FLOODFLOW CHARACTERISTICS OF HONCUT CREEK AT STATE HIGHWAY 70 BRIDGES NEAR LIVE OAK, CALIFORNIA

U.S. GEOLOGICAL SURVEY

Open-File Report 81-1010

Prepared in cooperation with the

CALIFORNIA DEPARTMENT OF TRANSPORTATION

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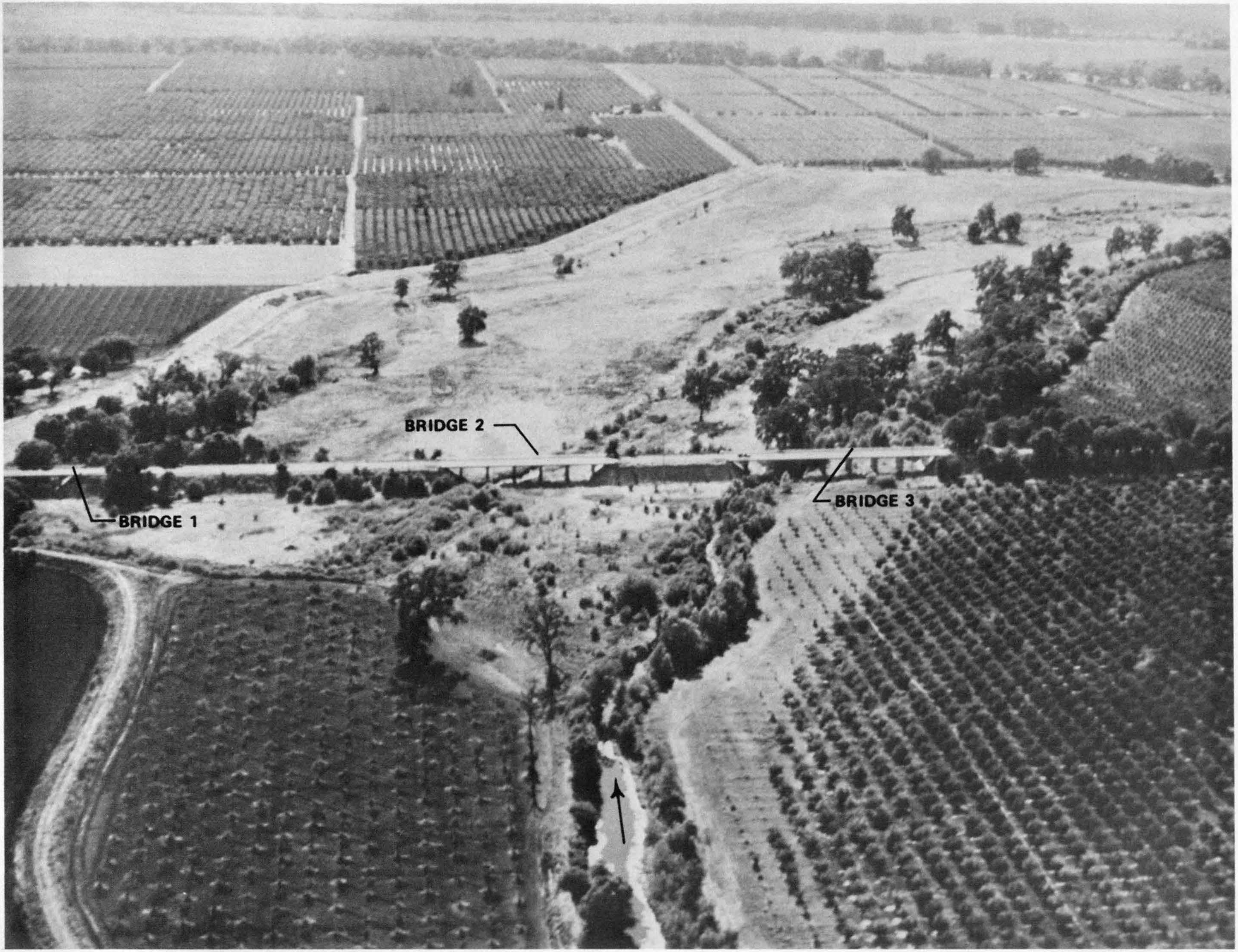

Looking downstream (west) at State Highway 70 crossing of Honcut Creek near Live Oak, California.
(Photographed July 1980)

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Sacramento, California
March 1982

UNITED STATES DEPARTMENT OF THE INTERIOR

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GEOLOGICAL SURVEY

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CONVERSION FACTORS

The inch-pound system of units is used in this report. For those readers who prefer to use metric (SI) units rather than inch-pound units, the conversion factors for the terms used in this report are listed below.

Multiply	By	To obtain metric units
ft (feet)	0.3048	m (meters)
ft/s (feet per second)	0.3048	m/s (meters per second)
ft^2 (square feet)	0.0929	m^2 (square meters)
ft^3/s (cubic feet per second)	0.0283	m^3/s (cubic meters per second)
mi (miles)	1.609	km (kilometers)
mi^2 (square miles)	2.590	km^2 (square kilometers)

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 mean sea level.

FLOODFLOW CHARACTERISTICS OF HONCUT CREEK AT STATE HIGHWAY 70 BRIDGES NEAR LIVE OAK, CALIFORNIA

By J. C. Blodgett

ABSTRACT

State Highway 70 crosses Honcut Creek near Live Oak about 3 miles upstream from its confluence with the Feather River by a series of three bridges separated by short approach embankments. The California Department of Transportation is planning to replace or widen the three bridges. This report evaluates flow characteristics of the existing and proposed crossings. The distribution of flow across the floodplain and water-surface elevation of Honcut Creek at the site are affected by levees, a natural channel constriction, agricultural improvements on the floodplain, and high water levels on the Feather River.

The average recurrence interval for overbank flow is less than 2 years, and for flows equal to the flood of January 12, 1980 (discharge, 10,100 cubic feet per second), is about 2.5 years. A flood with an average recurrence interval of 50 years would discharge about 19,000 cubic feet per second. Flooding caused by high stages on the Feather River has occurred seven times during the period 1964-80.

For flows exceeding 20,000 cubic feet per second on Honcut Creek, and assuming present bridge conditions, backwater at the approach section about 400 feet upstream from the bridge is about 0.4 foot. If bridge 1 (left bank bridge) is eliminated, backwater conditions at the approach section would increase to 0.5 foot. Backwater effects extend upstream more than 3,000 feet when flows exceed about 5,000 cubic feet per second.

The present arrangement of the bridges and approach embankments occupies about 66 percent of the channel (between the levee and high ground). Measurements of the average velocity of flow at a bridge range from 1 to 3.2 feet per second, depending on the flood stages of the Feather River. The maximum point velocity of flow measured during the 1979-80 flood season was 5.6 feet per second. In general, flow velocities will be less than about 6 feet per second because flooding and high stages on the Feather River create ponded conditions at the bridge site. For present channel and bridge conditions, overbank flows are distributed among the three bridges in a proportion of about 10, 40, and 50 percent for flows from 2,850 to 8,480 cubic feet per second.

INTRODUCTION

The California Department of Transportation, Division of Highways (CALTRANS), is planning to replace or widen three bridges across Honcut Creek near Live Oak to improve the traffic-handling capability and safety of State Highway 70. Proposed improvements include widening two of the existing bridges and removal of a third smaller bridge.

At the request of CALTRANS, the U.S. Geological Survey made a study in 1979 and 1980 of the hydraulic characteristics of floodflow at the State Highway 70 crossing of Honcut Creek near Live Oak (fig. 1; city of Live Oak is not shown in fig. 1 but is located 4.2 mi southwest of site).

The purpose of this study was to evaluate the characteristics of flooding at the State Highway 70 approach and bridges across Honcut Creek, and potential changes in floodflow characteristics if the proposed bridge improvements are made. Scope of the study included the determination of historic flood levels and discharges at the site, frequency of flooding, backwater effects from the bridges, effect of flows of the Feather River, and the velocity and distribution of flow among the various bridges. The project also included evaluating existing features at the site, such as identification of the levee system, that affect the extent and location of inundation of the flood plain during floods.

DESCRIPTION OF STUDY AREA

Bridge Site

State Highway 70 crosses the North and South Forks of Honcut Creek about 3.2 mi upstream from its confluence with the Feather River. The highway crosses the creek by a series of three concrete bridges (fig. 2), constructed in 1940, that are supported by precast concrete pile bents. An approach embankment placed on high ground on the right bank (in this report, the left and right banks are referenced looking downstream) and a levee on the left bank flood plain (fig. 1) constrict overbank flow at the site to the various bridge openings. A description of the bridges is given in table 1.

The spacing of the pile bents is sufficient to pass most debris, but placement and angle of skew of the bents near spans 3 and 4 of bridge 3 (fig. 2) causes localized disruption of flow when floating debris catches on the pile bents.

TABLE 1. - Description of State Highway 70 bridges across Honcut Creek near Live Oak

CALTRANS No.	Bridge designation used in report	Channel crossing	Bridge length (ft)	Distance between pile bents (ft)	Maximum waterway area below bridge soffit (ft^2)
16-20	1	South Honcut Creek	107	30	1,444
12-59	2	Middle (North) Honcut Creek	197	30	3,230
12-60	3	North Honcut Creek	257	30	4,530

Flood Plain

The State Highway 70 crossing is located within the Feather River floodway, and flows and water levels of Honcut Creek at the bridge site are affected by flood stages on the Feather River located 3.2 mi downstream from the bridge site (fig. 1). The junction of the low-water channels of North and South Honcut Creeks is near cross section 8 (fig. 1).

Cross sections of the Honcut Creek channels and flood plain were surveyed to determine the capacity of the floodway between the left bank levee and high ground on the right bank (fig. 1). The cross sections were located where changes in the flow capacity appeared significant, such as flow constrictions, and at points needed to define the extent of inundation during floods. Plots of the cross sections are arranged in figure 3 in downstream order so changes in the capacity of the floodway are more apparent. The width of the channel and flood plain is about 4,100 ft at cross section 9, 2,300 ft at cross section 7, and 1,500 ft at cross section 6. Floodflows do not have direct access to the low part of the flood plain at cross section 6 between stations 1600 and 3900 because high ground between cross sections 6 and 7 upstream blocks downstream movement of the flow. Flows are constricted at the bridges (cross section 4) and downstream at cross section 0.1 where the channel and floodway are about 900 ft wide.

The flood plain at the bridge site ranges from a width of about 4,000 ft (fig. 1) to 900 ft. A levee on the left bank flood plain (fig. 1) prevents overflow to the south during floods on Honcut Creek and the Feather River. The left bank flood plain between cross sections 6 and 9 upstream from the bridge site has been leveled for agricultural purposes, and is partly protected by low levees that are subject to overtopping when flows of Honcut Creek exceed about 2,000 ft^3/s.

