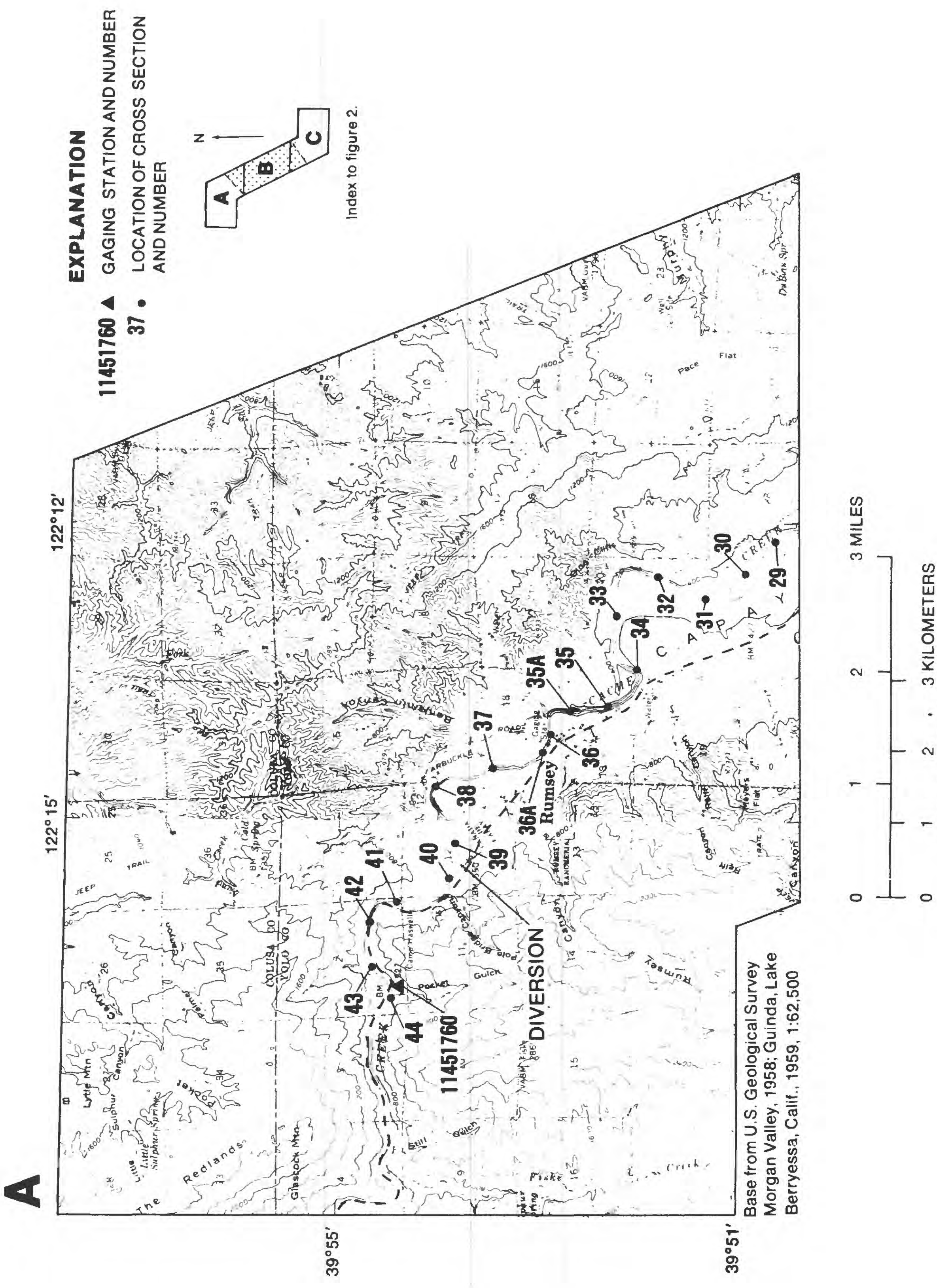
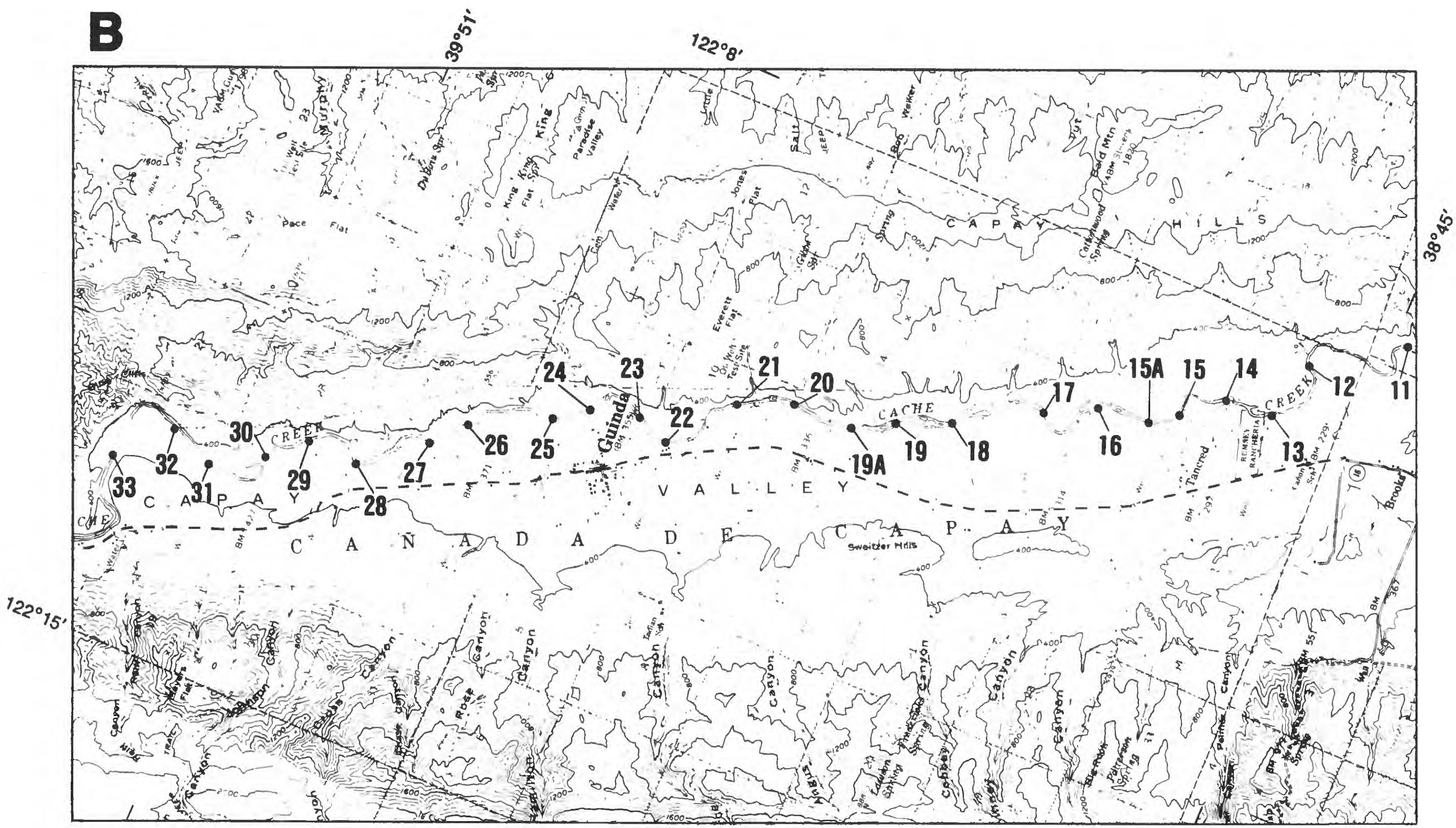


FIGURE 2.—Gaging stations and cross sections in the study area.



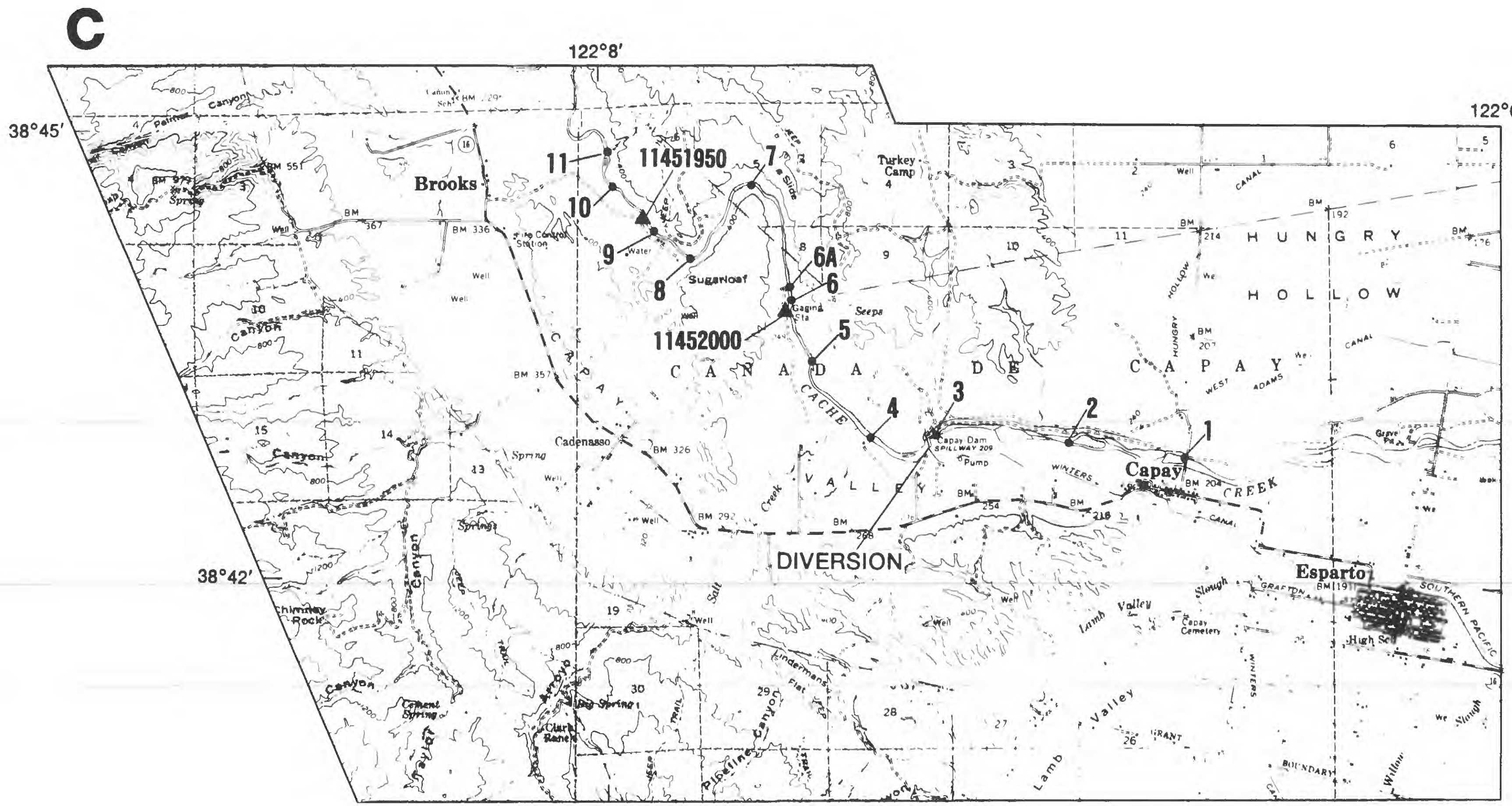
Base from U.S. Geological Survey
Morgan Valley, 1958; Guinda, Lake
Berryessa, Calif., 1959, 1:62,500

0 1 2 3 MILES

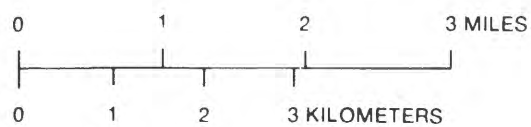
0 1 2 3 KILOMETERS

CONTOUR INTERVAL 80 FEET
Datum is sea level

FIGURE 2.— Gaging stations and cross sections in the study area—Continued.



Base from U.S. Geological Survey
Morgan Valley, 1958; Guinda, Lake
Berryessa, Calif., 1959, 1:62,500



CONTOUR INTERVAL 80 FEET
Datum is sea level

FIGURE 2.– Gaging stations and cross sections in the study area–Continued

sections. A series of highwater marks was surveyed at selected cross sections after annual peak flows during water years 1984, 1985, and 1986. Aerial photographs were used to provide horizontal control for surveys of highwater marks and cross sections.

Areas eroded at streambanks were measured by comparing bankline locations shown on aerial photographs taken in calendar years 1953, 1957, 1964, 1972, 1983, and 1984. Sources of aerial photographs were the U.S. Army Corps of Engineers, the U.S. Soil Conservation Service, and the U.S. Geological Survey. Boundaries of eroded areas were drawn by tracing banklines, shown on the aerial photographs, onto tracing paper and then tracing banklines shown on photographs taken on the next later date. Landmarks on each photograph were identified and matched before banklines were compared and traced. Areas outlined on tracing paper were measured with a digitizer. Eroded areas outlined from pairs of photographs (1953-57, 1957-64, 1964-72, 1972-83, and 1983-84) provided measurements for five periods.

Minimum flow that is related to bank erosion was estimated by extrapolating curves that relate areas of erosion to daily volumes of flows at the Cache Creek near Capay streamflow-gaging station (fig. 3). Daily mean flows, in cubic feet per second, were converted to daily volumes of flow, in acre-feet, in order to relate volumes above a given minimum to areas of erosion during selected periods. Volumes of flow were computed for all days during water years 1953-85 when daily mean flows were greater than 2,500 ft^3/s. These computed volumes of flow were added to obtain the total volumes of flow greater than selected minimums for the period included in each set of photos used to measure erosion. Volumes of flow were converted from daily mean flows greater than 5,000, 3,000, and 2,500 ft^3/s. Extrapolation (fig. 3) indicates that erosion approaches zero as the volume of flow decreases to 6,000 acre-feet (converted from a daily mean flow of 3,000 ft^3/s). Daily mean flows do not indicate fluctuations or maximum values, and erosive flows must vary along the creek; the minimum value, therefore, is an estimate based on flows near the downstream end of the study reach.

