FLOOD DATA FOR THE SACRAMENTO RIVER AND BUTTE BASIN, SACRAMENTO VALLEY, CALIFORNIA 1980-90

By Jerry G. Harmon

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Conversion Factors

Multiply	By	To obtain
acre-foot (acre-ft)	0.001233	cubic hectometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic yard (yd^3)	0.7646	cubic meter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
ton	0.9072	megagram

Vertical Datum

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Definition

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. In this report, years are water years unless otherwise noted.

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Abstract

Floodflows and peak stages of floods were measured and channel cross sections were surveyed at sites along the Sacramento River and in Butte Basin, Sacramento Valley, California, during 1980-90 to document magnitudes of flooding and channel changes. The study reach extends from rivermile 200 near Hamilton City to rivermile 134 near Meridian. Data were collected for each flood at about 70 sites that include streamflow gages, crest-stage gages, bridges and road overflows on State Highway 162 east of Butte City, and locations of historical high-water marks. Six cross sections of the river between rivermiles 193.7 near Big Chico Creek and 183.3 near Ordbend were surveyed annually during calendar years 1981-84 and 1986-90.

Floodflows (peak flow 157,000 cubic feet per second) almost equaled the design flow capacity of the river at Butte City on March 2, 1983, when the peak stage of 93.0 feet was 5 feet below the top of the levee. This was the largest flood recorded at Butte City during 1980-90. The most recent flood occurred February 18-19, 1986, when the peak stage in the river at Butte City was 92.0 feet and the peak flow was 145,000 cubic feet per second.

INTRODUCTION

Floodflows and peak stages of floods were measured at sites along the Sacramento River and in Butte Basin during 1980-90 to document magnitudes of flooding. The study reach extends from rivermile 200 near Hamilton City to rivermile 134 near Meridian (fig. 1); the rivermile system was designated by the U.S. Army Corps of Engineers (1984). Because streambank erosion and channel migration of the river may change proportional amounts of flow in the river and Butte Basin, peak stage and channel geometry changes were monitored in the study reach during 1980-90. Six cross sections of the river were surveyed annually during calendar years 1981-84 and 1986-90 to determine the extent of channel migration and scour caused by channel erosion. This report presents data that supplement flood data assembled during earlier studies of flooding of the Sacramento River and Butte Basin for 1874-1978 (Blodgett, 1981) and 1973-77 (Simpson, 1978). Studies of floodflows in the Sacramento River and Butte Basin have been reported by the U.S. Geological Survey in cooperation with the California Department of Water Resources and other agencies since 1970.

Butte Basin is an agricultural area on the flood plain east of the Sacramento River (fig. 1) between Big Chico Creek and Meridian. Rice is the principal crop, but orchards and row crops also are cultivated in the area. Much of the basin is a waterfowl-wintering area that is enhanced by flooding. Changes in the distribution of flows across the flood plain are caused by farming activities, growth or clearing of vegetation, and roadway and bridge construction (Blodgett and Stiehr, 1974).

During periods of flooding on the Sacramento River between Big Chico Creek and Meridian (fig. 1), flows inundate Butte Basin. Levees on the left (east) bank of the river downstream from rivermile 176 near Glenn prevent flooding into Butte Basin; however,