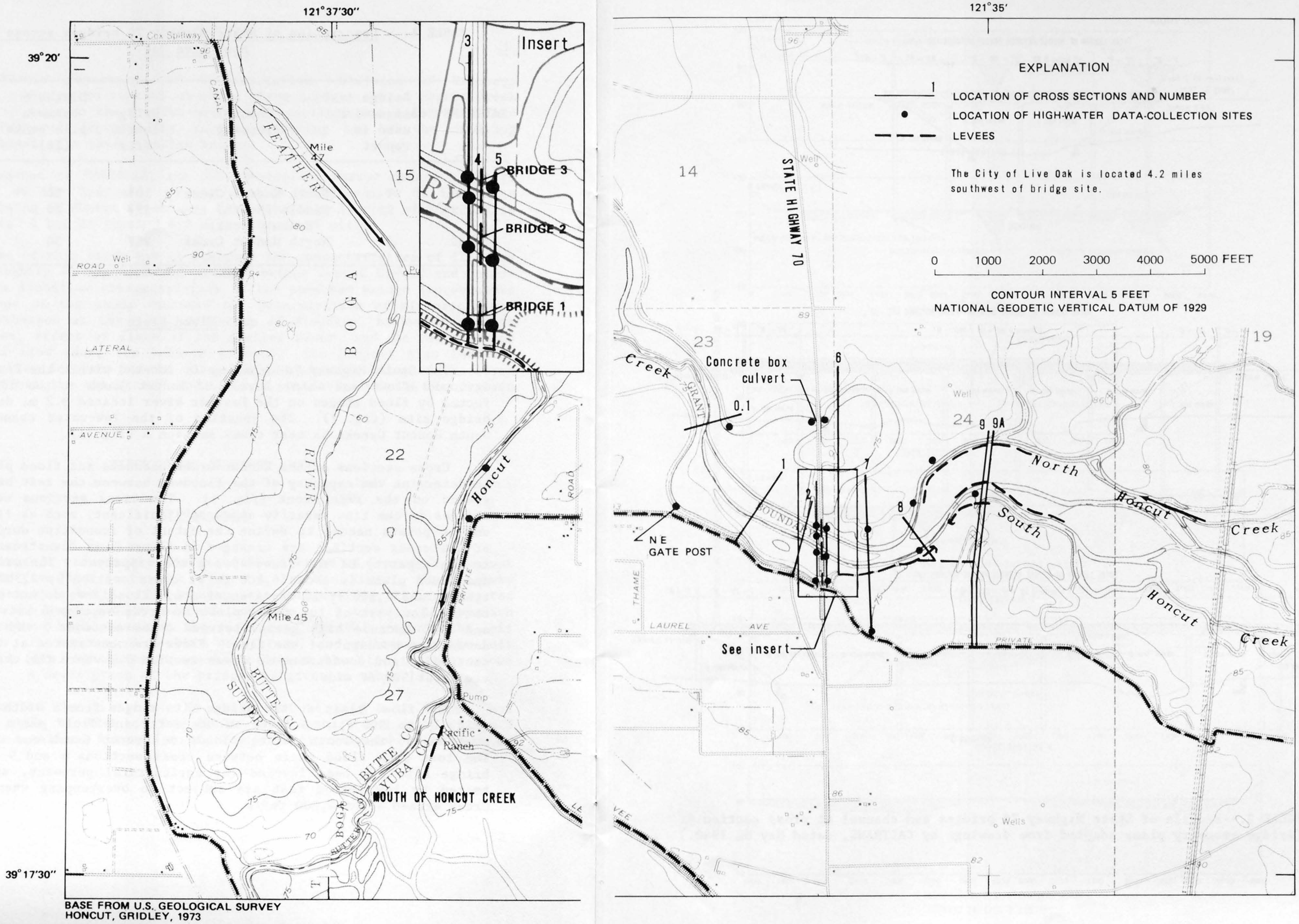

FIGURE 1.--Bridge site and adjacent flood plain, Honcut Creek at State Highway 70 near Live Oak.

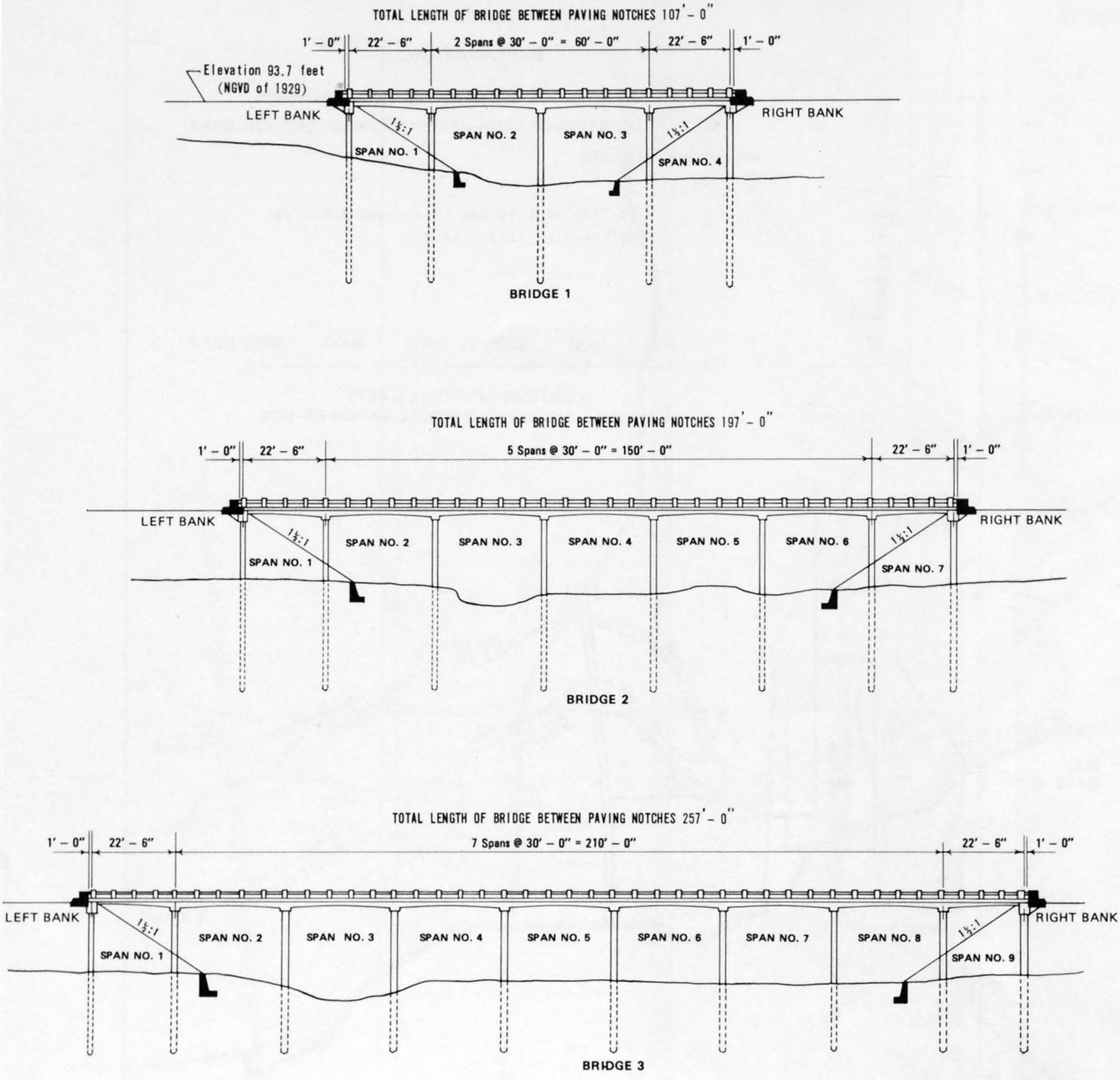

FIGURE 2.--Profile of State Highway 70 bridges and channel at cross section 4. (Bridge geometry plans adapted from drawings by CALTRANS, dated May 6, 1940.)

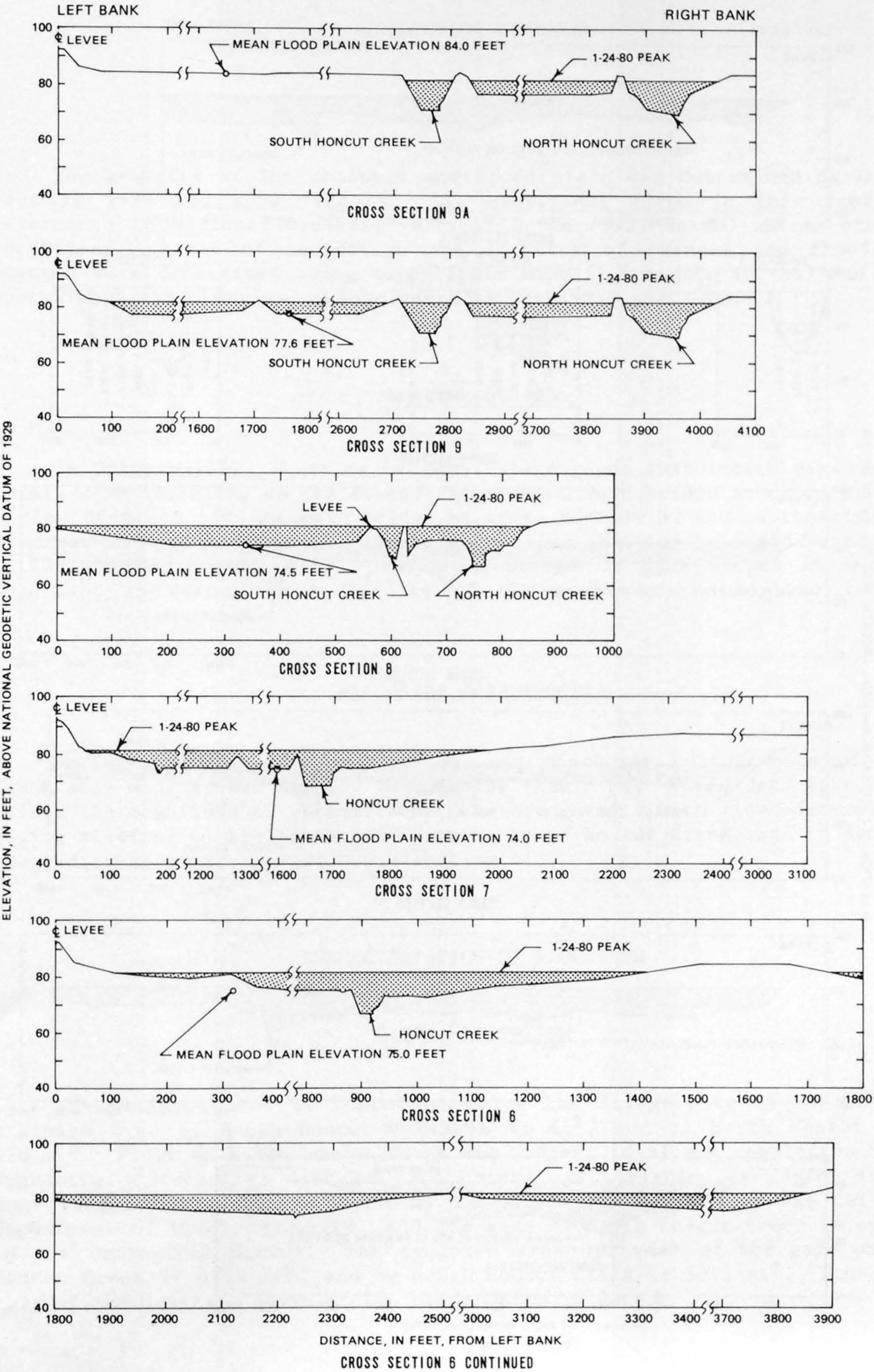

FIGURE 3.--Cross sections of Honcut Creek channel in vicinity of State Highway 70 crossing. Locations of cross sections are shown in figure 1.