Description of the Study Area

The Cache Creek drainage basin, including Clear Lake drainage basin, is in the Coast Ranges northwest of Sacramento, California (fig. 1). Streamflow in Cache Creek begins at the controlled outlet channel of Clear Lake in Lake County. Cache Creek flows from Clear Lake through Cache Creek Canyon, a narrow and steep 30-mile reach, to Capay Valley in Yolo County. The creek flows through the Capay and Sacramento Valleys to the Yolo bypass, a flood-control channel for the Sacramento River (fig. 1). Creek flow is controlled at the dam at Indian Valley Reservoir on North Fork Cache Creek (fig. 1). Two diversions (fig. 2) supply irrigation water to Capay Valley and downstream areas during the summer. The dam near Rumsey diverts less than 3 percent of low flows, but the dam near Capay diverts nearly all the flow reaching that point during the dry season. The low-water diversion dams have no significant effect on high flows.

The climate of the study area is characterized by cool, moist winters and warm, dry summers. Mean annual precipitation in Cache Creek drainage basin ranges from about 17 inches at the lower end of the basin to about 50 inches at the upper end. Most of the precipitation falls as rain from storms moving inland from the Pacific Ocean. About 85 percent of the annual precipitation occurs during November through March. Mean annual precipitation in Capay Valley is about 23 inches (Lustig and Busch, 1967).

Open stands of oak trees and chaparral grow on the hills surrounding Capay Valley. Oak, pine, cottonwood, willow, and black-walnut trees grow near Cache Creek and its tributaries in Capay

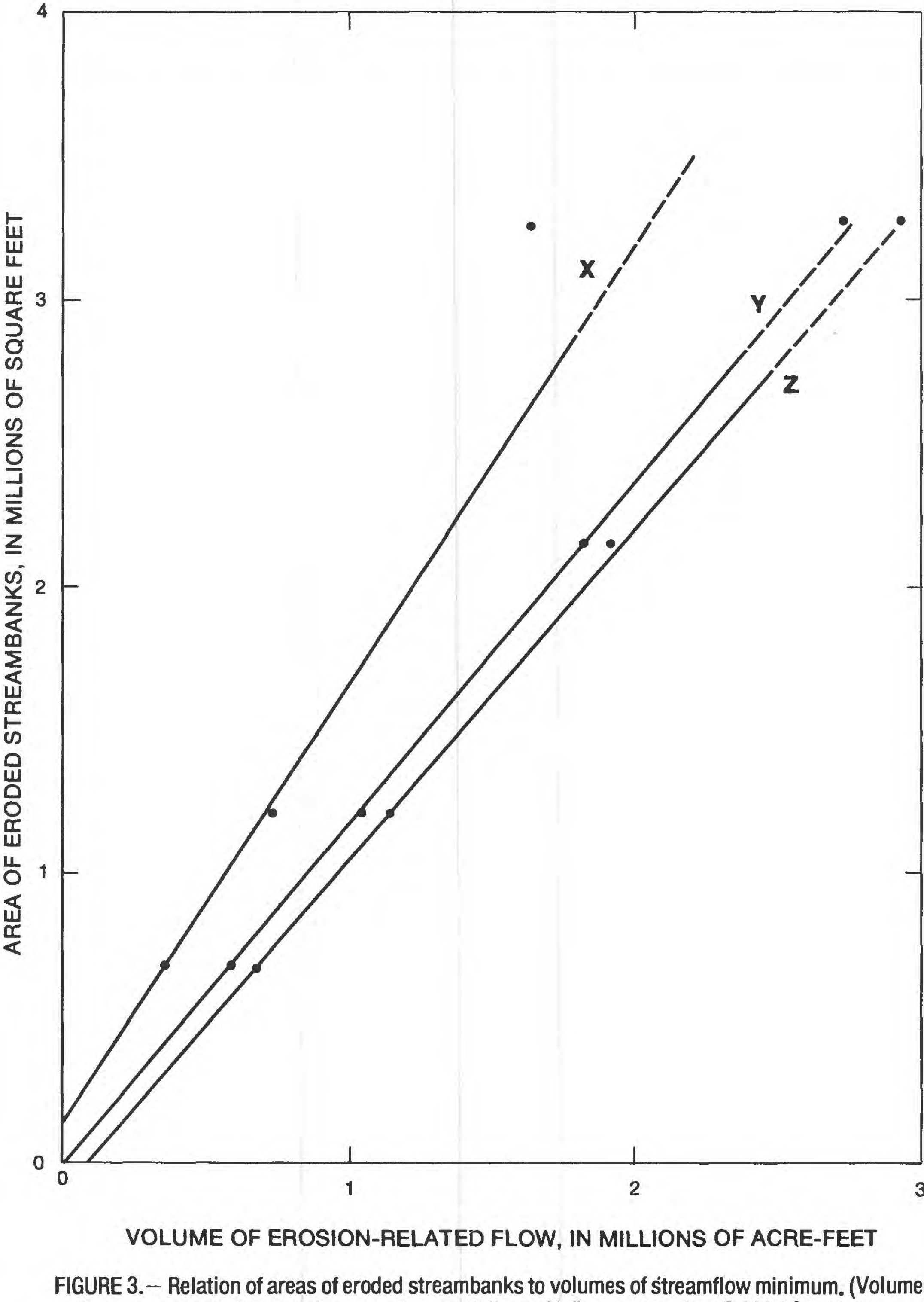


FIGURE 3.— Relation of areas of eroded streambanks to volumes of streamflow minimum. (Volumes of flow are converted from daily mean flows as follows: X, flow greater than 5,000 ft^3/s; Y, flow greater than 3,000 ft^3/s; and Z, flow greater than 2,500 ft^3/s.)

Valley. Tamarisk and willows are dominant plants on sand bars in the channel of Cache Creek. Annual grasses and forbs dominate the uncultivated grasslands in the area. Before development, Capay Valley was covered by a dense oak forest (Andrews, 1972).

Virtually all land in Capay Valley and the surrounding hills is used for agriculture. Almond and English-walnut orchards, alfalfa, and row crops are cultivated in the floodplain of the valley. Cattle, horses, and sheep are raised on grasslands and irrigated pastures where soils are not suitable for cultivation. Irrigation water occasionally is pumped directly from the creek by farms and ranches not served by canals or wells.

Geology and Soils

Upstream from Capay Valley, the Cache Creek drainage basin is underlain by Lower Cretaceous marine formations, Pliocene and Pleistocene continental deposits, and the Franciscan Complex (Lustig and Busch, 1967). Capay Valley and the adjacent hills are underlain by Upper Cretaceous marine formations, Pliocene and Pleistocene continental deposits, and the Tehama Formation. The marine formations contain shale and sandstone; the continental deposits contain silt-clay, sand, and gravel; the Franciscan Complex contains volcanic and marine sedimentary rocks; and the Tehama Formation contains cemented or partly cemented sand and gravel beds, partially cemented silt, and clay (Olmsted and Davis, 1961). Although the formations and continental deposits generally are overlain by alluvium and soils, many of them are partly exposed in the basin.

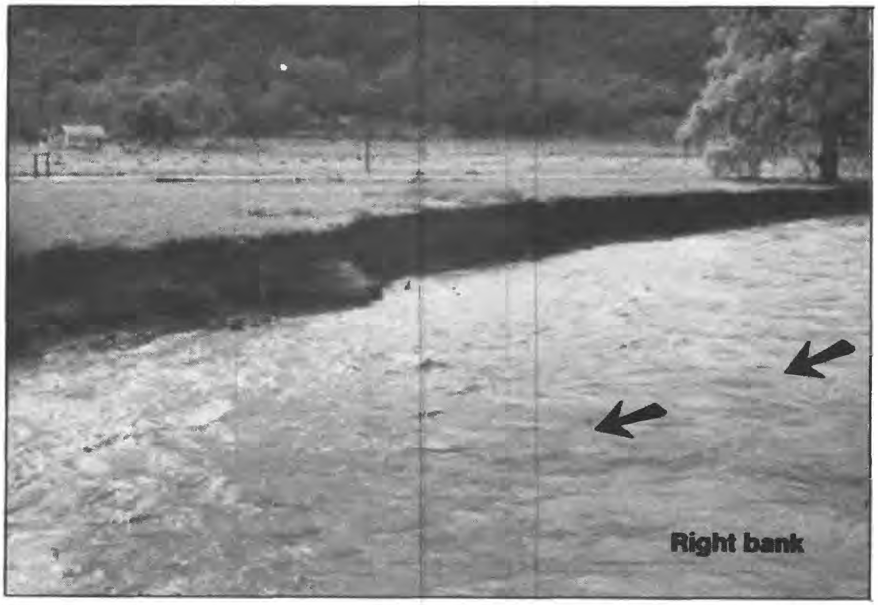
Nine types of soil bordering Cache Creek have been mapped in Capay Valley and the adjacent hills (Andrews, 1972). Brentwood and Yolo soils are high-fertility silt loams and silty-clay loams formed on alluvium under a dense oak forest in Capay Valley. Balcom and Sehorn soils, formed in alluvium and colluvium from the Tehama Formation, are moderate- to high-fertility soils overlying soft calcareous sandstone or siltstone on uplands. Other soils bordering Cache Creek in Capay Valley have low-to-moderate fertility (Andrews, 1972).

In Capay Valley, the left bank[1] of Cache Creek generally borders steep hillsides, and the right bank is adjacent to valley farmlands. The streambanks of Cache Creek are composed of a wide variety of materials: bedrock, boulders, cobbles, gravel, sand, silt, clay, and various combinations of these materials. Eroded streambanks near cross sections 43 and 36A are shown in figure 4. Soils developed over alluvium and colluvium are exposed. The channel bed of Cache Creek contains clasts composed of soil developed on alluvium, sandstones, shales, volcanics, conglomerates, and sedimentary rocks (Lustig and Busch, 1967). The size class of most rocks in the channel is gravel. The downstream channels of tributaries in the study reach contain rocks similar in size and composition.

Most of the soils and deposits in the basin consist of unconsolidated materials with low cohesion, so that they have little resistance to erosion. Crumbling bedrock formations, slumps, debris slides on steep hillsides, streambank erosion, and sheet and rill erosion contribute sediment to the channel. Most of the transported sediment moves downstream during high flows of short duration, which occur nearly every year.

[1]In this report, left and right banks are designated as if the reader is facing downstream.

A



CROSS SECTION 36A

B

CROSS SECTION 43

FIGURE 4.— Photographs showing (*A*) fine material exposed on right bank at cross section 36A and (*B*) various sizes of material on left bank near cross section 43. (Arrows indicate direction of flow.)

STREAMFLOW

Streamflow data used in this study were recorded at six gaging stations (table 1). Two of the stations were activated and operated as streamflow and sediment stations during 1984-86. The station above Rumsey, discontinued in 1976, was reactivated, and a new station near Brooks was activated October 1, 1983. Cache Creek near Capay was operated during 1942-76. Stations at Yolo, near Lower Lake, and North Fork Cache Creek below Indian Valley Dam were in continuing operation for other studies. Flows at Cache Creek near Brooks are considered equivalent to flows at Cache Creek near Capay because the difference in drainage areas is less than 0.5 percent. Nearly all the flow is diverted at Capay Dam between Brooks and Yolo (fig. 2) during the April-to-September irrigation season. Mean annual flows for stations with more than 30 years of record at the end of the 1985 water year are 381 ft^3/s near Lower Lake, 686 ft^3/s near Capay, and 544 ft^3/s at Yolo.

Flow records for Cache Creek near Lower Lake and North Fork Cache Creek below Indian Valley Dam were used to estimate daily flows for periods of no record at the station above Rumsey. Recorded annual flows at the Yolo station ranged from no flow during 1977 to 1,773,000 acre-ft during 1983.

TABLE 1.--*Streamflow-gaging stations in Cache Creek drainage basin used for this report*

[mi^2, square miles]

Station name and No.	Drainage area (mi^2)	Period of record
Cache Creek near Lower Lake (11451000)	528	May 1944 to current year
North Fork Cache Creek below Indian Valley Dam (11451300)	121	October 1984 to current year
Cache Creek above Rumsey (11451760)	955	October 1960 to September 1962 June 1965 to September 1973 October 1983 to September 1986
Cache Creek near Brooks (11451950)	1,041	October 1983 to September 1986
Cache Creek near Capay (11452000)	1,044	May 1942 to September 1975 December 1975 to September 1976
Cache Creek at Yolo (11452500)	1,139	January 1903 to current year

SEDIMENT

Channel Bed and Bank Material

In order to determine the size distribution of channel material and compute bedload data, samples of bed material were collected or measured in the field at 45 of the 49 cross sections described in this report. Size distributions of the bed-material samples were measured by sieving and weighing dried samples. Field measurements of bed-material size were made using a technique described by Wolman (1954). Samples were collected with shovels and a large clamshell-type sampler for subsequent analysis. Where bed material was too coarse to collect with available equipment, particle-size distributions were measured in the field. More than 65 percent of the bed material analyzed is gravel and about 23 percent is coarser than gravel. Gravel is defined as rocks with intermediate axes between 2 mm (millimeters) and 64 mm. The range of median grain sizes (D-50) of the samples is 5 mm to 86 mm. The particle-size distribution at cross section 19A is given in table 2 as an example. Representative size distributions in cross sections are determined by mathematically weighting each sample in proportion to the width of channel it represents (Emmett and others, 1980).

Bank-material samples were collected to define erosible material. Collection of bank material was limited to 27 cross sections where the streambanks did not consist of bedrock, boulders, or cemented conglomerates. Bank-material samples are composed of sand, silt, and clay except at cross section 35A, where cobbles and gravel form the left bank.