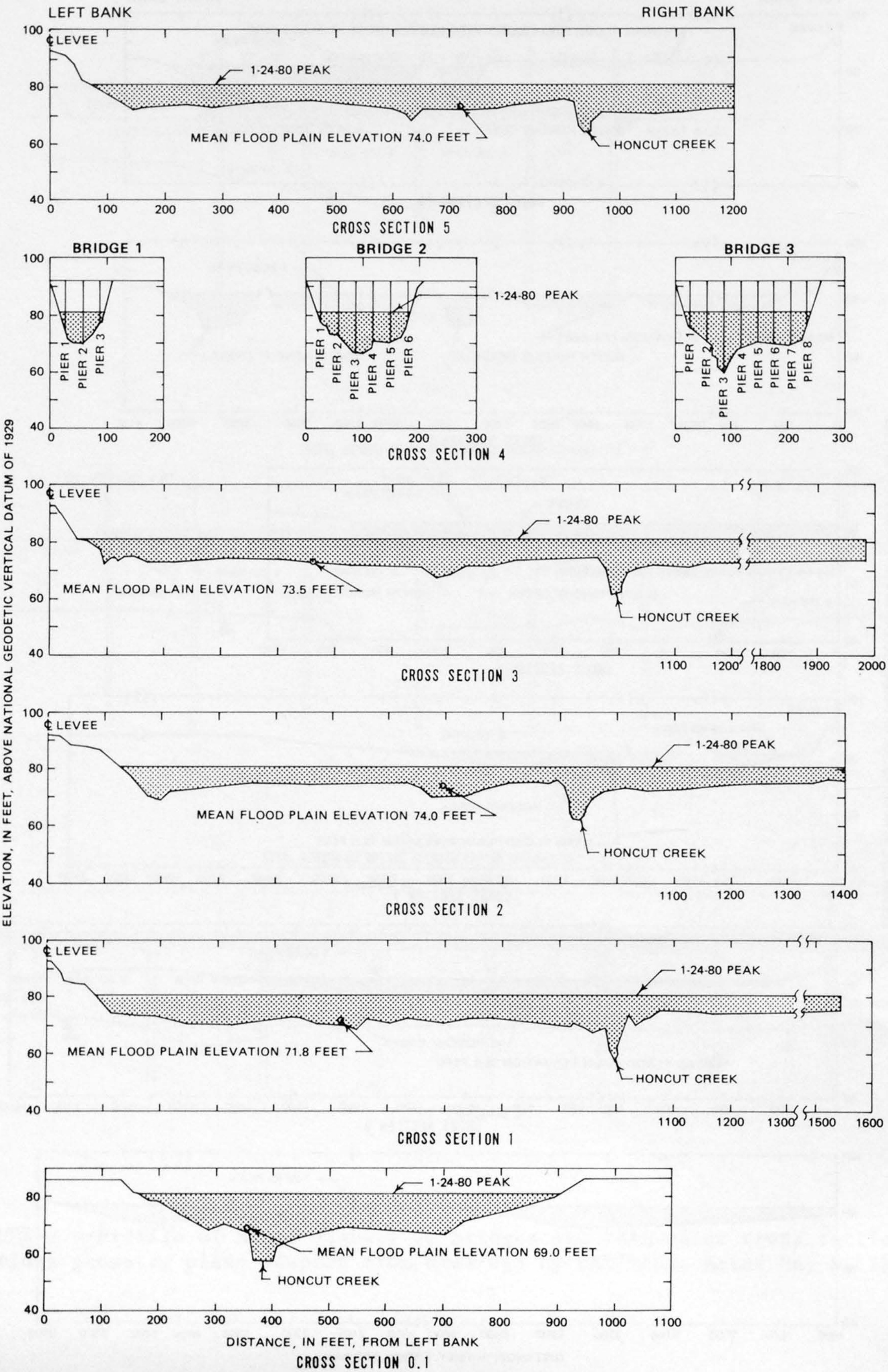

FIGURE 3.--Continued.

COLLECTION OF DATA

Field Surveys

The geometry of the channels and flood plain was determined during surveys in 1979 and 1980 (fig.1). All elevations given in this report are referenced to National Geodetic Vertical Datum (1929 datum) unless otherwise identified. Areas of inundation and location of channel and flood plain changes were determined using topographic maps (7.5-minute series) and aerial photographs taken during various years between 1973 and 1980.

Instrumentation

In October 1979, a series of crest-stage gages that record maximum water levels were installed on the downstream side of each bridge at cross section 4, on the upstream side of each bridge at cross section 5, and on the right bank at cross section 8 (fig. 1). These gages, supplemented by field surveys made during periods of flooding, provide a record of peak stages at locations important in describing hydraulics of the creek at the highway crossing.

Discharge Measurements

During the 1979-80 flood season, six discharge measurements of Honcut Creek were made at the Highway 70 crossing (table 2). These data were used to relate the magnitude of streamflow at the bridge site with flows determined at gaging stations on the North and South Forks of Honcut Creek, and to develop a stage-discharge relation at cross section 4.

CHARACTERISTICS OF FLOODFLOW

Gaged Streamflow

The drainage area of Honcut Creek at the bridge site is 206 mi^2. The drainage area of South Honcut Creek is 86 mi^2, and of North Honcut Creek, 120 mi^2. Flows on North Honcut Creek are subject to slight regulation by Lake Wyandotte. Streamflow data on both creeks are collected at gaging stations near Bangor. The gage on North Honcut Creek is operated by the California Department of Water Resources, and the gage on South Honcut Creek is operated by the Geological Survey. The drainage area upstream of the gage on North Honcut Creek is 47.1 mi^2, and on South Honcut Creek is 30.6 mi^2. Thus, about half of the drainage basin at the bridge site is gaged.

TABLE 2. - Discharge measurements of Honcut Creek, made in 1979 and 1980 at State Highway 70 crossing near Live Oak

Date	Bridge No.	Width (ft)	Area (ft^2)	Mean velocity (ft/s)	Water-surface elevation[1] (ft, NGVD)	Discharge (ft^3/s)
Dec. 26, 1979	1	--	--	0	72.93	No flow
	2	--	--	0	72.98	No flow
	3	162	540	1.89	73.39	1,020
Total						1,020
Jan. 12, 1980	1	62	321	2.17	78.19	698
	2	150	855	3.23	77.58	2,770
	3	216	1,363	2.82	77.38	3,850
Total						7,318
Jan. 14, 1980	1	62	384	.75	78.72	287
	2	154	1,094	.91	78.71	992
	3	213	1,704	.92	78.71	1,570
Total						2,849
Feb. 19, 1980	1	67	310	1.68	77.77	520
	2	148	856	2.26	77.32	1,930
	3	209	1,275	1.82	77.21	2,320
Total						4,770
Feb. 21, 1980	1	68	453	1.94	80.16	878
	2	159	1,206	2.70	80.12	3,260
	3	219	1,946	2.19	80.34	4,340
Total						8,478
Mar. 13, 1980	1	--	--	--	--	No flow
	2	--	--	--	--	No flow
	3	25	102	2.24	67.62	228
Total						228

[1]Water-surface elevations were measured at the downstream side of the bridges (cross section 4) and are the average of stages observed during the discharge measurements. Refer to frontispiece for location of bridges.

A comparison of floods on North and South Honcut Creeks (table 3) indicates that during years of lower magnitude storms, flooding of each basin may occur independently of each other. During the 21 years of data that are suitable for comparison, the annual maximum flood for each basin occurred on different dates seven times.

TABLE 3. - Annual maximum flood elevations and discharges of North and South Honcut Creeks near Bangor

[Bangor (not shown in fig. 1) is about 11.5 mi northeast of the study area. The gaging station on North Honcut Creek is operated by California Department of Water Resources. Elevations are referenced to local datum]

Water year	South Honcut Creek			North Honcut Creek		
	Date of flood	Elevation (ft)	Discharge (ft^3/s)	Date of flood	Elevation (ft)	Discharge (ft^3/s)
1952	11-20-51	8.68	3,170			
1952	1-12-52	8.28	2,660			
1953	1-08-53	8.00	2,320			
1954	1-17-54	7.40	1,640			
1955	12-09-54	5.43	460			
1956	12-23-55	11.15	6,340			
1957	2-24-57	7.61	1,840			
1958	4-02-58	8.09	2,410			
1959	2-16-59	8.29	2,630			
1960	2-08-60	8.63	2,980	2-07-60	8.57	2,890
1961	1-31-61	6.23	[1]815	1-31-61	7.69	1,780
	3-17-61	6.39	915	3-17-61	--	([2])
1962	2-09-62	9.70	4,320	2-09-62	--	[1,3]2,600
	2-15-62	6.94	[1]1,250	2-15-62	9.08	3,620
1963	10-13-62	12.40	8,280	10-13-62	--	[3]9,900
1964	1-20-64	8.62	2,960	1-21-64	9.46	5,010
1965	12-26-64	19.25	17,600	12-26-64	11.57	10,700
1966	1-04-66	6.98	1,280	1-04-66	7.48	1,820
1967	1-21-67	10.95	6,040	1-21-67	11.11	9,060
1968	1-30-68	7.35	[1]1,580	1-30-68	8.62	3,030
	2-19-68	7.55	1,740	2-19-68	8.15	[1]2,420
1969	1-13-69	8.78	[1]3,160	1-13-69	10.73	6,930
	1-21-69	9.84	4,500	1-21-69	10.27	[1]5,690
1970	1-14-70	9.37	3,890	1-14-70	11.16	6,930
1971	12-02-70	8.17	[1]2,450	12-02-70	9.02	3,480
	3-26-71	8.90	3,300	3-26-71	--	[1,3]3,000
1972	12-24-71	6.36	900	12-24-71	7.32	1,020
1973	2-27-73	9.37	3,890	2-27-73	12.03	8,740
1974	1-16-74	9.07	3,500	1-16-74	10.18	4,710
1975	2-01-75	9.38	3,910	2-01-75	--	[1,3]5,700
	2-12-75	8.87	[1]3,260	2-12-75	11.09	7,340
1976	2-29-76	4.58	247	2-29-76	5.86	300
1977	1-03-77	3.23	54	1-03-77	5.05	115
1978	1-14-78	8.73	[1]3,040	1-14-78	10.89	6,450
	1-16-78	8.96	3,300	1-16-78	10.27	[1]4,990
1979	2-14-79	7.56	1,850	2-14-79	8.98	[1]2,310
	2-28-79	7.54	[1]1,830	3-01-79	9.49	2,970
1980	1-12-80	9.42	3,880	1-12-80	10.88	5,090

[1]Secondary peak discharge.
[2]Discharge not available.
[3]Estimated on basis of correlation with records for South Honcut Creek near Bangor.

Floods of December 1979 and January-February 1980

Floods in December 1979 and January-February 1980 were large enough to cause overbank flooding upstream and downstream from the State Highway 70 crossing. The location and direction of channel and overbank flow observed during these floods are shown by arrows in figure 4. A bench constructed between points A and B (fig. 4) during land-leveling operations acts as a boundary for overbank flow and affects the amount of flow contraction near cross section 9.

Overbank flow in the vicinity of point E (fig. 4) normally is confined between the highway embankment and a low levee 250 ft upstream. Water reaching this location must pass through bridge 1 or travel laterally about 300 ft north and pass through bridge 2. Surveys of water levels during the 1979-80 flood season indicate flows are constricted more at bridge 1 than at the other bridges. During site surveys on February 21, 1980 (discharge 8,500 ft^3/s), the drop in water surface was 0.5 ft through bridge 1, 0.4 ft through bridge 2, and 0.3 ft through bridge 3.

Areas inundated during the flood of January 13-20, 1980, in the vicinity of the State Highway 70 crossing are shown in figure 5. Some of the overflow on the right bank flood plain occupies an old slough upstream from the highway. Much of this overflow passes downstream through a concrete box culvert under the highway that is located about 2,000 ft north of bridge 3.

Changes in landform over the years have also affected the location of the channels so the juncture of the North and South Forks of Honcut Creek are presently near point D (fig. 4). A defined channel for middle Honcut Creek, referred to in table 1, extends upstream from bridge 2 about 400 ft before merging with the leveled ground in an orchard. The overflow weir at point C (fig. 4) allows inundation of the left bank flood plain and prevents large differences in water-surface elevations that could cause scour and erosion problems on the flood plain if the existing levees failed during floods. The presence of dumped rock riprap and scour on the flood plain at point C, observed during site surveys in 1979 and 1980, indicates overflow is a common occurrence, and flow velocities are high enough to require local revetment on the left side of the creek bank.

Flood Profiles

Longitudinal profiles of various floods for a reach 12,000 ft long in the vicinity of the bridge site were assembled, as shown in figure 6, for use in evaluating flow characteristics at the bridge site. The profiles show the height of the left bank levee and bridge soffit elevation relative to historical flood levels. Locations where the channel capacity varies are represented by breakpoints in the overall trend of the profiles.

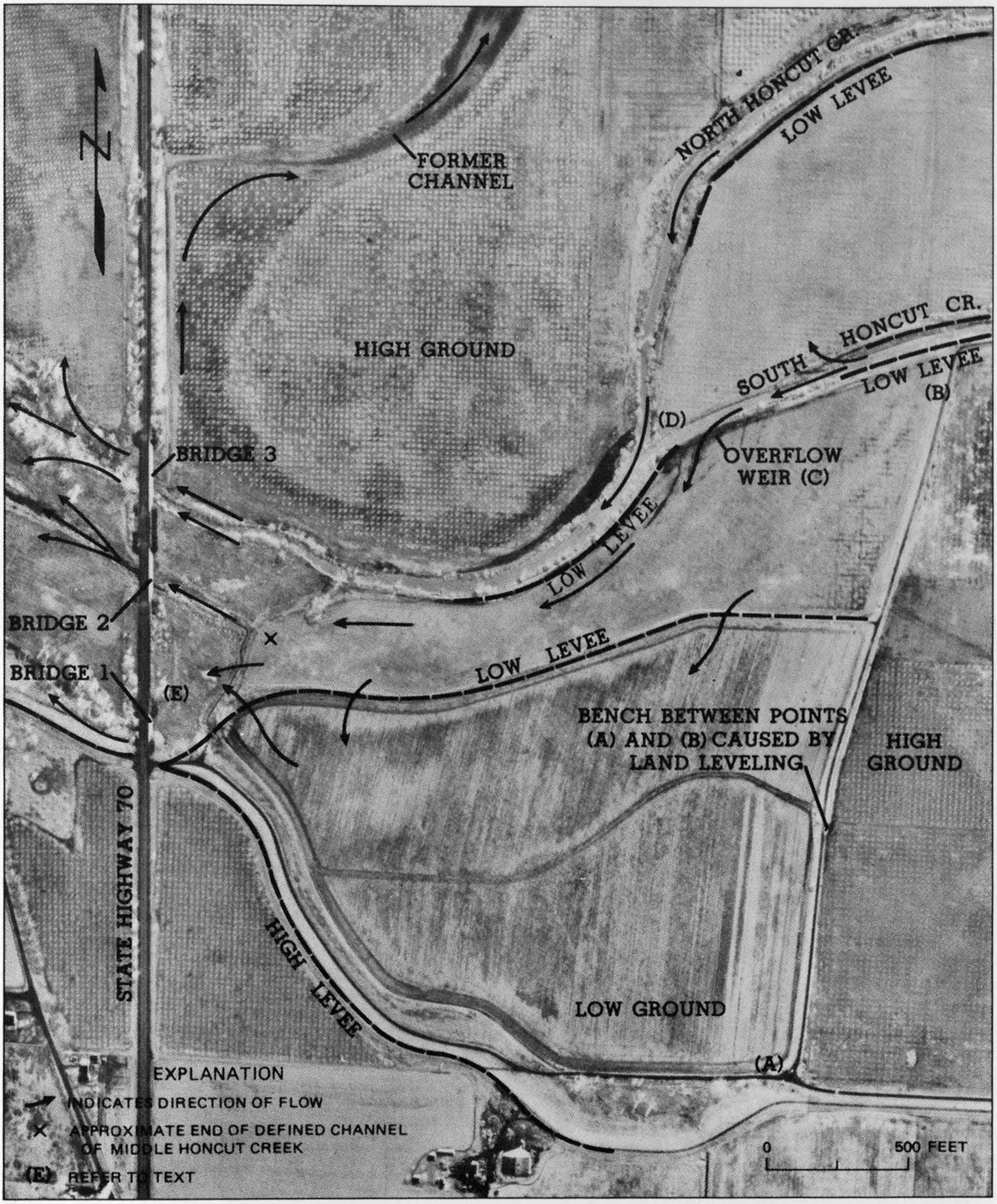

FIGURE 4.--Aerial view of flood plain, levees, and State Highway 70 bridges across Honcut Creek, March 10, 1980. (Photograph courtesy of CALTRANS.)

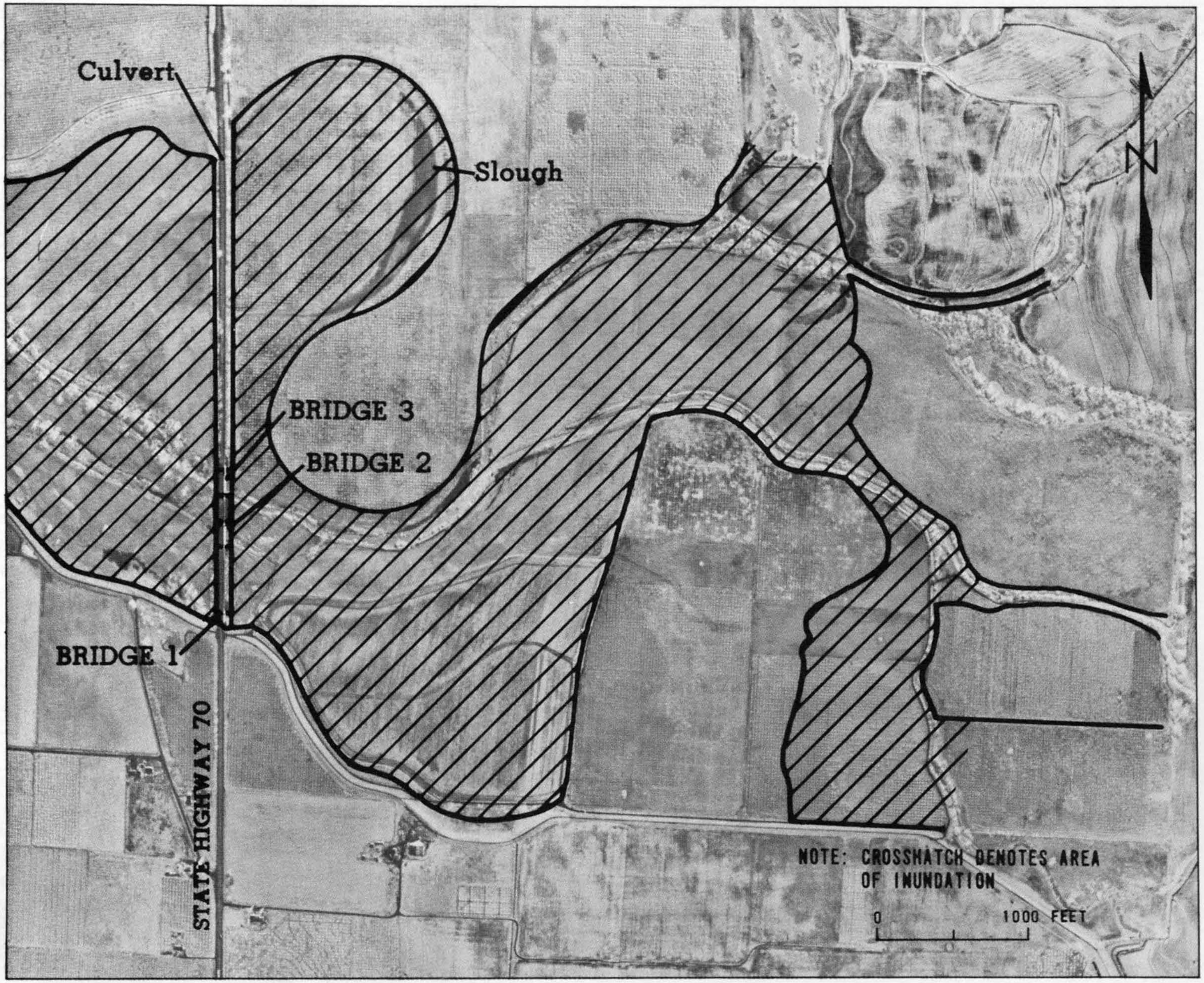

FIGURE 5.--Area of inundation during flood of January 13-20, 1980, at State Highway 70 crossing of Honcut Creek. (Aerial photograph base map dated May 1, 1980, courtesy of CALTRANS. Areas of inundation determined from a series of aerial photographs dated January 18, 1980, by the California Department of Water Resources.)