Bedload Discharge

Daily bedload discharges at two gaging stations were computed using relations based on streamflow and bedload measurements (fig. 5). The station above Rumsey is just upstream from Capay Valley, and the station near Brooks is near the downstream end of the valley. Bedload discharges were computed by the Meyer-Peter and Muller method (U.S. Bureau of Reclamation, 1960) and measured with a Helley-Smith bedload sampler. The Meyer-Peter and Muller method requires the size distribution of bed material and hydraulic data including streamflow, velocity, width, hydraulic radius, friction slope, and roughness coefficient. Hydraulic data usually are obtained by streamflow measurements and surveying water-surface profiles. Bedload-sampler measurements are conditioned by two assumptions: (1) bedload is transported within 76 mm (nozzle size) above the streambed, and

TABLE 2.--*Particle-size distribution of four samples of bed material in cross section 19A, November 21, 1984, in percentage finer than indicated size*

[Location of cross section 19A is shown in figure 2]

Sample No.	Channel width (feet)	Particle size (millimeters) 0.125	0.250	0.500	1.00	2.00	4.00	8.00	16.0	32.0	64.0	128
1	60	--	--	--	--	--	--	0	4	15	64	100
2	89	--	0	2	4	7	10	12	18	40	81	100
3	94	--	0	2	3	5	8	10	21	43	72	100
4	23	0	1	9	19	26	35	49	71	92	100	--

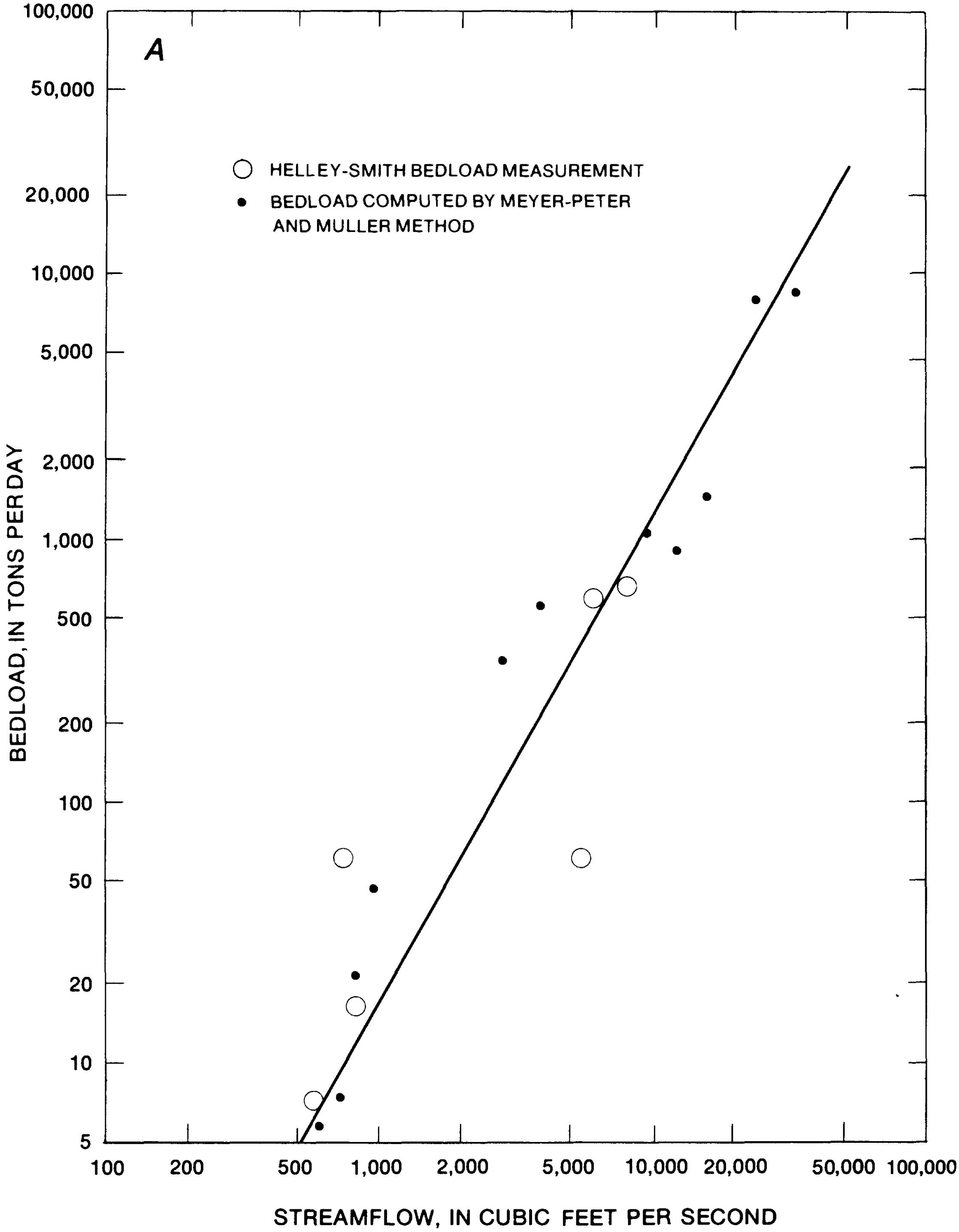


FIGURE 5.— Relation of bedload discharge to streamflow, 1984-86
A, Cache Creek near Brooks.

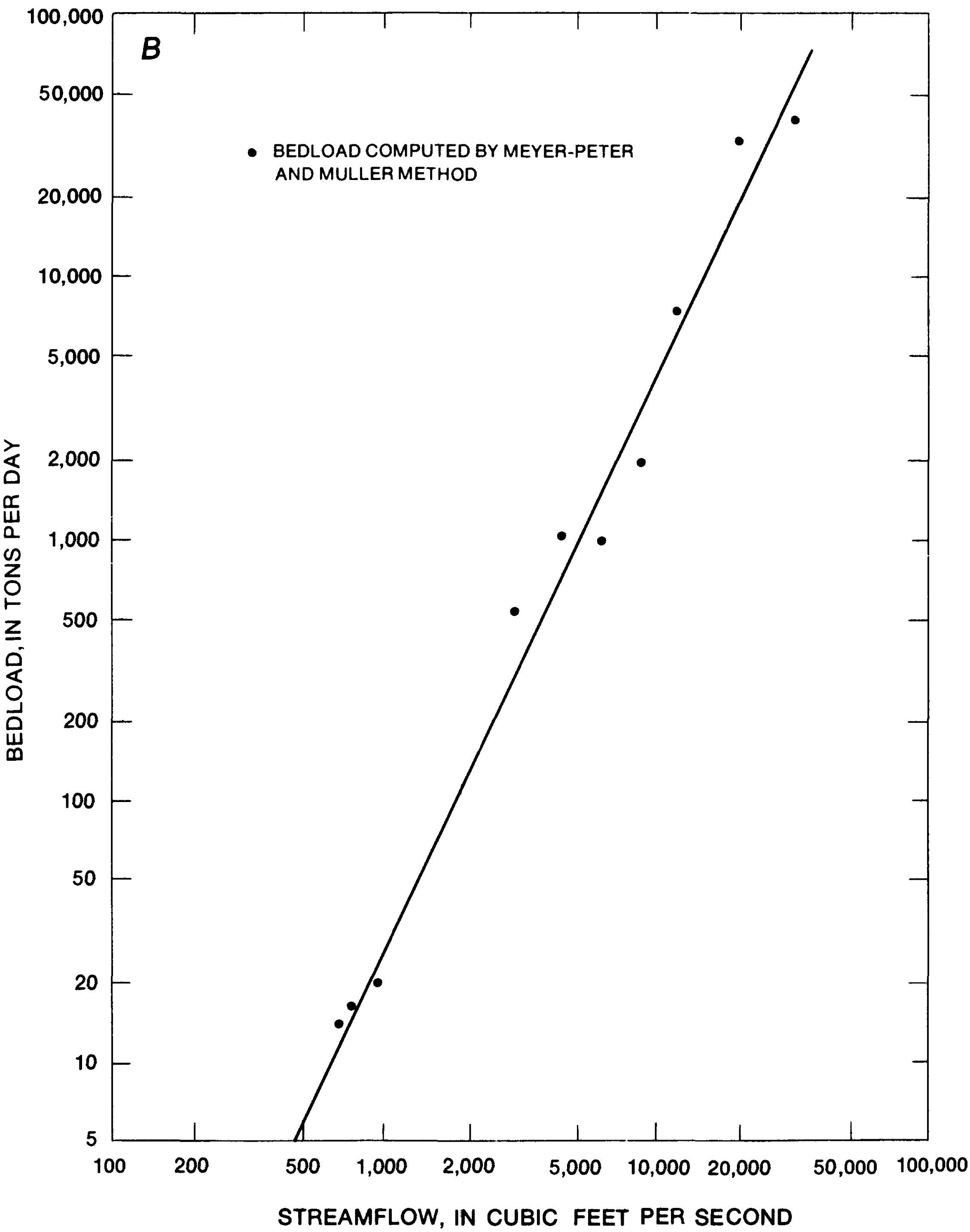


FIGURE 5.– Relation of bedload discharge to streamflow, 1984-86 –Continued. *B*, Cache Creek above Rumsey.

(2) particle sizes of bedload are between 0.2 mm (mesh size of sample container) and 76 mm (Helley and Smith, 1971). The largest material collected with the sampler in Cache Creek was finer than 64 mm at maximum flow sampled (8,070 ft³/s). More than 85 percent of the total bedload sampled was finer than 16 mm.

Suspended-Sediment Discharge

Suspended-sediment discharges at the gaging stations near Brooks and above Rumsey were computed for November through May of each year of the study. The daily streamflow and sediment discharges are published in the annual water-resources data reports prepared by the U.S. Geological Survey (1955-70, 1971-74, 1976-82), Fogelman and others (1984), Fogelman and others (1985 and 1986), Mullen and others (1987 and 1988) and Mullen and others (1988). Daily mean suspended-sediment discharges were computed from streamflow records and daily mean concentrations of suspended sediment. The daily mean concentrations are obtained from curves drawn between concentrations plotted on hydrographs (Porterfield, 1972). Yearly totals of suspended-sediment discharge per acre-foot of streamflow were compared in table 3 to the totals computed for a previous study by Lustig and Busch (1967). The sediment-transport rate for 1984-86 is lower than for 1960-63 at Cache Creek near Brooks and near Capay. Regulation, which began in 1974 at Indian Valley Reservoir, probably is the major factor in the reduced rate because the drainage area above Indian Valley is about one-fourth (23.6 percent) of the total drainage between Clear Lake and the station near Brooks.

Data summarized in table 4 show a provisional relation between streamflow and suspended sediment on a long-term basis. High concentrations of suspended sediment may be carried by low flows as well as by high flows, depending on storm intensity and time of occurrence during the year. The amount of fine sediment available for transport generally decreases progressively through the storm season. Short-term relations may be used with streamflow records to estimate suspended-sediment discharges for periods when no samples were collected if the period is near the time of the temporary relation (fig. 6).

TABLE 3.--*Streamflow and suspended-sediment discharge at selected gaging stations on Cache Creek*

[Stations at Cache Creek near Brooks and near Capay are considered equivalent for this report. Data are from station near Capay for 1960-63 and near Brooks for 1984-86 water years. ft³/s, cubic feet per second]

Water year	Streamflow (ft³/s)	Suspended-sediment discharge	
		Tons	Tons per acre-foot of streamflow
Cache Creek above Rumsey (11451760)			
1960	118,200	284,000	1.21
61	116,200	148,500	.64
62	192,700	654,000	1.71
63	292,000	1,174,000	2.03
84	431,500	680,200	.79
85	121,700	34,400	.14
86	454,700	2,355,000	2.61
Cache Creek near Brooks (11451950) and Cache Creek near Capay (11452000)			
1960	114,900	363,900	1.62
61	106,800	85,700	.40
62	168,600	791,600	2.37
63	291,000	2,079,000	3.60
84	491,600	1,023,000	1.05
85	124,800	38,100	.15
86	527,600	2,872,000	2.74

TABLE 4.--*Suspended-sediment concentration and discharge over a range of flows for selected gaging stations in the Cache Creek drainage basin*

[Stations at Cache Creek near Brooks and near Capay are equivalent. Data were taken near Brooks for 1960-63 and near Capay for 1983-85 calendar years. Suspended-sediment concentration is given in milligrams per liter, which is equivalent to parts per million within the range of values presented in this paper. ft^3/s, cubic feet per second; mg/L, milligrams per liter; ton/d, tons per day]

Date	Time (hours)	Streamflow (ft^3/s)	Suspended sediment Concentration (mg/L)	Suspended sediment Discharge (ton/d)
		11451760 Cache Creek above Rumsey		
1960				
February 8	1125	20,100	8,190	444,500
February 9	0815	9,460	2,530	64,600
February 10	0800	4,280	1,400	16,200
February 11	0830	1,780	446	2,140
December 1	1200	12,000	20,100	651,200
December 1	1630	7,770	5,500	115,400
1961				
January 26	1600	918	2,000	4,960
January 31	1220	5,350	4,640	67,000
March 15	0740	606	2,270	3,710
March 17	0800	1,000	1,810	4,890
December 1	1500	3,180	5,060	43,400
December 2	0815	2,460	561	3,730
1962				
February 9	1120	3,230	5,540	48,300
February 9	1430	3,760	3,620	36,800
February 14	1320	2,820	1,220	9,290
February 14	1520	4,730	3,230	41,300
February 14	1615	5,920	5,410	86,500
February 14	1645	6,530	5,930	104,600
February 14	1925	11,400	15,100	464,800
February 15	0730	7,520	4,290	87,100
February 15	1200	6,220	2,800	47,000
February 15	1245	6,060	2,700	44,200
February 16	0735	4,170	1,740	19,600
February 17	0800	2,150	618	3,590
February 18	1700	3,010	1,450	11,800
February 19	0730	1,730	373	1,740
March 6	0730	7,790	5,190	109,200
March 7	0730	6,250	1,830	30,900
March 9	0730	4,720	1,020	13,000

TABLE 4.--*Suspended-sediment concentration and discharge over a range of flows for selected gaging stations in the Cache Creek drainage basin*--Continued

Date	Time (hours)	Streamflow (ft^3/s)	Suspended sediment Concentration (mg/L)	Suspended sediment Discharge (ton/d)
11451760 Cache Creek above Rumsey--Continued				
1963				
January 30	1205	1,310	2,730	9,660
January 30	1730	10,200	16,100	443,400
January 31	1150	11,400	9,460	291,200
March 28	0805	7,180	2,690	52,100
March 28	1405	6,040	1,550	25,300
April 19	1245	4,300	429	4,980
December 27	1200	6,590	762	13,600
1983				
December 27	1200	6,590	762	13,600
1984				
April 10	0930	569	36	55
November 27	1725	588	4,270	6,780
1985				
February 8	0700	2,970	5,460	43,800
February 8	1005	3,660	2,670	26,400
1986				
December 2	1420	1,500	1,230	4,980
February 14	1145	21,200	10,400	595,000
February 15	1245	7,360	3,220	64,000
February 18	1430	11,200	3,250	98,300
March 10	1145	9,250	1,630	40,700
11452000 Cache Creek near Capay (1960-63) and 11451950 Cache Creek near Brooks (1983-85)				
1960				
February 3	1045	740	202	404
February 8	1230	13,400	5,170	187,000
December 1	1600	6,010	1,810	29,400
December 2	1435	1,450	609	2,380

TABLE 4.--*Suspended-sediment concentration and discharge over a range of flows for selected gaging stations in the Cache Creek drainage basin*--Continued

Date	Time (hours)	Streamflow (ft³/s)	Suspended sediment Concentration (mg/L)	Suspended sediment Discharge (ton/d)
11452000 Cache Creek near Capay (1960-63) and 11451950 Cache Creek near Brooks (1983-85)--Continued				
1961				
February 16	1350	745	105	211
1962				
February 9	1340	2,880	3,920	30,500
February 9	1500	2,990	3,320	26,800
February 10	1130	1,750	724	3,420
February 15	1830	6,510	2,470	43,400
1963				
January 30	1230	964	1,700	4,420
February 1	1540	10,200	3,810	105,000
February 6	1425	825	312	695
March 28	1125	7,460	2,990	60,200
1983				
December 9	1430	9,230	2,010	50,100
December 27	0900	9,300	1,220	30,600
December 27	1400	8,310	1,060	23,800
1984				
February 14	0845	961	622	1,610
1985				
February 8	1205	4,420	4,380	52,300
February 8	1315	4,610	3,900	48,500
March 27	1230	837	667	1,510
March 28	1300	626	288	487
1986				
January 17	0800	2,190	1,760	10,400
January 17	1300	1,500	1,120	4,540
January 30	1130	1,580	1,740	7,420
February 13	0930	4,140	3,030	33,900
February 14	1130	26,500	9,410	673,000
March 10	1015	17,200	3,560	165,000

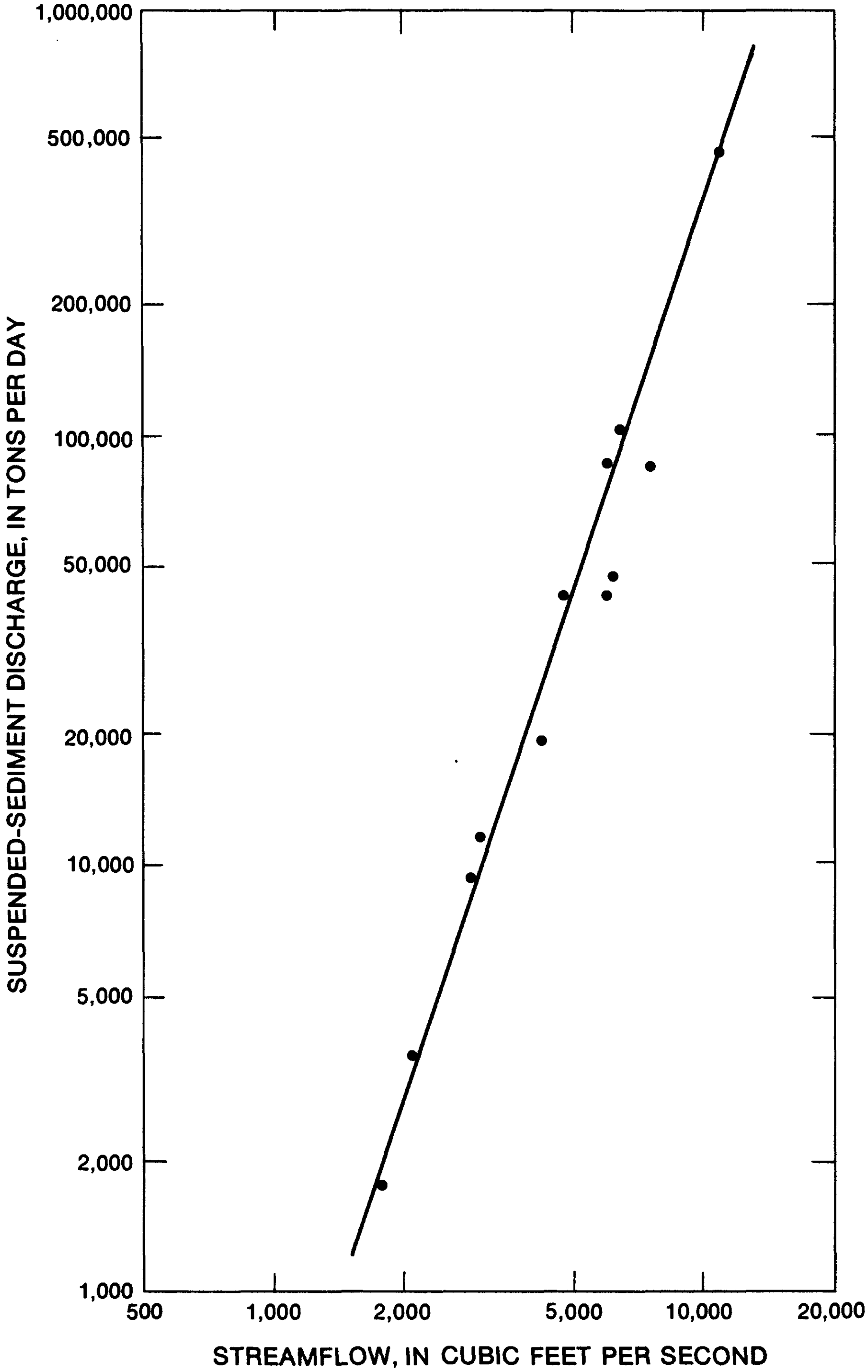


FIGURE 6.— Relation of streamflow and suspended-sediment discharge, Cache Creek above Rumsey, February 14-19,1962.

Total Sediment Discharge

Daily suspended-sediment discharges computed using hydrographs and daily bedload discharges computed by ratings were added to obtain the total sediment discharge at a station. Annual total storm-season sediment discharges are shown in table 5. The normal downstream increase in sediment discharge between Rumsey and Brooks (table 3) is attributed to tributary inflow and an increase in drainage area of 86 mi^2. During 1984-86, the total sediment discharges per square mile of drainage area were 3,480 tons above the Rumsey station and 3,870 tons near the Brooks station.

CHANNEL CHARACTERISTICS

Channel Geometry

Cross sections of the channel, monumented for future recovery, were surveyed at 49 sites (fig. 2). Plots of all cross sections along with water-surface elevations from the peak of December 25, 1983, are shown in figure 7. Accuracy of level surveys are third order for vertical control, but elevations are reported to the nearest 0.1 foot. Cross sections 10, 24, 30, 35A, and 37 (active erosion sites) were surveyed each year from 1983 to 1986 to document changes caused by streambank erosion, bed scour, and bed fill. Successive surveys show a much greater amount of bank erosion at cross section 24 than at the other sections, but the mean bed elevation at section 24 varied only 0.4 foot. Changes in cross section 24 are shown in figure 8.

Mean bed elevations determined by level surveys in 1983-86 are given in table 6 for cross sections 9, 10, 24, 30, 35A, and 37. The elevations were computed by averaging elevations below the elevation of the top of the cut bank. Overall, bed elevations were nearly stable; three cross sections showed slight aggradation and the other three showed slight degradation. Bed elevations fluctuated at all six cross sections. Gravel was excavated from the channel within the study reach for fill material during 1983-86.

Mean bed elevations also were obtained from streamflow measurements made at gaging stations above Rumsey during 1963-86 and near Capay during 1957-84. The first and last mean bed elevations differed by only -0.9 foot above Rumsey and +1.0 foot near Capay.

TABLE 5.--*Annual total storm-season sediment discharges at two sites on Cache Creek*

[ft^3/s, cubic feet per second]

Station name and No.	Water year	Annual streamflow (ft^3/s)	Total sediment discharge (tons)	Bedload (percent)	Peak flow (ft^3/s)
Cache Creek above Rumsey (11451760)	1984	431,500	776,000	12	20,700
	85	121,700	35,800	4	3,850
	86	454,700	2,508,000	6	34,000
Cache Creek near Brooks (11451950)	1984	491,600	1,087,000	6	26,000
	85	124,800	38,600	1	4,620
	86	527,600	2,905,000	1	37,800

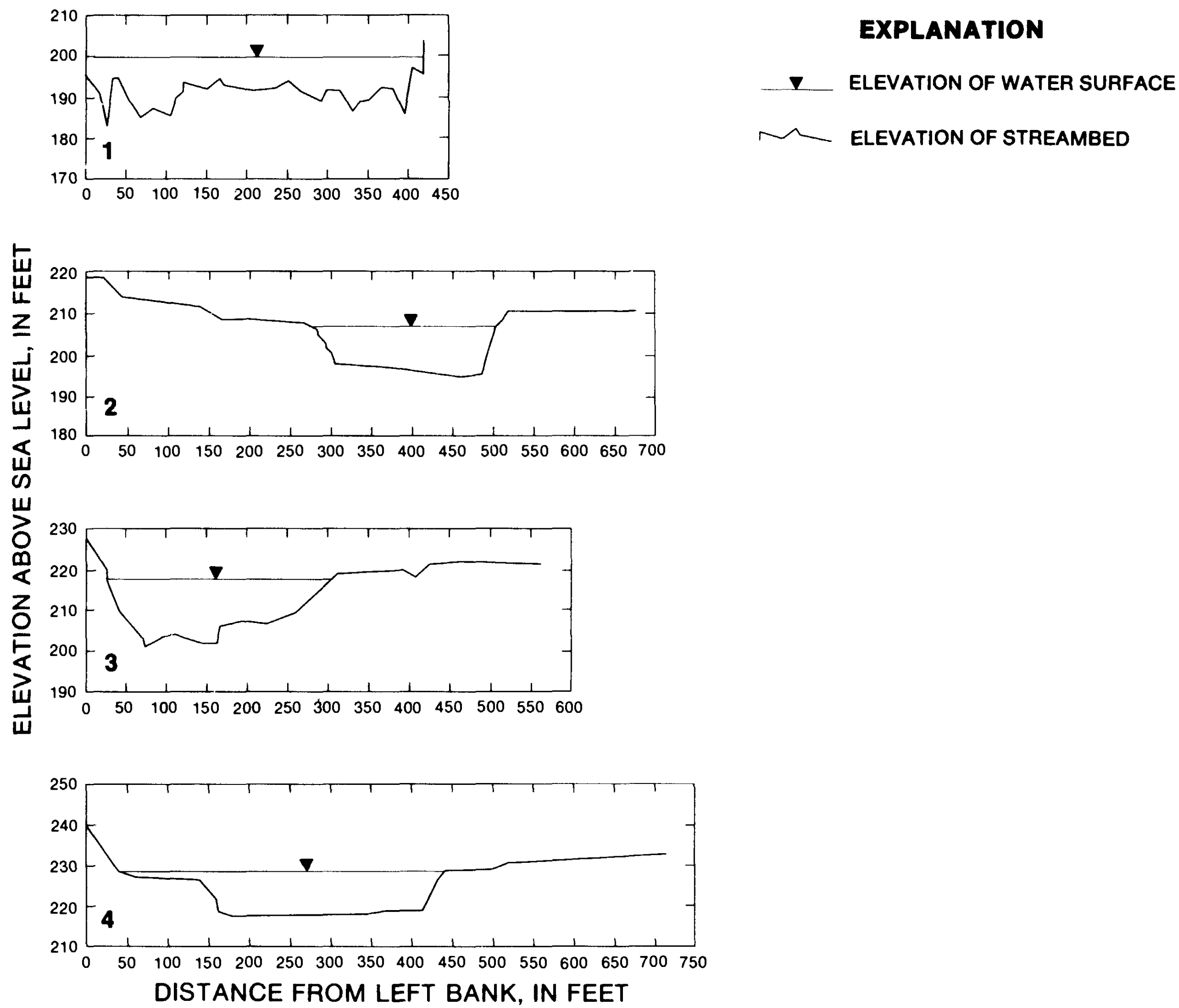


FIGURE 7.— Cross sections of Cache Creek, 1984 water year, and water-surface elevations for 1984 peak.

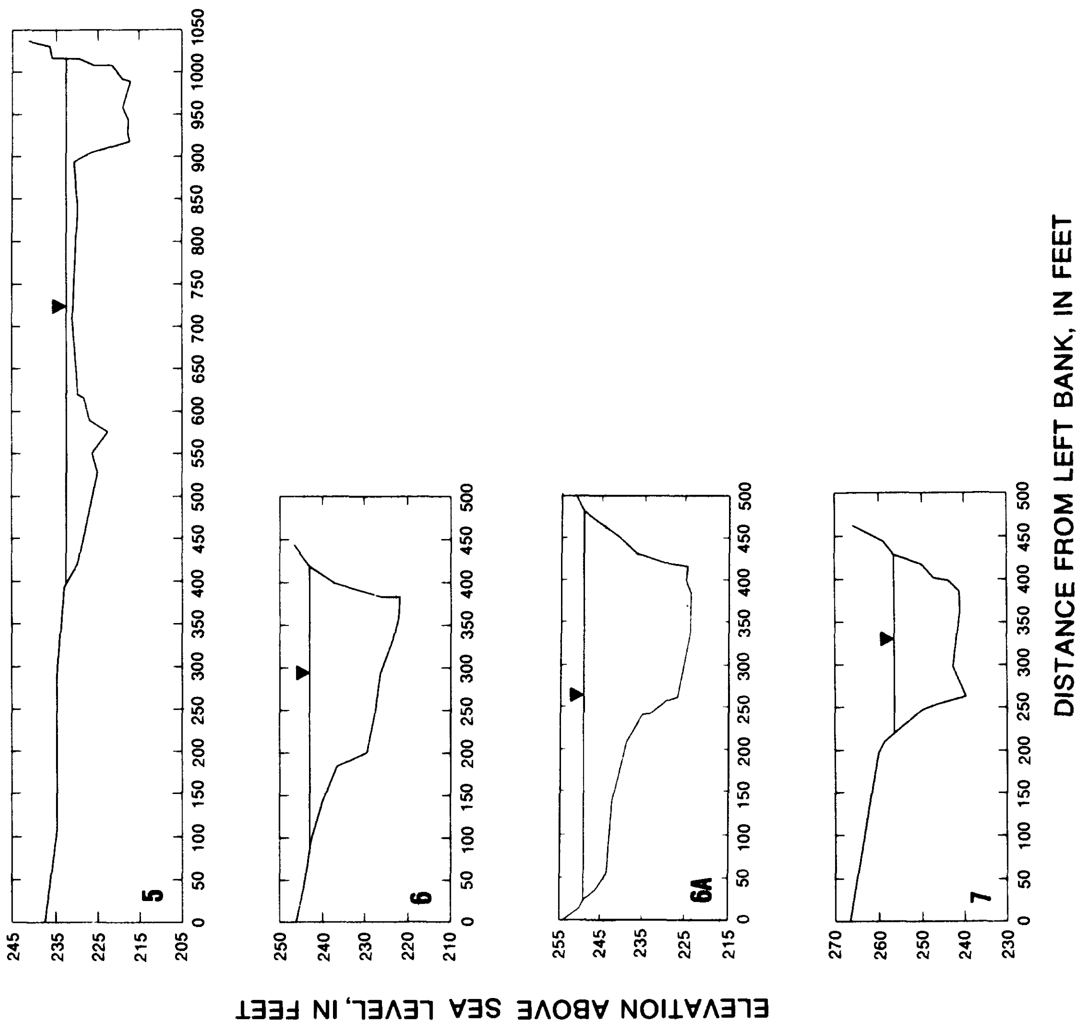


FIGURE 7. – Cross sections for Cache Creek, 1984 water year, and water-surface elevations for 1984 peak —Continued.