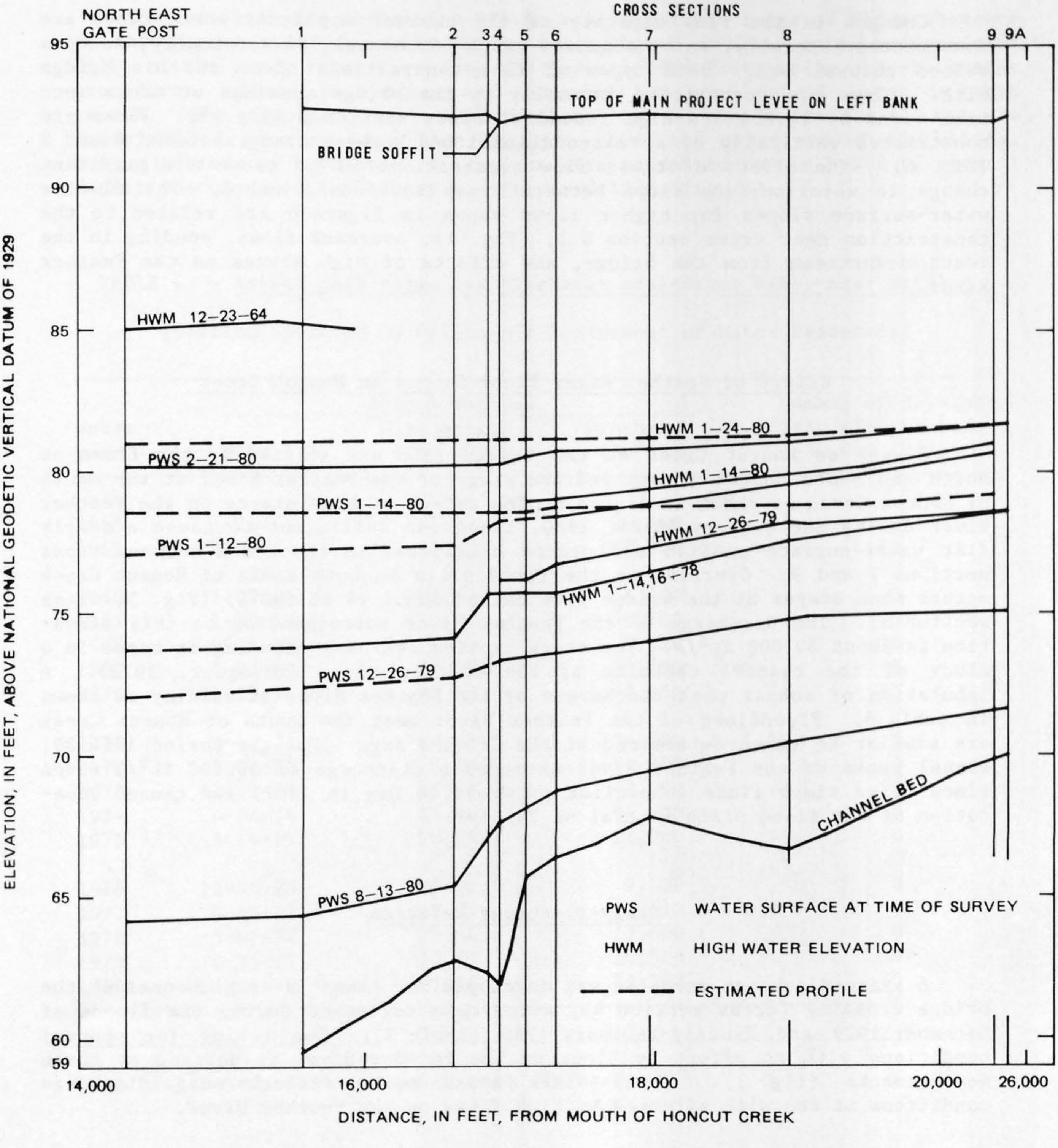

FIGURE 6.--Profiles of Honcut Creek in vicinity of State Highway 70 bridge site. Location of cross sections are shown in figure 1.

Changes in the flow capacity of the channel may occur where flows are constricted laterally, as by a narrow reach of channel, or vertically, as by a raised channel bed. Both types of flow contractions occur at this bridge site. Flows are constricted laterally by the bridge openings at cross section 4 and by levees and high ground at cross section 6 (fig. 3). Flows are constricted vertically by a raised channel bed between cross sections 4 and 8 (fig. 6). The effect of these flow contractions is to cause a significant change in water-surface slope between cross sections 2 and 6. The flatter water-surface slopes for higher flows shown in figure 6 are related to the constriction near cross section 0.1, (fig. 1), overbank flows, ponding in the reach downstream from the bridge, and effects of high stages on the Feather River.

Effect of Feather River Flood Stages on Honcut Creek

Stages on Honcut Creek at the bridge site are related to the flows of North and South Honcut Creeks and the stage of the Feather River at the mouth of Honcut Creek as shown in figure 6. The effect of high stages on the Feather River during the January 13-24, 1980, flood was sufficient to cause a nearly flat water-surface profile and ponded conditions in the reach between cross sections 1 and 9. Overflow to the flood plain on both banks of Honcut Creek occurs when stages at the bridge site exceed about 74 ft (NGVD) (fig. 3, cross section 5). The discharge of the Feather River corresponding to this elevation is about 30,000 ft^3/s. The stage causing overbank flooding is based on a study of the channel capacity of the Feather River (Blodgett, 1972). A tabulation of annual peak discharges of the Feather River at Gridley is shown in table 4. Floodflows of the Feather River near the mouth of Honcut Creek are similar to those determined at the Gridley gage. For the period 1964-80, annual peaks of the Feather River exceeded a discharge of 30,000 ft^3/s seven times (five times since completion of Oroville Dam in 1967) and caused inundation of the flood plain a total of 75 days.

Stage-Discharge Relation

A stage-discharge relation was developed for flows in each channel at the bridge crossing (cross section 4), using data collected during the floods of December 1979 and January-February 1980 (table 2). The rating for channel conditions with no effect by flows on the Feather River is defined by three measurements (fig. 7). Three other measurements reflect stage-discharge conditions at the site affected by high flows on the Feather River.

To assist in the definition of the rating for the range of flows observed at the gaging stations on North and South Honcut Creeks, water-surface profiles of the study reach were computed for selected flows using step-backwater procedures. These procedures are discussed in more detail later in this report. The computed water-surface elevations at cross section 4, and the associated discharges were then used to define the upper end of the rating. During periods of backwater, discharges were estimated on the basis of channel conditions observed in January and February 1980 (fig. 7).

TABLE 4. - Annual peak stage and discharge of Feather River near Gridley

[Station operated by California Department of Water Resources]

Water year	Annual maximum			Number of days per year flow exceeds 30,000 ft^3/s
	Date	Gage height (ft, NGVD)	Discharge (ft^3/s)	
1964	1-21-64	82.27	23,500	0
1965	12-23-64	97.52	151,000	11
1966	1-05-66	78.69	14,000	0
1967	1-30-67	85.79	45,600	5
1968	2-13-68	74.33	5,420	0
1969	1-22-69	87.29	56,400	8
1970	1-27-70	89.90	72,900	17
1971	3-30-71	80.70	24,300	0
1972	2-09-72	76.88	11,800	0
1973	1-19-73	85.78	47,000	3
1974	4-04-74	87.07	54,700	18
1975	5-14-75	76.31	11,000	0
1976	12-04-75	75.62	9,400	0
1977	4-30-77	73.25	3,210	0
1978	3-07-78	78.34	17,400	0
1979	2-25-79	[1]77.77	[1]15,500	0
1980	1-15-80	91.54	89,100	13
Total				75

[1]Estimated stage and daily mean discharge.

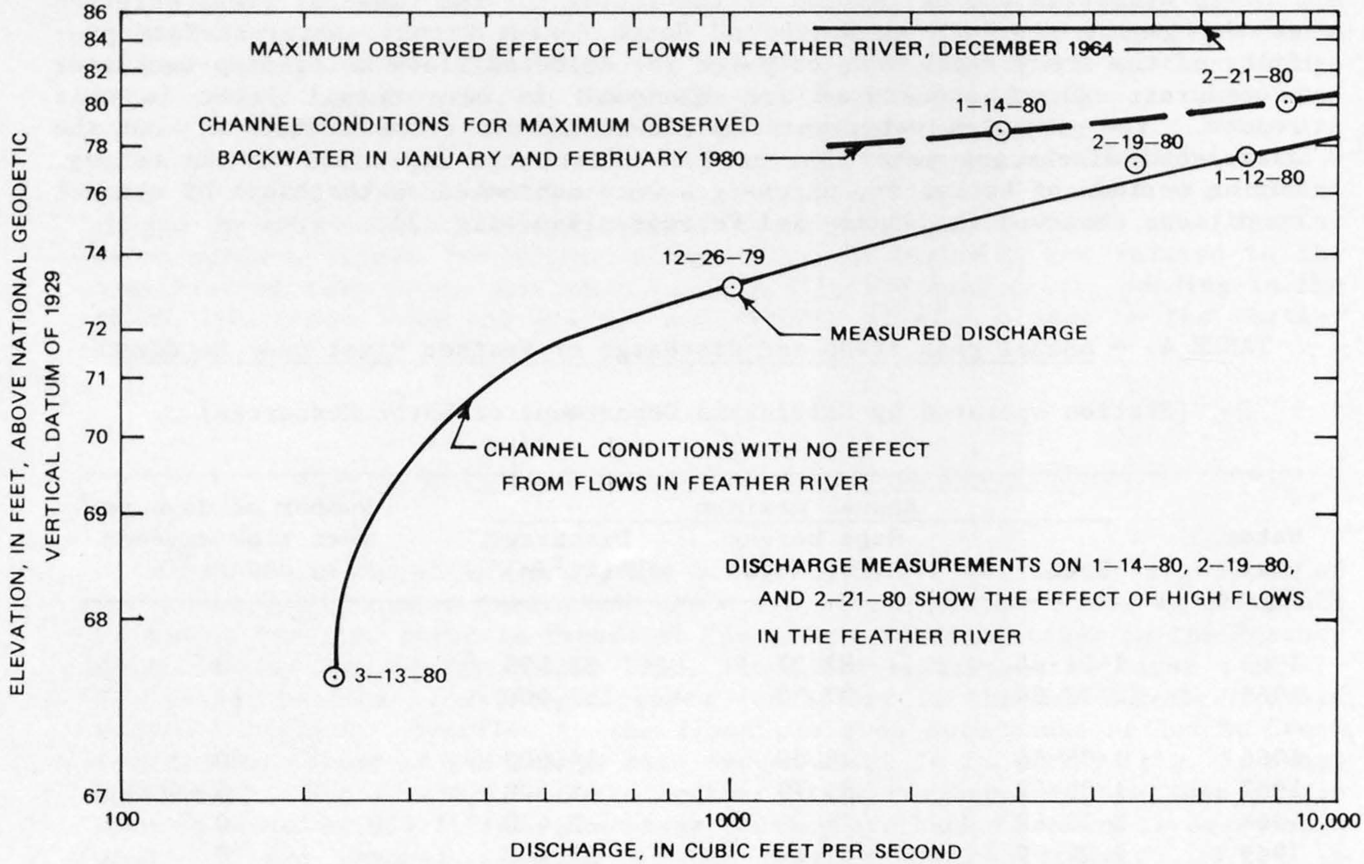

FIGURE 7.--Relation of water-surface elevation and discharge at downstream side of State Highway 70 bridges 1, 2, and 3 across Honcut Creek.

Determination of Annual Peak Discharge at Bridge Site

The magnitude of annual peak flow at the bridge site for the period 1960-80 was derived by combining the flow of similar floods on North and South Honcut Creeks near Bangor (table 3) and adjusting for channel losses and inflow. Flows were adjusted on the basis of a relation (fig. 8) developed using data obtained at the bridge site during floods in 1979 and 1980 and corresponding flows at the two upstream gaging stations. The total flow of North and South Honcut Creeks, and estimated annual maximum discharge at State Highway 70 crossing for the period 1960-80 are shown in table 5.