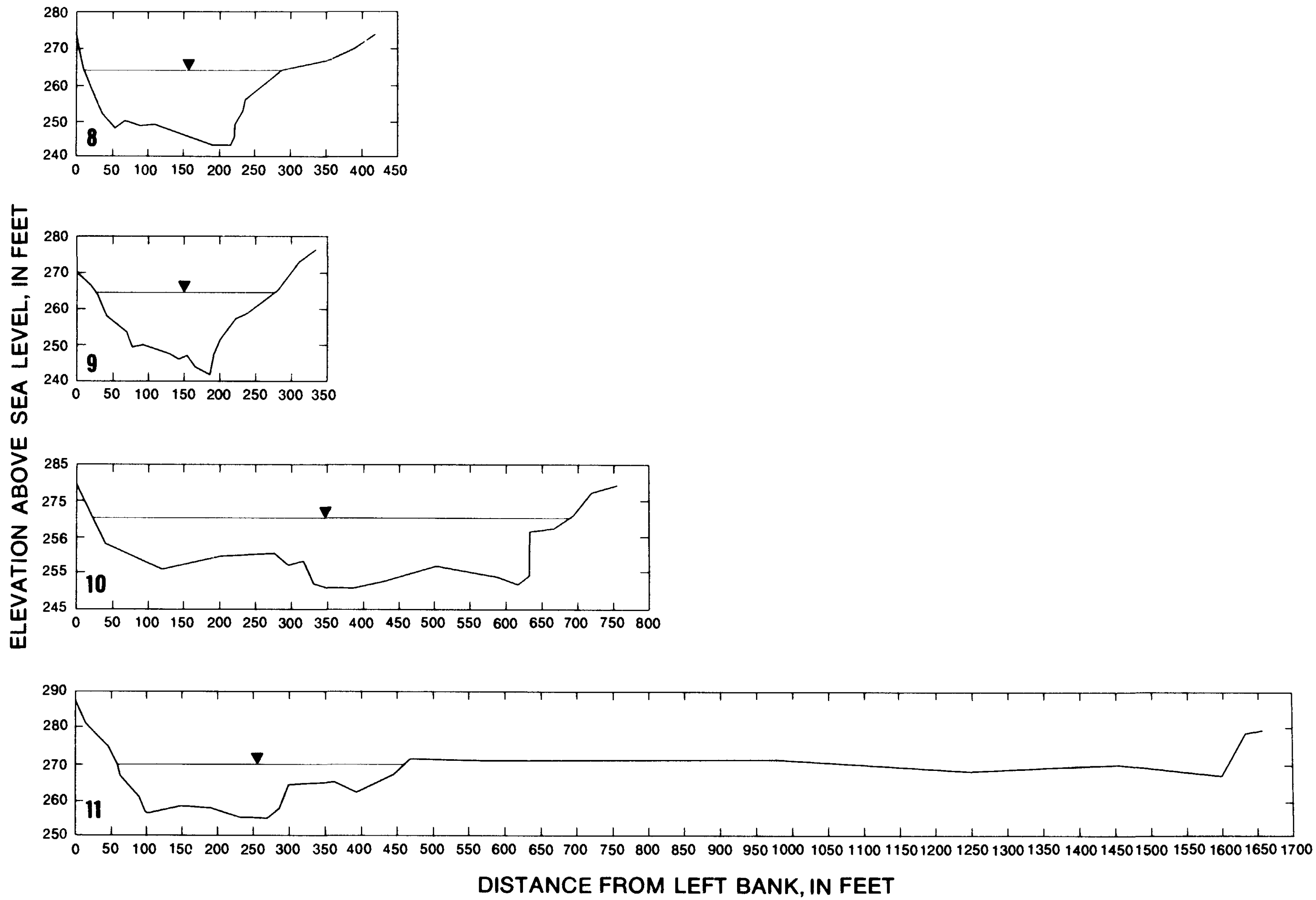


FIGURE 7.— Cross sections of Cache Creek, 1984 water year, and water-surface elevations for 1984 peak—Continued.

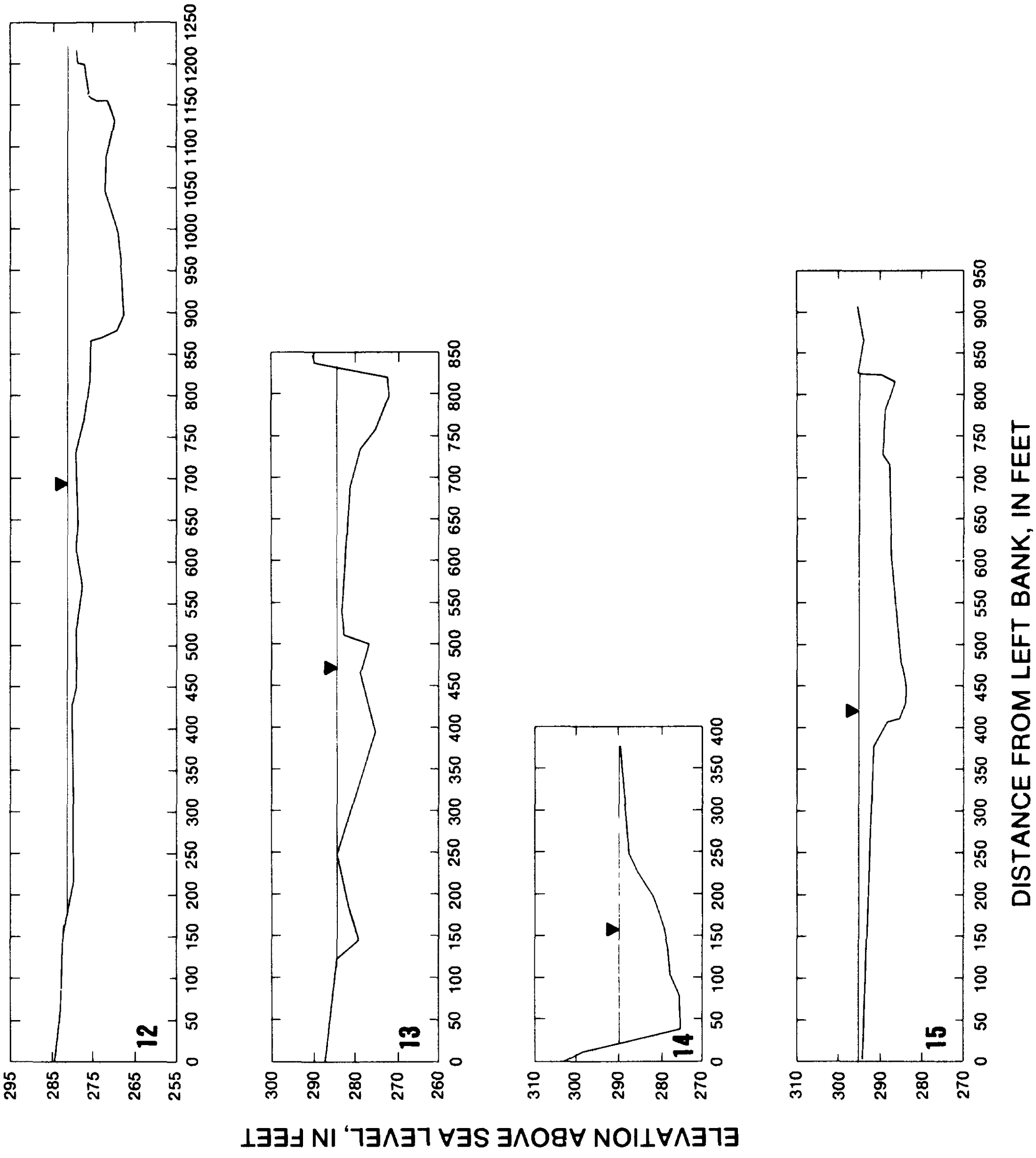


FIGURE 7.—Cross sections of Cache Creek, 1984 water year, and water-surface elevations for 1984 peak—Continued.

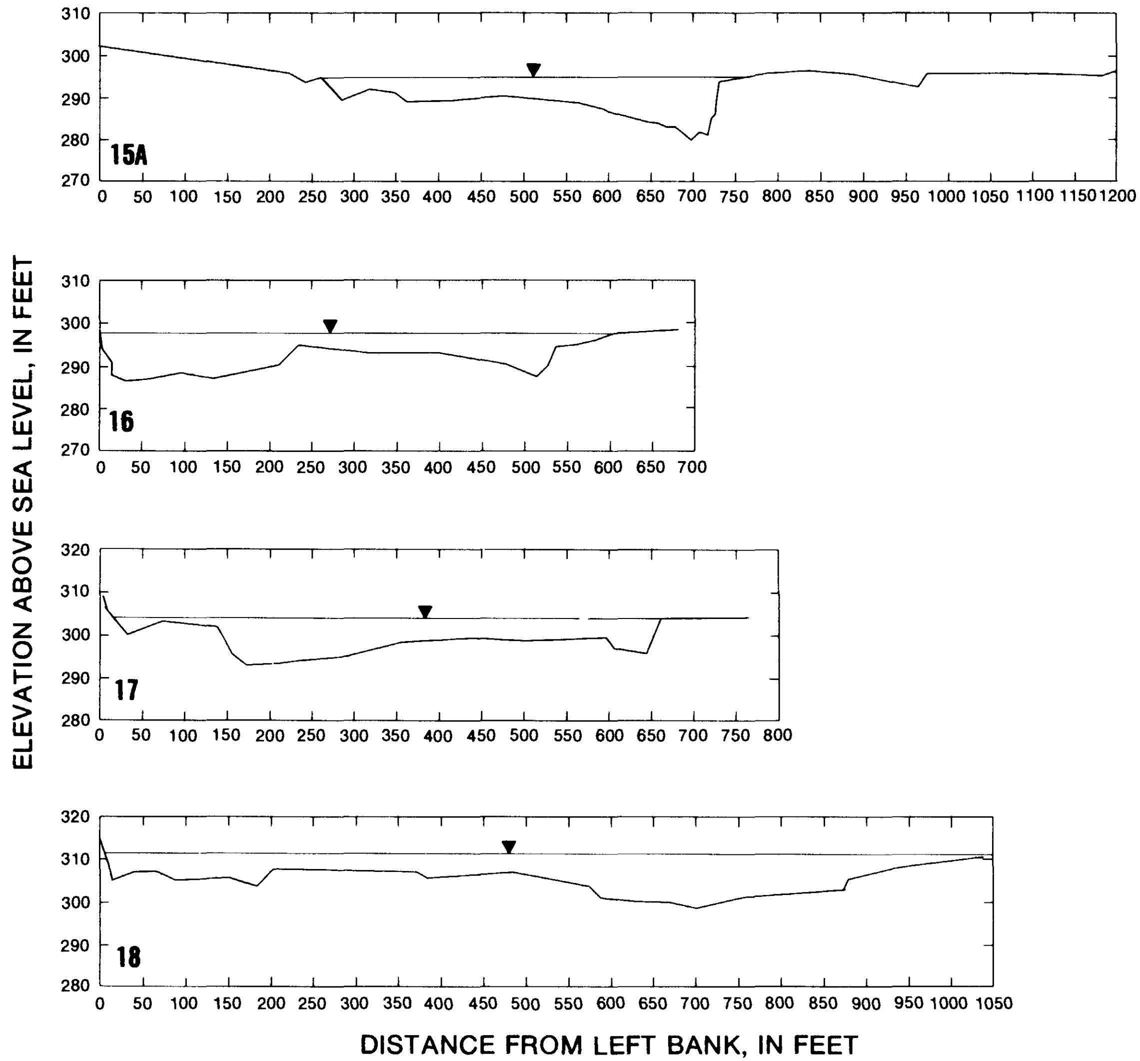


FIGURE 7.— Cross sections of Cache Creek, 1984 water year, and water-surface elevations for 1984 peak—Continued.

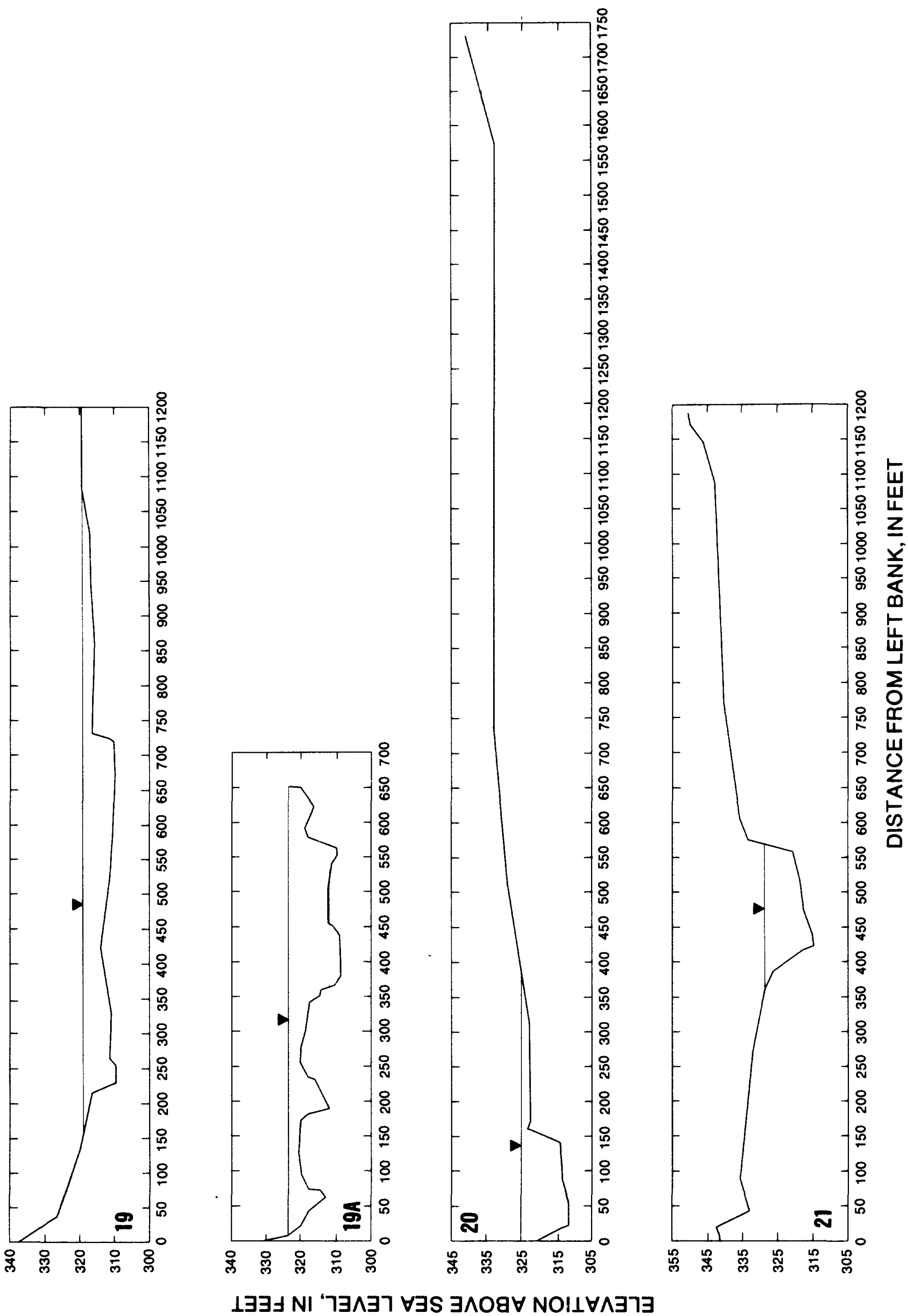


FIGURE 7.— Cross sections of Cache Creek, 1984 water year, and water-surface elevations for 1984 peak—Continued.

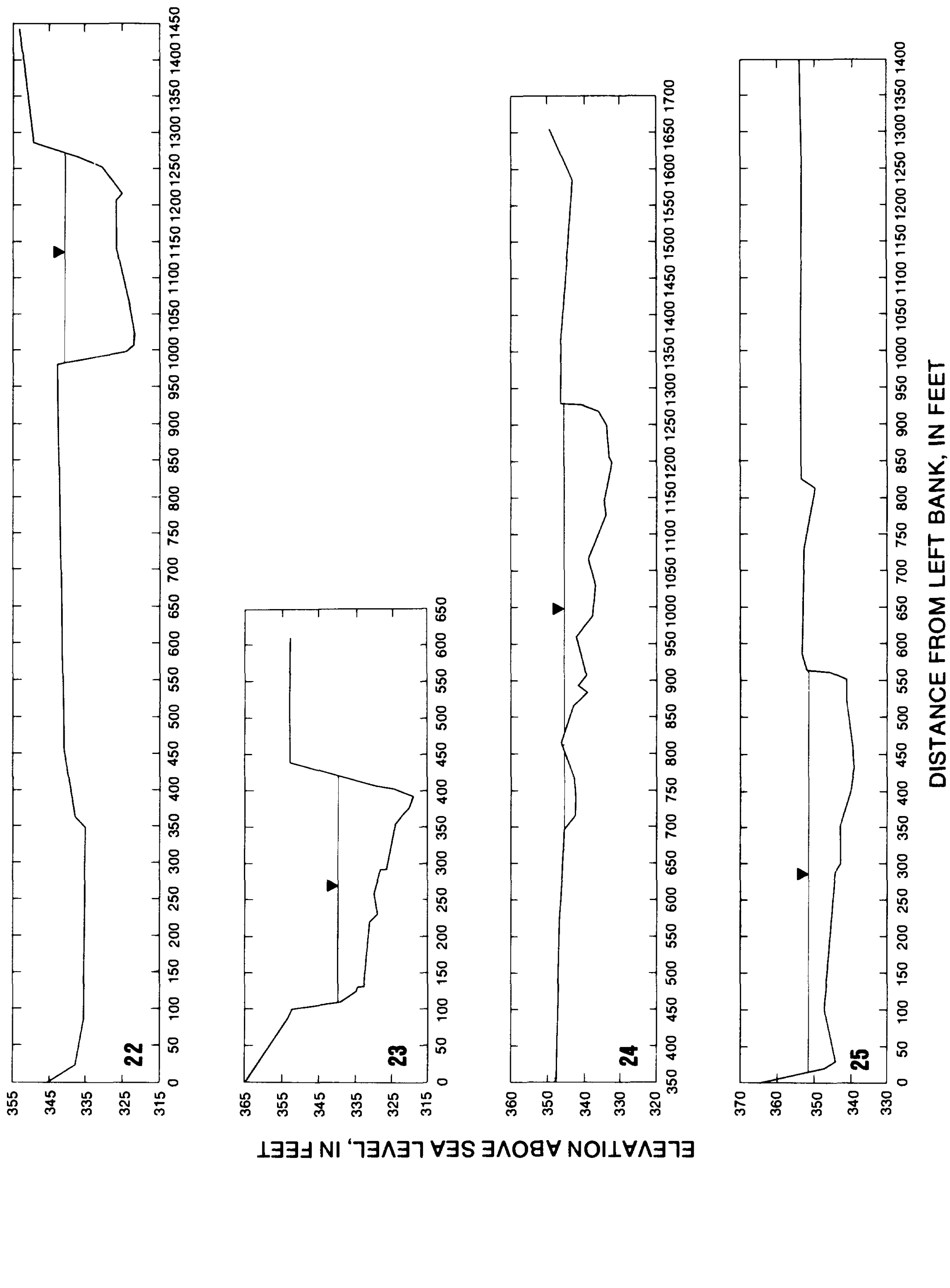


FIGURE 7. — Cross sections of Cache Creek, 1984 water year, and water-surface elevations for 1984 peak—Continued.

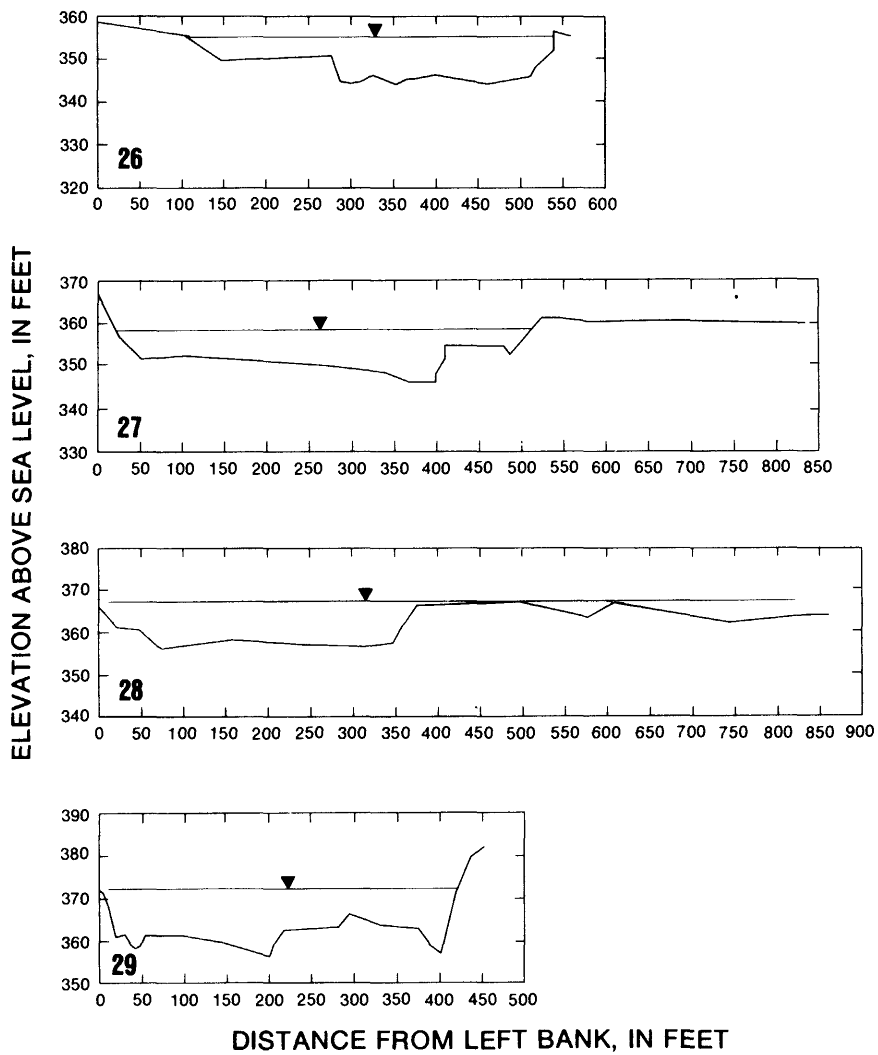


FIGURE 7.— Cross sections of Cache Creek, 1984 water year, and water-surface elevations for 1984 peak—Continued.

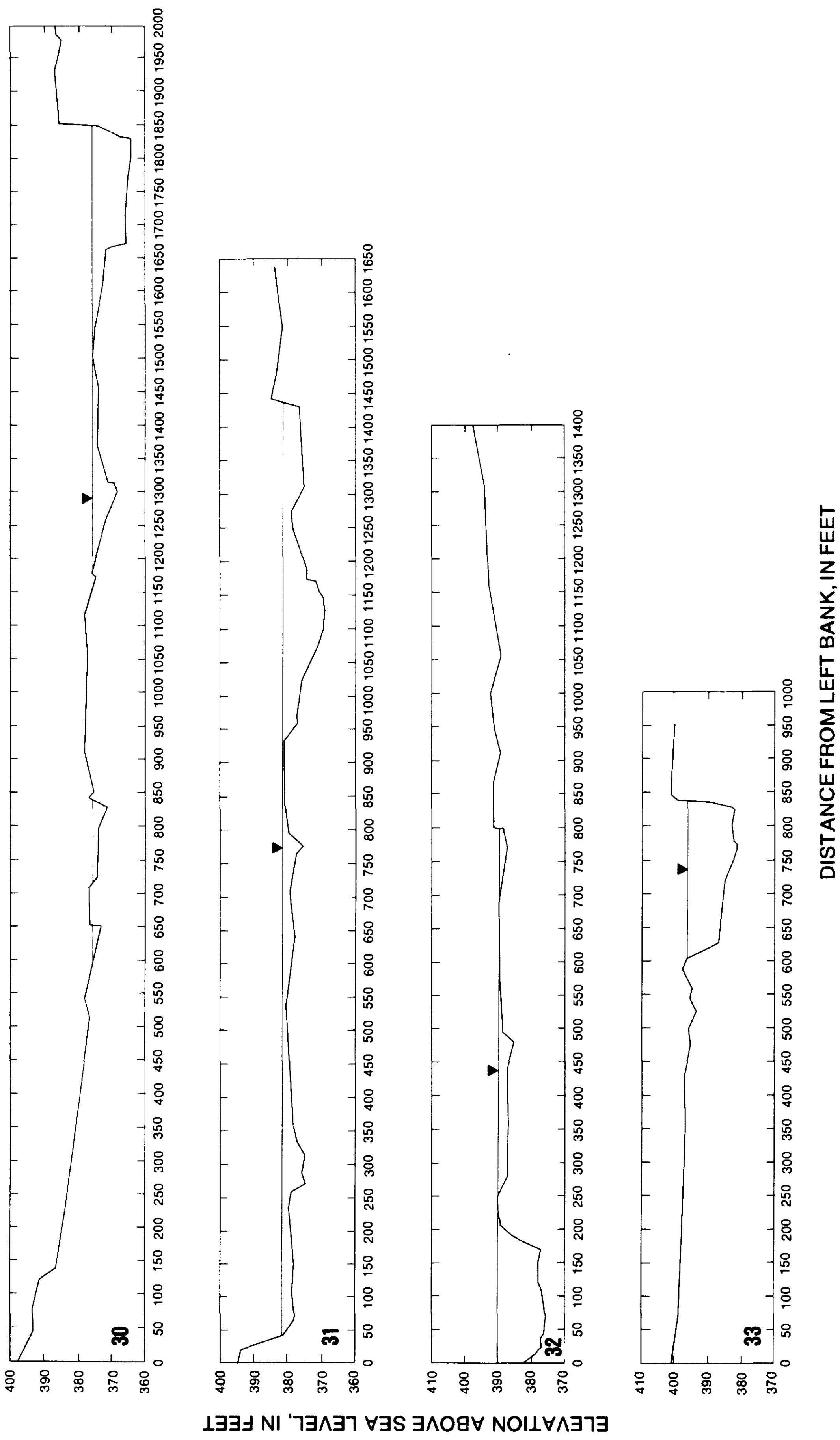


FIGURE 7.— Cross sections of Cache Creek, 1984 water year, and water-surface elevations for 1984 peak —Continued.

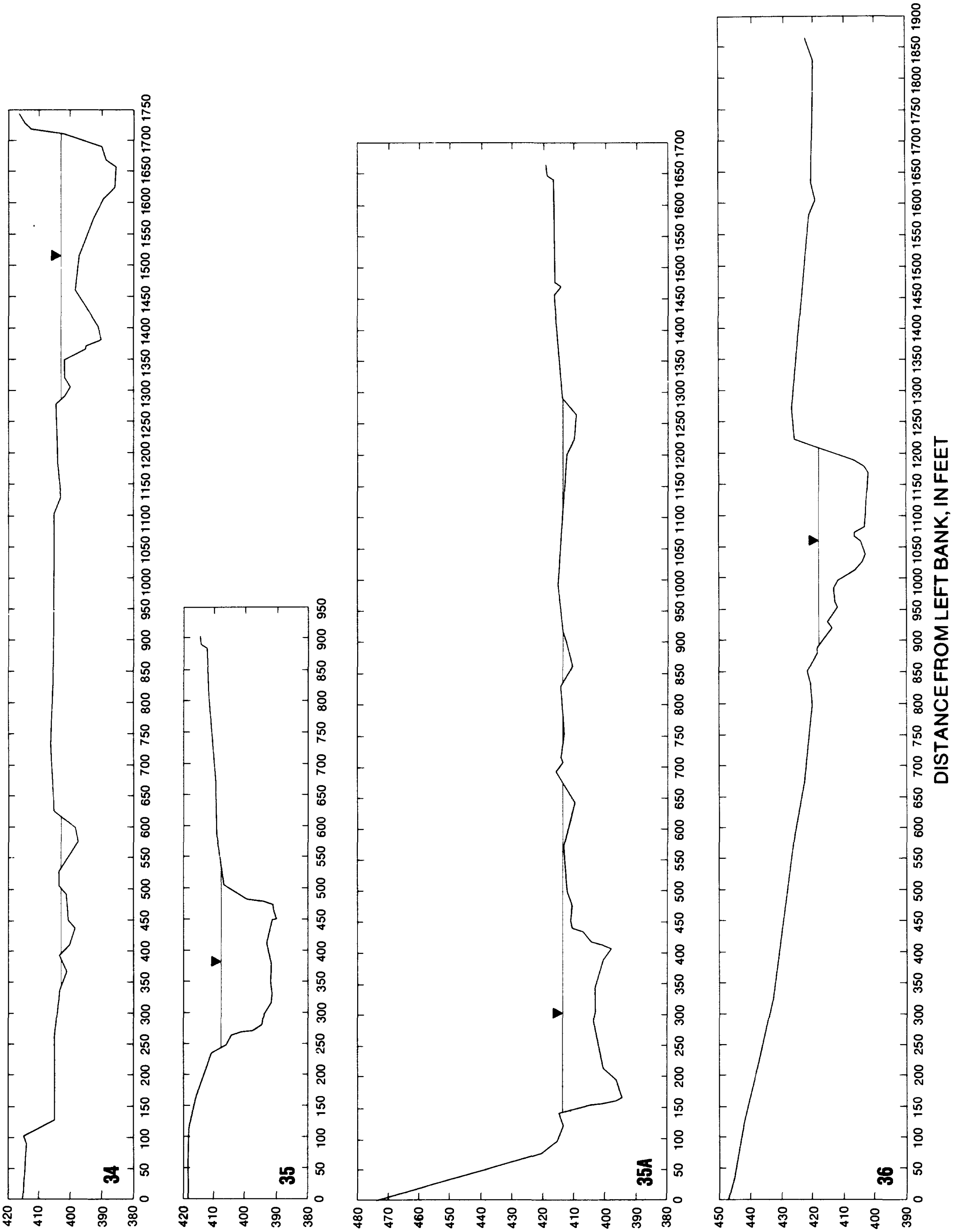


FIGURE 7.— Cross sections of Cache Creek, 1984 water year, and water-surface elevations for 1984 peak—Continued.