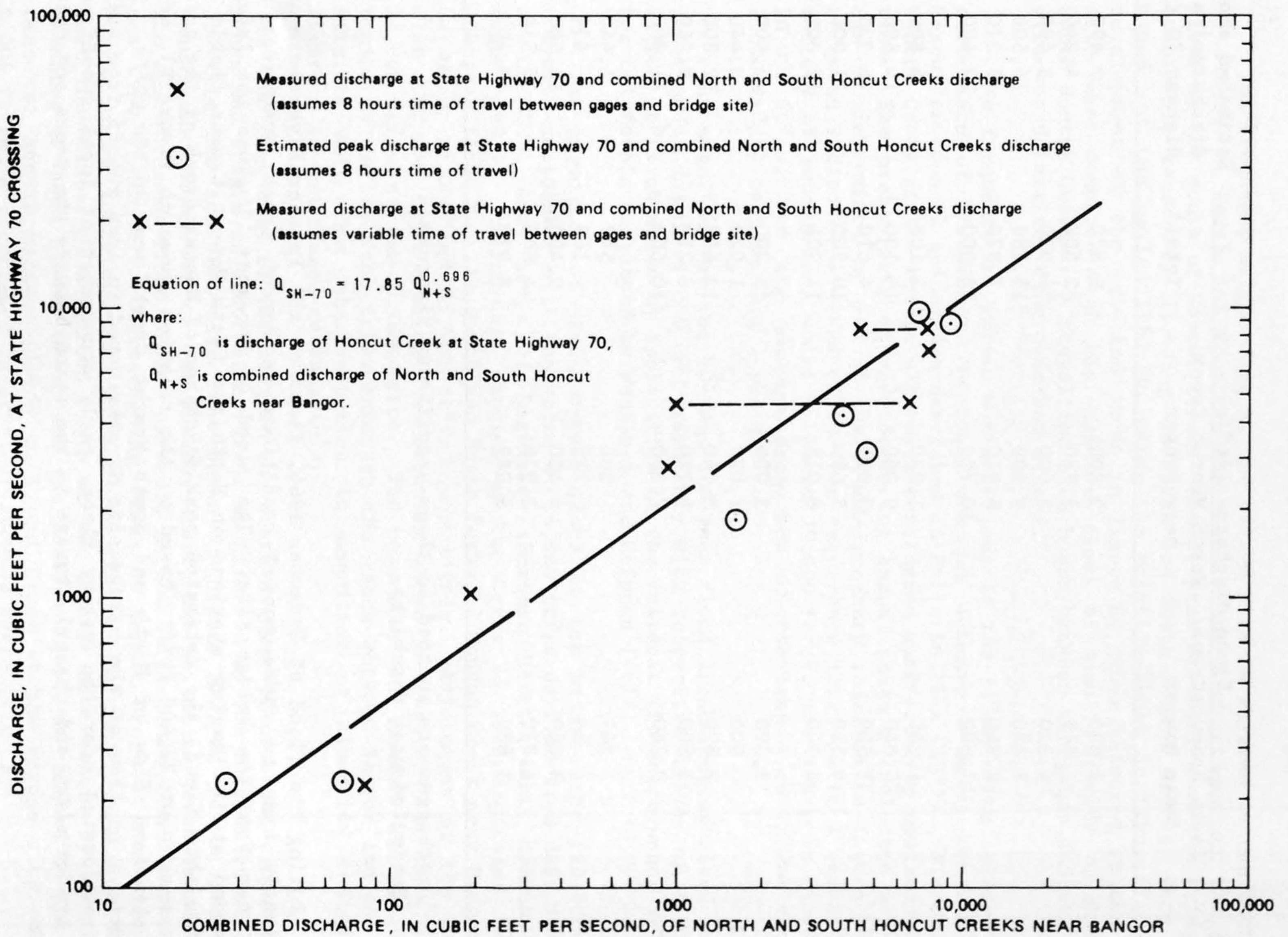

FIGURE 8.--Relation of discharge at State Highway 70 crossing and combined discharge of North and South Honcut Creeks near Bangor.

TABLE 5. - Estimated annual maximum discharge at State Highway 70 crossing for period 1960-80

Water year	Flood discharge (ft^3/s): South Honcut Creek near Bangor	Flood discharge (ft^3/s): North Honcut Creek near Bangor	Flood discharge (ft^3/s): Total[1]	Estimated annual peak discharge[1] at State Highway 70 (ft^3/s)
1960	2,980	2,890	5,870	7,490
1961	815	1,780	[2]2,600	4,240
1962	4,320	2,600	[2]6,920	8,400
1963	8,280	9,900	[2]18,180	16,500
1964	2,960	5,010	7,970	9,270
1965	17,600	10,700	28,300	22,400
1966	1,280	1,820	3,100	4,800
1967	6,040	9,060	15,100	14,500
1968	1,580	3,030	4,610	6,330
1969	4,500	5,690	10,200	11,000
1970	3,900	8,015	11,900	12,300
1971	3,300	3,000	[2]6,300	7,900
1972	900	1,020	1,920	3,440
1973	3,890	8,740	12,600	12,800
1974	3,500	4,710	8,210	9,460
1975	3,260	7,340	[2]10,600	11,300
1976	247	300	547	1,440
1977	54	115	169	634
1978	3,040	6,450	9,490	10,500
1979	1,830	2,970	4,800	6,510
1980	3,880	5,089	8,970	10,100

[1]Discharges are rounded to three significant figures.
[2]Estimated peak discharge.

During the flood of December 1964, flows on the Feather River were sufficiently high to cause ponded conditions on Honcut Creek downstream and upstream from the bridge site. The flood of December 1964 was the largest recorded at the gaging stations on North and South Honcut Creeks (table 3). During this flood, the estimated peak discharge of Honcut Creek at the bridge site was about 22,400 ft^3/s (based on the relation shown in figure 8), while the combined flow of North and South Honcut Creeks was 28,300 ft^3/s. The reduction in flow at the bridge site is attributed to less runoff from tributaries located near the valley floor, early occurrence of local runoff near the bridge site, and channel storage in the reach between the gages and bridge site.

Flood Frequency

The frequency of flooding at the bridge site is related to the occurrence of floods on North and South Honcut Creeks and high stages on the Feather River at the mouth of Honcut Creek. Annual peak discharges at the bridge site (table 5), caused by flooding of North and South Honcut Creeks, were determined for the period 1960-80, using the relation shown in figure 8. In the development of the relation shown in figure 8, flows measured at the bridge site were compared with the combined flows of similar floods on North and South Honcut Creeks. A traveltime of 8 hours between the gages and the bridge site was determined from observed stages.

The frequency of annual maximum flows at the bridge site related to the occurrence of flooding on Honcut Creek was determined using the U.S. Water Resources Council guidelines described in Bulletin 17-A (1977). Floodflows on Honcut Creek at the bridge site were considered unaffected by upstream regulation. The probability of exceedence for annual peaks of selected magnitudes can be determined by use of the flood-frequency relation in figure 9. This relation indicates a flood of 50-year recurrence interval (a 2 percent probability of exceedence) would be about 19,000 ft^3/s, the 100-year flood about 20,000 ft^3/s, and the average frequency of overbank flow (flow exceeding 2,000 ft^3/s) is less than 2 years.

The magnitude of the 50- and 100-year flood discharges obtained from the relation in figure 9 compares favorably with respective values of 17,200 and 21,600 ft^3/s obtained by application of the regional flood-frequency relations for California developed by Waananen and Crippen (1977).

The magnitude of the 100-year flood at the bridge site (20,000 ft^3/s) compares reasonably with the value of 24,000 ft^3/s derived from data furnished by the U.S. Army Corps of Engineers (Herbert Hereth, oral communication, August 1981). Preliminary studies by the Corps in 1975 indicated that the 100-year flood for the South and North Forks of Honcut Creek near Bangor would be about 16,000 and 45,500 ft^3/s respectively. Adjustment of the combined flow (30,500 ft^3/s) using the relation shown in figure 8 gives a flow of 24,000 ft^3/s at the bridge site. The potential for channel storage and the timing of inflow from tributaries in the reach between Bangor and the bridge site is such that the reduction in magnitude of floodflow indicated in figure 8 is considered reasonable.

The frequency of flooding at the State Highway 70 crossing caused by high flows and stages on the Feather River is affected by the regulation of flow at Oroville Dam near Oroville (not shown in figure 1). As stated previously, annual maximum floods on the Feather River, sufficient to cause inundation of the Honcut Creek flood plain, exceeded 30,000 ft^3/s seven times between 1964 and 1980 (table 4). Corresponding flows of Honcut Creek at the bridge site during these years exceeded 9,000 ft^3/s (table 5). This comparison suggests that inundation of the flood plain at the bridge site caused by the combined flooding of both Honcut Creek and the Feather River is related to the occurrence of annual maximum floods on Honcut Creek at the bridge site exceeding 9,000 ft^3/s, a recurrence interval of about 2 years (fig. 9).

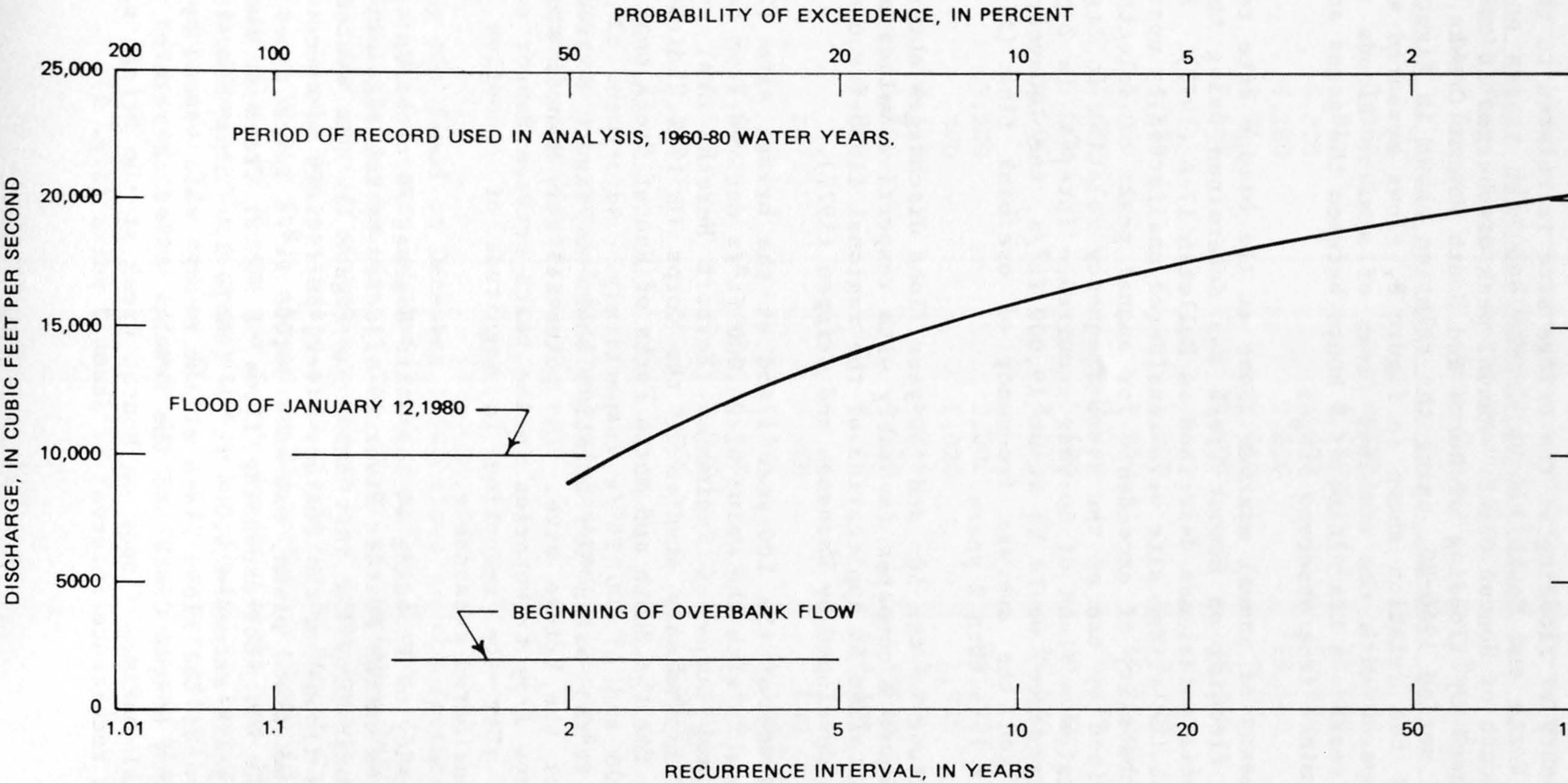

FIGURE 9.--Frequency relation of annual maximum discharge for Honcut Creek at State Highway 70 crossing.

HYDRAULIC CHARACTERISTICS OF THE BRIDGES

Computation of Water-Surface Profiles

The contraction of a stream channel causes a change in the slope of a water-surface profile. A contraction may be caused by natural local changes in the flow capacity such as a narrowing of the channel, the construction of levees that restrict the lateral movement of overbank flow, or a bridge structure that confines the flows to the opening(s).

Backwater is defined as the increase in water-surface elevation above a stage that would occur for flow conditions unconfined by a constriction such as a bridge opening. Backwater may also be caused by high stages on a tributary located downstream from the bridge site (in this case, the Feather River), but for purposes of this discussion, the effects of high flows on the Feather River are considered separately.

The method for determining water-surface elevations at various locations in the vicinity of a bridge constriction is based on application of the continuity and energy equations between the bridge and approach cross sections. Details of the procedures for computing the hydraulics of bridge constrictions are discussed by Matthai (1968), Bradley (1970), and Shearman (1976).

Water-surface elevations of several floods in the vicinity of the Honcut Creek bridge site were documented during the 1979-80 flood season, as shown in figures 1 and 6. These data indicate floodflows are constricted in the vicinity of the crossing at cross sections 0.1, 4, and 9 (fig. 1). The analysis for backwater conditions upstream from the bridge site consisted of computing water-surface profiles for the reach between cross sections 1 and 9A (figs. 1 and 6), in which section 4 is at the downstream side of the bridges, and section 6 is the approach section. Water-surface profiles for flows between 1,000 and 25,000 ft^3/s were computed for the bridges in present position (as-is), and for conditions assuming bridge 1 is removed. The computed profiles for different flows are given in tables 6-8 and are based on the stage-discharge relation developed at cross section 4 (fig. 7) and channel and levee conditions surveyed in 1979 and 1980.

The data in table 6 represent profiles for present bridge opening conditions, data in table 7 represent channel conditions prior to construction of the bridge, and the data in table 8 represent profiles that would probably result if bridge 1 (fig. 2) was removed.

The main levees on the left bank flood plain (fig. 2) were high enough to contain all flow. The hydraulic characteristics of the channel and bridges in the study reach were determined using measurements of discharge and water-surface profiles observed during the floods of December 1979 and January-February 1980. The accuracy of the computed water-surface elevations given in tables 6-8 is considered to be within 0.1 ft on the average and about 0.2 ft at a cross section.

The extent of backwater caused by the present bridge at cross section 6 may be determined by comparing water-surface elevations for similar flows in tables 6 and 7. A summary of the effects of backwater at the bridge site for various flow conditions is given in table 9. Backwater caused by the present bridge does not occur until flows of Honcut Creek exceed 3,000 ft^3/s. The maximum amount of backwater at the approach section (cross section 6) was 0.5 ft (discharge 25,000 ft^3/s), assuming no effect from flows on the Feather River. For flows on the Feather River similar to those observed in 1980, the

TABLE 6. - Computed elevations of water surface at cross sections in study reach for present bridge and channel conditions

Discharge (ft^3/s)	Elevation, in feet (NGVD), at cross section, assuming no effect of flows on the Feather River									
	1	2	3	4	5	6	7	8	9	9A
1,000	72.5	72.8	72.8	72.9	--	73.1	73.8	74.6	75.7	75.7
3,000	75.1	75.2	75.3	75.3	--	75.5	76.0	76.6	77.8	77.8
5,000	76.4	76.5	76.6	76.6	--	76.9	77.2	77.6	78.6	78.6
10,000	78.4	78.5	78.5	78.4	--	78.7	79.0	79.3	80.0	80.0
15,000	79.3	79.5	79.5	79.4	--	79.9	80.2	80.4	81.1	81.1
20,000	80.1	80.3	80.4	80.1	--	80.8	81.2	81.4	82.1	82.1
25,000	80.7	81.0	81.1	80.8	--	81.6	82.0	82.2	83.0	82.9

Discharge (ft^3/s)	Elevation, in feet (NGVD), at cross section, for flow conditions on the Feather River that occurred during floods in January and February 1980									
	1	2	3	4	5	6	7	8	9	9A
1,000	78.2	78.2	78.2	78.2	--	78.2	78.2	78.2	78.2	78.2
3,000	78.7	78.7	78.7	78.7	--	78.7	78.7	78.7	78.9	78.9
5,000	79.0	79.0	79.0	79.0	--	79.1	79.1	79.2	79.4	79.4
10,000	80.6	80.6	80.6	80.6	--	80.7	80.8	80.9	81.2	81.2
15,000	81.7	81.7	81.8	81.7	--	82.0	82.1	82.1	82.4	82.4
20,000	82.3	82.4	82.4	82.2	--	82.6	82.7	82.8	83.2	83.2
25,000	83.0	83.1	83.1	83.0	--	83.5	83.6	83.7	84.2	84.2

effects of backwater at cross section 6 caused by the bridges was 0.1 ft (discharge 25,000 ft^3/s). The reduction in backwater during high stages on the Feather River is related to ponding effects and resulting higher stages at the downstream side of the bridges (cross section 4) even though flows of Honcut Creek have not increased. During extremely high stages on the Feather River, such as those observed during the flood of December 24, 1964, all backwater caused by flows on Honcut Creek was apparently eliminated, and a nearly level water-surface profile in the downstream part of the study reach was observed (fig. 6).

TABLE 7. - Computed elevations of water surface at cross sections in study reach assuming all bridges and roadway embankment removed

Discharge (ft^3/s)	Elevation, in feet (NGVD), at cross section, assuming no effect of flows on the Feather River									
	1	2	3	4	5	6	7	8	9	9A
1,000	72.5	72.8	72.8	--	73.0	73.3	73.9	74.7	75.7	75.7
3,000	75.1	75.2	75.3	--	75.4	75.5	76.0	76.6	77.8	77.8
5,000	76.4	76.5	76.6	--	76.6	76.6	77.0	77.5	78.6	78.6
10,000	78.4	78.5	78.5	--	78.5	78.5	78.8	79.2	79.9	79.9
15,000	79.3	79.5	79.5	--	79.5	79.5	79.9	80.2	81.0	81.0
20,000	80.1	80.3	80.4	--	80.4	80.4	80.8	81.1	81.9	81.8
25,000	80.7	81.0	81.1	--	81.1	81.1	81.6	81.9	82.7	82.6

Discharge (ft^3/s)	Elevation, in feet (NGVD), at cross section, for flow conditions on the Feather River that occurred during floods in January and February 1980									
	1	2	3	4	5	6	7	8	9	9A
1,000	78.2	78.2	78.2	--	78.2	78.2	78.2	78.2	78.2	78.2
3,000	78.7	78.7	78.7	--	78.7	78.7	78.7	78.7	78.9	78.9
5,000	79.0	79.0	79.0	--	79.0	79.0	79.1	79.1	79.4	79.4
10,000	80.6	80.6	80.6	--	80.6	80.6	80.7	80.8	81.0	81.0
15,000	81.7	81.8	81.8	--	81.8	81.8	81.9	82.0	82.3	82.3
20,000	82.3	82.4	82.4	--	82.4	82.4	82.5	82.7	83.1	83.1
25,000	83.0	83.1	83.1	--	83.1	83.1	83.3	83.5	83.9	83.9

TABLE 8. - Computed elevations of water surface at cross sections in study reach assuming bridge 1 is removed

Discharge (ft^3/s)	Elevation, in feet (NGVD), at cross section, assuming no effect of flows on the Feather River									
	1	2	3	4	5	6	7	8	9	9A
1,000	72.5	72.8	72.8	73.0	--	73.1	73.8	74.6	75.7	75.7
3,000	75.1	75.2	75.3	75.3	--	75.5	76.0	76.6	77.8	77.8
5,000	76.4	76.5	76.6	76.6	--	76.8	77.1	77.5	78.6	78.6
10,000	78.4	78.5	78.5	78.4	--	78.8	79.0	79.3	80.0	80.0
15,000	79.3	79.4	79.5	79.3	--	79.9	80.2	80.4	81.1	81.1
20,000	80.1	80.3	80.4	80.1	--	80.9	81.3	81.5	82.2	82.1
25,000	80.7	81.0	81.1	80.7	--	81.7	82.1	82.3	83.0	83.0

Discharge (ft^3/s)	Elevation, in feet (NGVD), at cross section, for flow conditions on the Feather River that occurred during floods in January and February 1980									
	1	2	3	4	5	6	7	8	9	9A
1,000	78.2	78.2	78.2	78.2	--	78.2	78.2	78.2	78.2	78.2
3,000	78.7	78.7	78.7	78.7	--	78.7	78.7	78.7	78.9	78.9
5,000	79.0	79.0	79.0	79.0	--	79.1	79.2	79.2	79.5	79.5
10,000	80.6	80.6	80.6	80.5	--	80.7	80.9	81.0	81.2	81.2
15,000	81.7	81.8	81.8	81.6	--	82.0	82.2	82.3	82.6	82.6
20,000	82.3	82.4	82.4	82.2	--	82.7	83.1	83.2	83.6	83.6
25,000	83.0	83.1	83.1	82.9	--	83.5	84.2	84.2	84.6	84.6

TABLE 9. - Summary of backwater effects for various flow conditions at State Highway 70 crossing

[See fig. 1 for location of bridge 1]

	Backwater, in feet, at cross section 6			
	Present bridge condition		Assuming bridge 1 removed	
Discharge (ft^3/s)	No effect of Feather River flows	With effect of Feather River flows, observed in Jan.-Feb. 1980	No effect of Feather River flows	With effect of Feather River flows, observed in Jan.-Feb. 1980
1,000	0.0	0.0	0.0	0.0
3,000	.0	.0	.0	.0
5,000	.2	.1	.2	.1
10,000	.2	.1	.3	.1
15,000	.4	.2	.4	.2
20,000	.4	.2	.5	.3
25,000	.5	.4	.6	.4

Bridge Geometry

The three bridges across Honcut Creek, constructed with precast concrete piles and high approach embankments (fig. 2), occupy about 66 percent of the channel based on a water-surface elevation of 80.5 ft at cross section 4 (see table 10). At a flow of 3,000 ft^3/s on Honcut Creek, the channel and floodway are reduced about 71 percent by the bridge and approach embankment. The reduction in flow area is large, in terms of percentage of the natural floodway as measured at cross section 5. The remaining channel area is still sufficient, however, to prevent average velocities of flow from exceeding about 6 ft/s.

Associated with the large reduction in flow area at the bridge site is the possibility that overbank flow may be forced to move laterally large distances to a bridge opening. Flows that move laterally tend to cause inefficient patterns of flow at the point of intersection with the normal downstream movement of main channel flow. Hydraulic problems at other sites, such as scour and bank erosion caused by lateral movement of overland flow along the upstream side of the embankment have been noted (Brice and Blodgett, 1978, p. 144). At this site, the presence of rigid revetment (concrete pavement on approach embankments, fig. 2) reduces the possibility of erosion of the embankments.