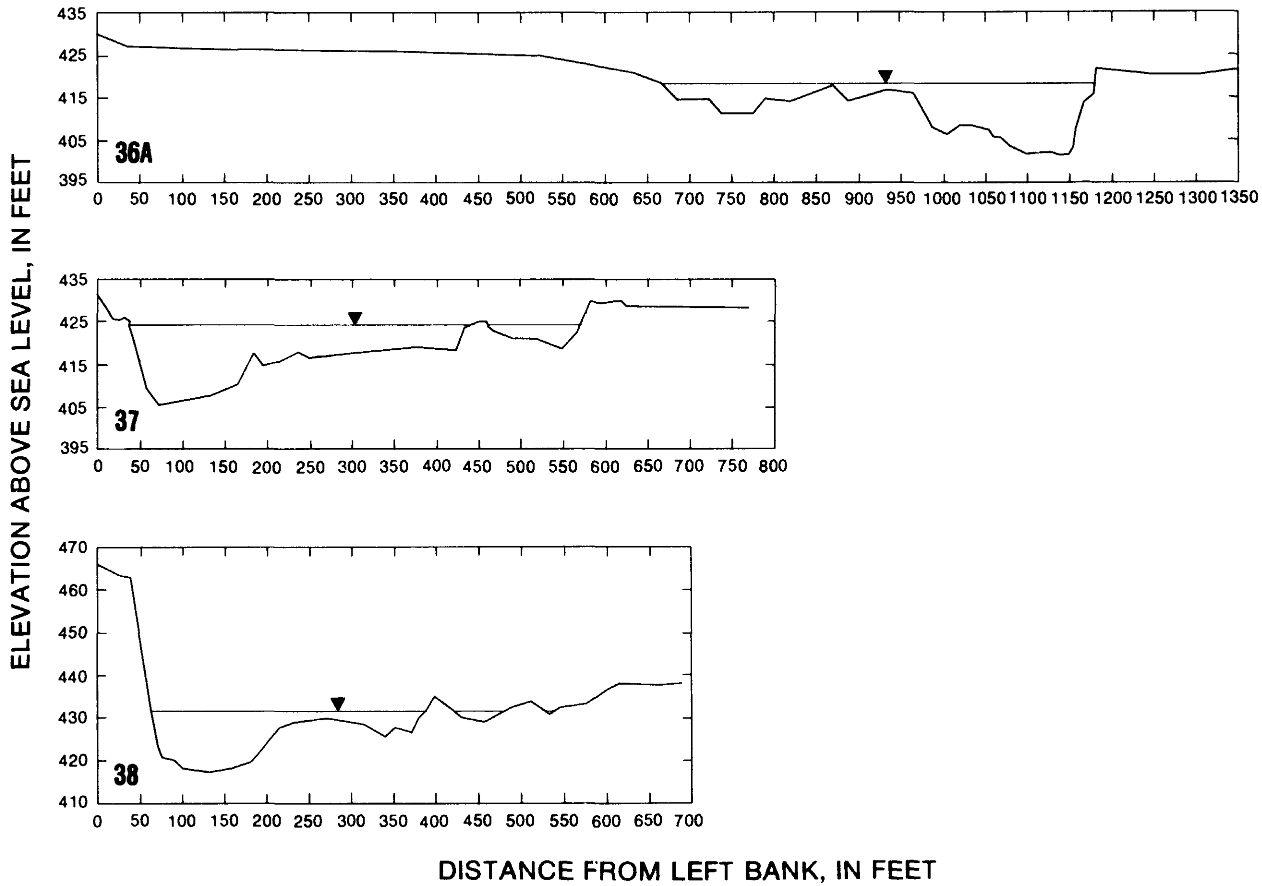


FIGURE 7.— Cross sections of Cache Creek, 1984 water year, and water-surface elevations for 1984 peak—Continued.

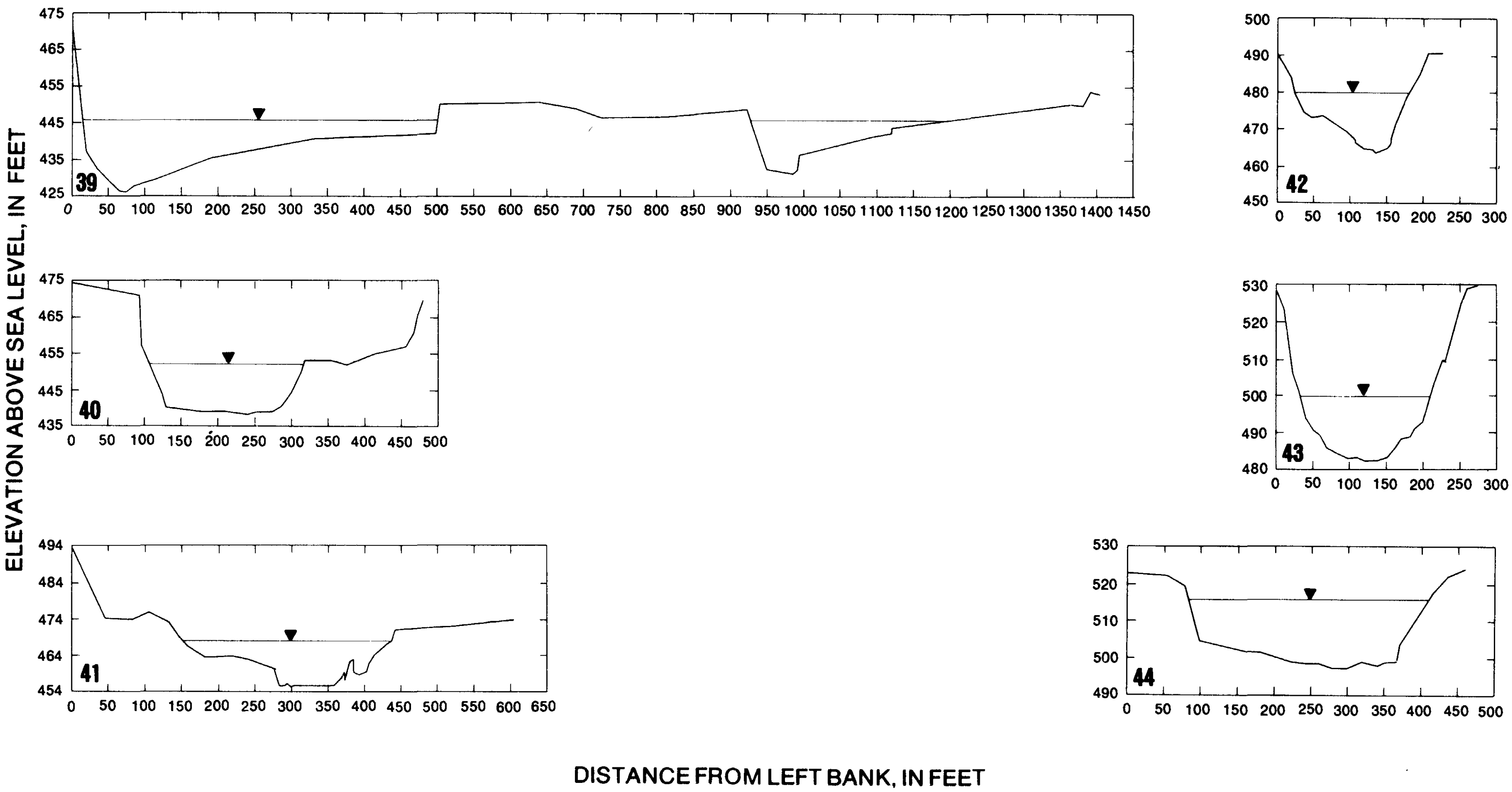


FIGURE 7.— Cross sections of Cache Creek, 1984 water year, and water-surface elevations for 1984 peak—Continued.

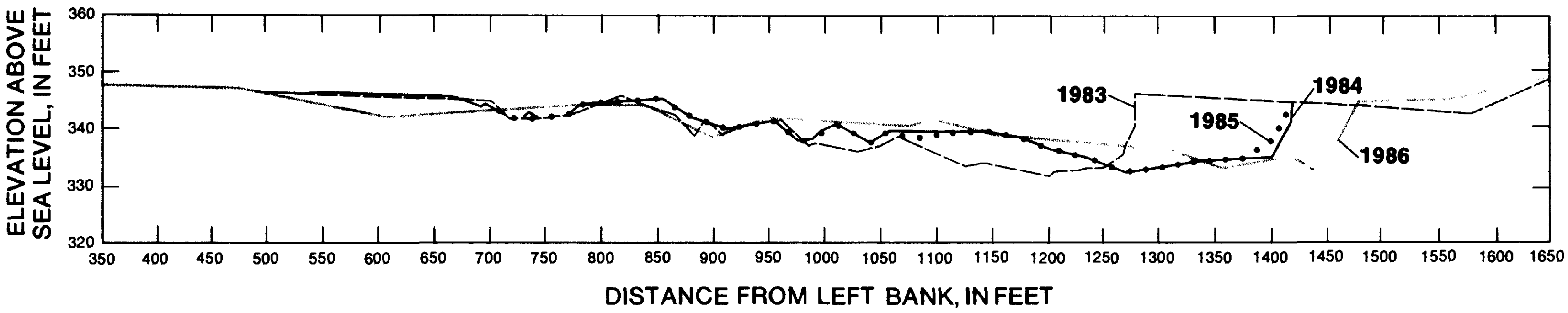


FIGURE 8.— Cross section 24, Cache Creek at Guinda, surveyed in 1983, 1984,1985, and 1986.

TABLE 6.--*Mean bed elevations, in feet, at six cross sections on Cache Creek*

[Locations of cross sections are shown in figure 2]

Water year	Cross section					
	37	35A	30	24	10	9
1983	417.9	407.8	373.2	340.6	257.1	246.3
84	416.4	406.6	373.5	340.8	256.9	245.9
85	416.6	406.8	374.7	340.5	255.6	246.2
86	417.4	407.6	374.1	340.9	256.4	246.8

Cross-section surveys show no significant changes in the vicinity of the streambanks during 1985, when the maximum daily flow was only 2,510 ft^3/s at the Brooks station, compared to 22,600 ft^3/s the previous year.

Sinuosity is defined as the ratio of reach length measured along the channel centerline to reach length measured along the valley centerline (Brice, 1977). Stream channels are classified as straight, sinuous (sinuosity between 1.05 and 1.50), or meandering. The sinuosity of four reaches of Cache Creek was measured on aerial photographs taken in 1953, 1957, 1964, 1972, 1983, and 1984 (table 7). The data indicate that Cache Creek is a sinuous stream in Capay Valley.

Water-Surface Slope

Water-surface slopes are based on elevations of high-water marks at selected cross sections and on channel distances between cross sections. Channel constrictions could create backwater conditions at cross sections 10 and 6A; therefore, high-water marks at these sites may not be good indicators of water-surface slope during peak flows.

TABLE 7.--*Sinuosity of selected reaches of Cache Creek, 1953-84*

[Reach is designated by cross sections that form upper and lower boundaries. Locations of cross sections are shown in figure 2]

Water year	Reach			
	40-36	36-23	23-14	14-4
1953	1.24	1.17	1.16	1.31
57	1.39	1.52	1.28	1.27
64	1.26	1.46	1.05	1.33
72	1.36	1.38	1.18	1.26
83	1.47	1.35	1.16	1.40
84	1.47	1.41	1.13	1.42

Water-surface slopes were computed for the peak flows of December 1983 and February 1986. The slopes were compared in four contiguous reaches designated by cross sections that form upper and lower boundaries (table 8). The channel-bed slopes, based on thalweg elevations from the cross sections surveyed in 1983-84, are presented for comparison. Water-surface slopes decrease downstream, and slopes in all four reaches were greater during the February 1986 peak (37,500 ft^3/s) than during the December 1983 peak (26,000 ft^3/s). Peak flows were recorded at the station near Brooks.

Lateral Migration

When streambanks erode, point bars usually form opposite the eroded bank, causing a shift in channel location referred to as lateral migration (Brice, 1977). Migration is measured by dividing the eroded area by length to compute average width, and net migration is the algebraic difference in width computed for both streambanks. The measured length is the greatest length of the eroded area. The difference in cumulative widths for each bank indicates the dominant

TABLE 8.--*Channel-bed and water-surface slopes of four reaches of Cache Creek*

[Reach is designated by cross sections that form upper and lower boundaries. Locations of cross sections are shown in figure 2. Values of slope are given in feet per foot. Channel-bed slope is based on thalweg elevations from cross sections surveyed in 1983-84]

Date	Reach 44-36	36-23	23-14	14-4
	Channel-Bed Slope			
1983-84	0.0200	0.0025	0.0017	0.0027
	Water-Surface Slope			
12-25-83	.0047	.0019	.0018	.0013
2-17-86	.0051	.0033	.0020	.0014

direction of erosion. The amount and rate of migration of Cache Creek was determined using aerial photographs taken in 1953, 1957, 1964, 1972, 1983, and 1984. Net migration was toward the right bank in three of four reaches in Capay Valley (table 9). Old tree lines shown in aerial photographs of 1953 indicate lateral migration previous to that year.