TABLE 10. - Proportion of channel occupied by the approach embankment and bridges across Honcut Creek

Cross section	Date of flood	Discharge (ft^3/s)	Reference elevation[1] (ft, NGVD)	Area of channel below reference elevation (ft^2) Bridge No. 1	2	3	Total area	Average velocity of flow (ft/s)	Total reduction in flow area (percent)
4	--	3,000	75.5	167	543	873	1,583	1.9	70.6
4	12-23-64	22,400	80.5	460	1,254	1,876	3,590	6.2	66.1
[2]5	--	3,000	75.5	--	--	--	5,382	.6	--
[2]5	12-23-64	22,400	80.5	--	--	--	10,603	2.1	--

[1]Reference elevation determined from figure 7.
[2]Net area of bridge opening.

Velocity of Flow

The velocity of flow through each of the bridges is related to the discharge of Honcut Creek, the discharge of the Feather River, the division of flow between bridges, and local features, such as bridge piers and abutments, that tend to affect the pattern of flow. During high stages on the Feather River, flow velocities may be reduced at the bridge site, even though the magnitude of flow of Honcut Creek is increasing. For example, as shown in table 2, average velocities during the discharge measurement of January 12, 1980 (discharge 7,318 ft^3/s) are greater than the velocities measured on February 21, 1980 (discharge 8,478 ft^3/s).

The variation of flow velocities across the channel at the downstream side of each opening, as determined during the measurement of January 12, 1980, is shown in figure 10. The large variation of velocity between measured verticals is attributed to the effect of pile bents located upstream from the measuring section. The mean velocity in a given vertical is the average of point velocities measured at 20 and 80 percent of depth. The maximum velocity at a vertical observed at the three bridges during the measurement of January 12, 1980, was 5.6 ft/s at bridge 2, compared with the mean velocity of 3.2 ft/s (table 2) for the cross section.

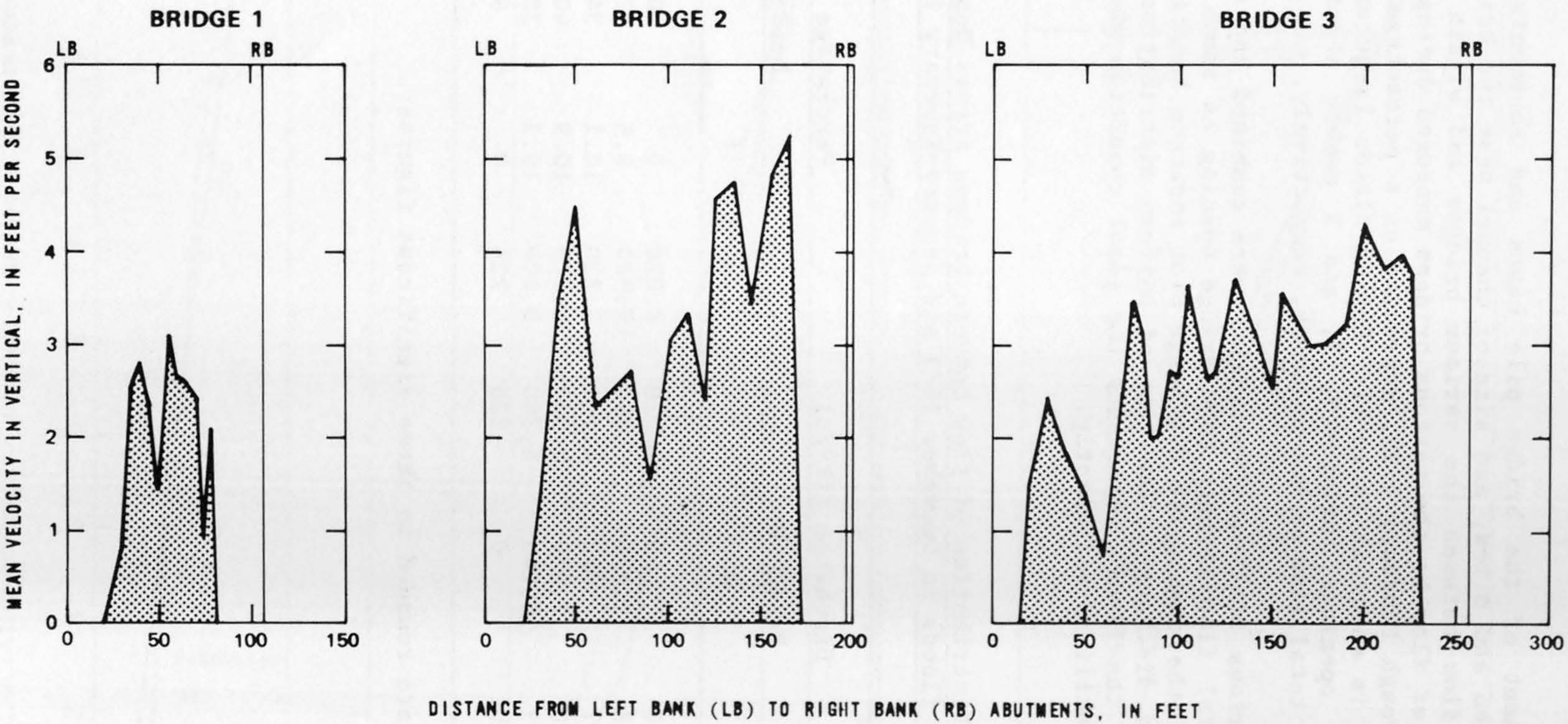

FIGURE 10.--Variation in velocity of flow through each bridge at State Highway 70 crossing of Honcut Creek during discharge measurement of January 12, 1980.

Distribution of Flow

The arrangement of the bridge pile bents and abutments, presence of riparian vegetation and dikes, and size of channel near the bridge affect the distribution of flow between the various bridges and within each opening. The distribution of flow to the various bridges measured during the floods of December 1979 through February 1980, expressed as a percentage of total flow of Honcut Creek, is shown in table 11. During floods large enough to cause flow through all openings, bridges 1, 2, and 3 convey about 10, 40, and 50 percent of the total flow of Honcut Creek, respectively.

Flows at various stations (verticals) were combined and expressed as a percentage of total flow through each bridge opening as shown in figure 11. Flatter slopes of the cumulative discharge plot indicate locations of reduced flow velocity and discharge. The line of uniform distribution of flow at a cross section in the figure represents the ideal condition where all of the cross section is utilized efficiently.

TABLE 11. - Distribution of flow between bridges across Honcut Creek during floods in December 1979 and January-February 1980

Date of measurement	Discharge (ft^3/s)				Percentage of total flow		
	Bridge No.			Total[1]	Bridge No.		
	1	2	3		1	2	3
12-26-79	0	0	1,020	1,020	0	0	100
1-12-80	698	2,770	3,850	7,320	9.5	37.9	52.6
1-14-80	287	992	1,570	2,850	10.1	34.8	55.1
2-19-80	520	1,930	2,320	4,770	10.9	40.5	48.6
2-21-80	877	3,260	4,340	8,480	10.3	38.5	51.2
3-13-80	0	0	228	228	0	0	100

[1]Discharges are rounded to three significant figures.

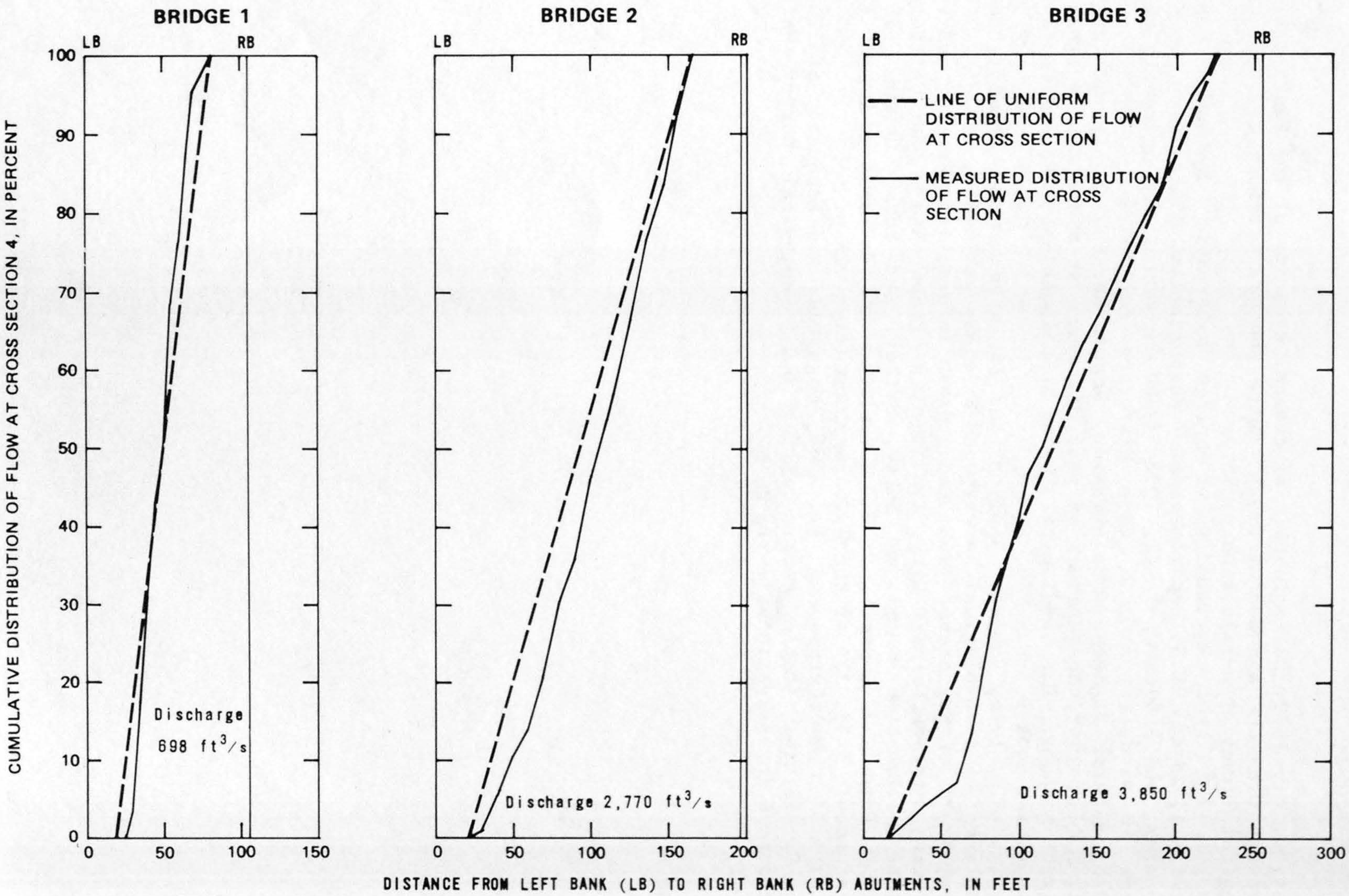

FIGURE 11.--Effect of bridge geometry and approach channel conditions on distribution of flow through bridges 1, 2, and 3 at State Highway 70 crossing of Honcut Creek during discharge measurements of January 12, 1980.

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