STREAMBANK EROSION AND VOLUMES OF FLOW

Comparison of aerial photographs from different dates show the location and extent of streambank erosion on both banks. Areas of eroded streambanks were estimated by measuring areas bounded by banklines shown in aerial photographs taken on subsequent dates. Scales of the photographs are 1:6,000 ±2 percent. Scales of the traced banklines were matched by reproducing landmarks and banklines. Areas of erosion by reach and

TABLE 9.--*Net migration of banks and difference in total widths of eroded areas on both banks in four reaches of Cache Creek, 1953-84*

[Reach is designated by cross sections that form upper and lower boundaries. Locations of cross sections are shown in figure 2]

Reach	Direction of net migration	Difference in total widths (feet)
44-36	Right bank	4
36-23	Right bank	1,090
23-14	Left bank	268
14-4	Right bank	1,183

period represented are shown in table 10. Reach 44-36 shows the least erosion per length of reach. Total measured erosion between 1953 and 1984 was about 300 acres. Accuracy of the measured areas of erosion is limited by distortion in photographs, type of digitizer used to measure areas, and thickness of pencil lines on tracing paper.

Graphic comparison indicates that the minimum daily volume of flow that results in bank erosion in the study area is about 6,000 acre-feet, measured at the station near Brooks. A relation was defined by plotting the measured areas of bank erosion against the volumes of daily flows converted from daily flow rates greater than 3,000 ft^3/s during periods when available aerial photographs were taken. Extrapolation of the line in figure 9 indicates that as daily flow volumes greater than 6,000 acre-ft approach zero, the area of bank erosion also approaches zero. No measurable bank erosion occurred in Capay Valley during the 1985 water year, for which the maximum daily flow volume near Brooks was 5,000 acre-ft. Field observation also indicates that bank erosion occurs within

TABLE 10.--*Areas of bank erosion in selected reaches of Cache Creek*

[Aerial-photography dates: April 24, 1953; August 1, 1957; July 8, 1964; March 25, 1972; September 12, 1983; and April 24, 1984. Reach is designated by cross sections that form upper and lower boundaries. Rate in square feet per foot. ft², square feet]

		Period between aerial-photography dates					
		1953-57		1957-64		1964-72	
Reach	Length of reach (feet)	Eroded area (ft²)	Rate	Eroded area (ft²)	Rate	Eroded area (ft²)	Rate
44-36	16,500	36,500	2.2	69,500	4.2	345,500	20.9
36-23	27,400	595,500	21.7	768,500	28.0	795,200	29.0
23-14	24,800	355,500	14.3	915,500	36.9	912,000	36.8
14-4	26,400	199,500	7.6	360,200	13.6	1,157,800	43.9

	Period between aerial-photography dates-- Continued				
	1972-83		1983-84		
Reach	Eroded area (ft²)	Rate	Eroded area (ft²)	Rate	Total eroded area 1953-84 (ft²)
44-36	240,000	14.5	77,500	4.7	769,000
36-23	1,678,800	61.3	287,800	10.5	4,100,000
23-14	1,806,800	72.9	203,500	8.2	4,200,000
14-4	2,325,800	88.1	96,000	3.6	4,100,000

the study area when the daily flow volume at the station near Brooks is greater than 6,000 acre-ft. Active bank erosion was observed just upstream from the station near Brooks on December 19, 1983, when the daily flow volume was 7,580 acre-ft. A streamflow measurement was made during that day.

The 1972-83 data show a greater amount of erosion per volume of flow than data for the other periods. Bank erosion rates may have been increased by the record high flows of 1983 when daily flows exceeded 6,000 acre-ft during 112 of the 139 days between December 22, 1982, and May 9, 1983, the start and end dates of the high-flow period.

Volumes of streamflow, in acre-feet, were computed from records of daily mean flows, in cubic feet per second, at Cache Creek near Capay (1943-76), at Yolo

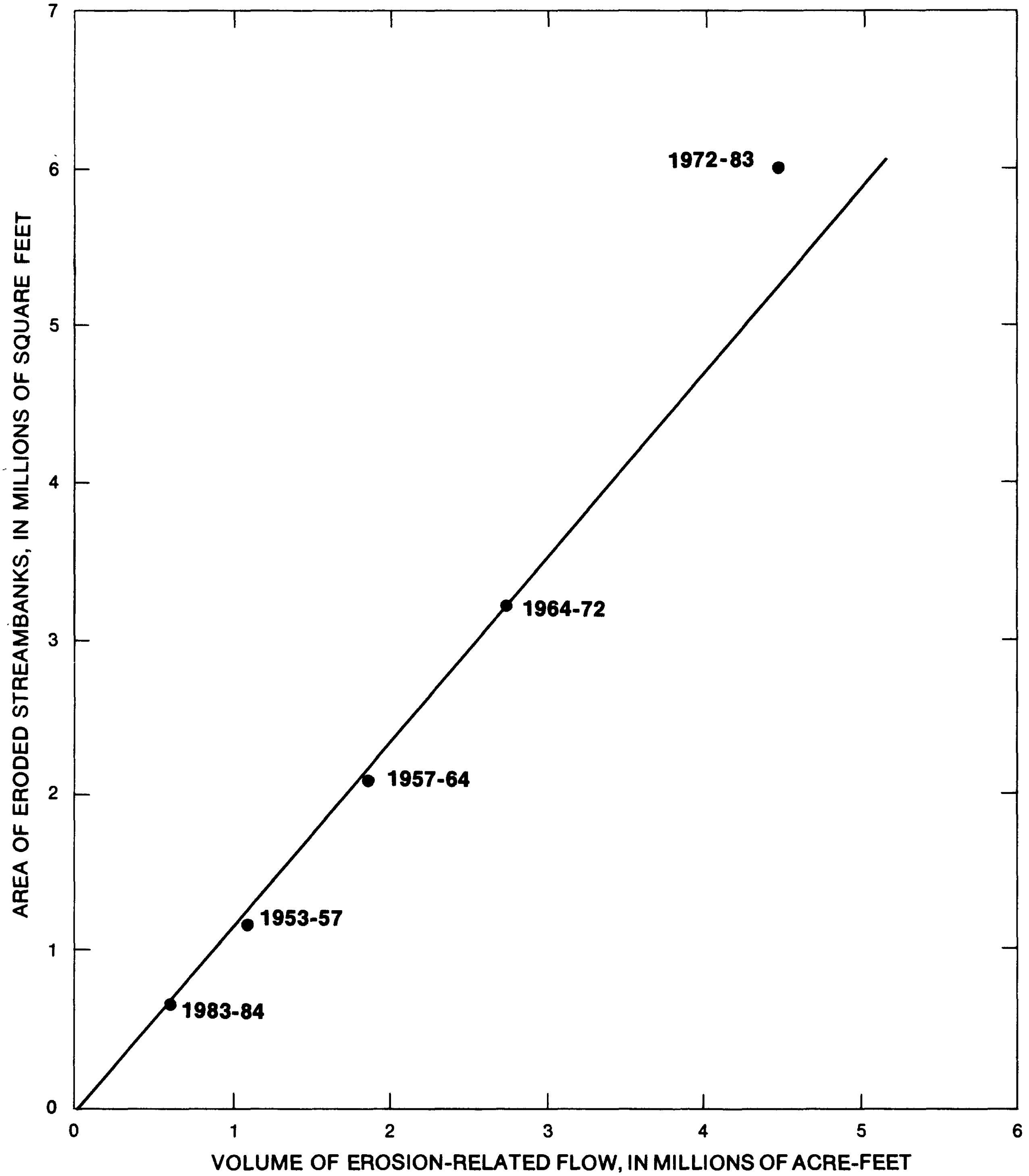


FIGURE 9.— Relation of areas of eroded streambanks to volumes of daily flows greater than 6,000 acre-feet.

(1977-83), and near Brooks (1984). Streamflow records at Cache Creek near Capay and near Brooks are considered equivalent. Records from Cache Creek at Yolo were used because the gage near Capay was discontinued in 1976.

Total volumes of flow for all months that included at least 1 day of flow greater than 6,000 acre-ft were computed from records of flow at Yolo and near Capay for January 1966 to April 1975, when both gages were operating. The difference in volume between the two gages was less than 2 percent; therefore, records at Yolo are considered adequate to represent flows at the Capay station during storm seasons only.

Flows exceeding 6,000 acre-ft on a daily mean basis do not occur every year. For example, in 1985 the maximum daily flow was 5,000 acre-ft. The recurrence interval of daily flows exceeding 6,000 acre-ft is 2 years. The mean annual number of days of flow exceeding 6,000 acre-ft is 16 (fig. 10); therefore, when daily flows exceed 6,000 acre-ft, they normally occur several times during a water year. The curve in figure 10 is based on 1943-85 flow records for Cache Creek near Capay and near Brooks.

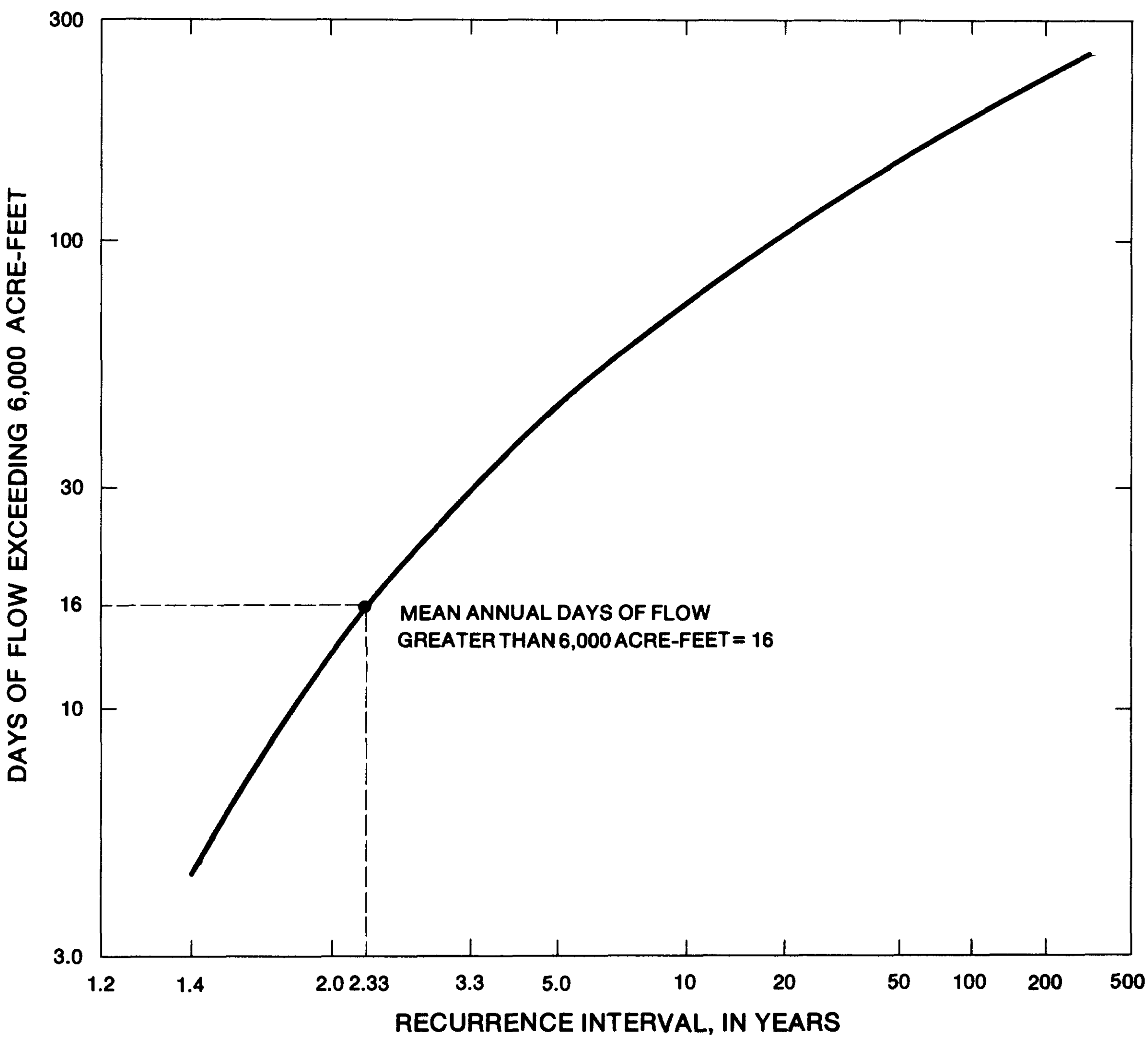


FIGURE 10.— Number of days per year that flows exceed 6,000 acre-feet, Cache Creek near Capay and near Brooks.

SUMMARY

Cache Creek flows from the outlet channel of Clear Lake, through Cache Creek Canyon and the Capay Valley, and out of the valley to the Yolo Bypass. The outlet channel from Clear Lake is small enough to restrict outflow from the lake, and flooding of residential and commercial lakefront property occurred after major storms in 1938, 1958, 1970, and 1983, and 1986. At a public meeting after the 1983 flood, a plan to enlarge the channel was presented. Channel enlargement would increase the flow-release capacity from the lake and prevent flooding of lakefront property. Capay Valley property owners expressed concern that the potential increase in Cache Creek streamflow rates would increase streambank-erosion rates in the agricultural communities of the valley.

The U.S. Geological Survey collected data to document preconstruction channel characteristics and assembled historical data to define flow conditions related to streambank erosion. Streamflow and sediment discharge records were computed for two recording gages. Comparison of the sediment data to data from a previous study shows that the sediment discharge per acre-foot of streamflow was lower during 1984-86 than during 1960-63. Bed-material samples collected at surveyed cross sections indicate that Cache Creek has a gravel bed. More than 65 percent of the material collected is gravel, and about 23 percent is coarser than gravel.

Bank material is sand, silt, and clay on the right bank at most of the cross sections in Capay Valley. Cross-sectional geometry at 49 sites and water-surface slopes in four reaches were determined by level surveys. Changes in cross-sectional geometry were documented by surveys repeated each year at six sites where bank erosion was predicted.

Comparisons of aerial photographs taken on six different dates between calendar years 1953 and 1984 were used to measure sinuosity, lateral migration, and areas of streambanks eroded by Cache Creek in Capay Valley. Cache Creek is classified as a sinuous stream. Eroded areas total about 300 acres and net migration was toward the right bank. The estimated minimum daily flow volume related to bank erosion is 6,000 acre-ft.

Recorded streamflow for the five periods between dates of aerial photographs was used to compute volumes of daily flow greater than 6,000 acre-ft. Volumes of flow were related to the eroded areas.

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