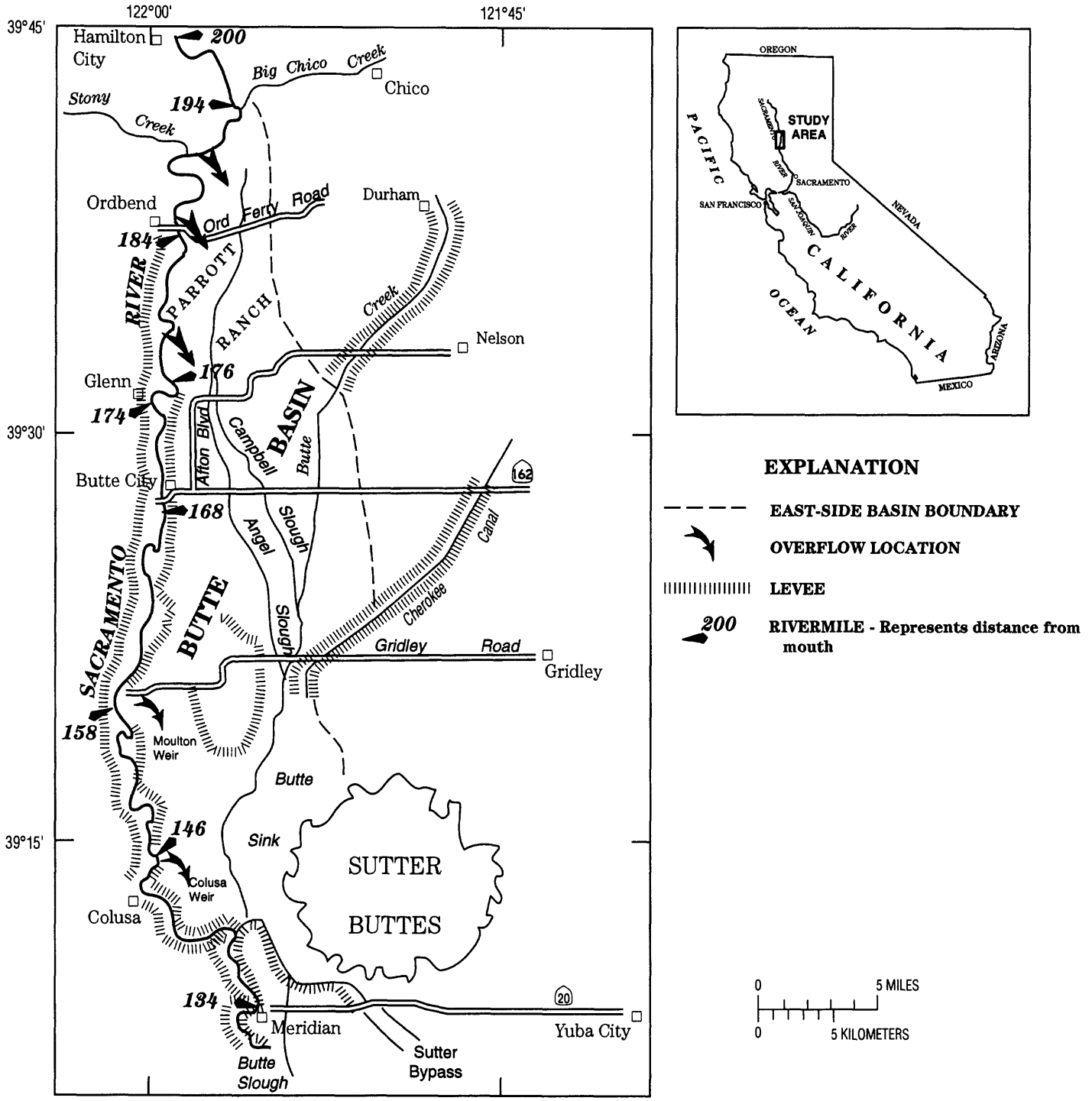


Figure 1. Location of study area. (Modified from Simpson, 1978).

during flows that exceed about 40,000 ft^3/s, controlled overbank flow into Butte Basin occurs at Moulton and Colusa Weirs near Colusa. When river flows exceed about 80,000 ft^3/s, flows begin to inundate Butte Basin between rivermiles 194 and 176 upstream from the end of the left-bank levee near Glenn by over-topping the riverbank and by entering sloughs and swales near the river channel. Filling of scour holes and modification of levees to regulate the amount of overbank flow to Butte Basin in the reach between rivermiles 194 and 176 were necessary following the floods in 1983 and 1986.

The diversions of floodwater to Butte Basin between Chico and Glenn decrease the total flow of the river within the leveed channel downstream from rivermile 176. The design flow capacity of the river in the leveed channel upstream from Moulton Weir to Butte City is 160,000 ft^3/s; overbank diversions from the river to Butte Basin near Chico prevent excessive flows that could cause overtopping of levees on both banks downstream from Glenn.

Overland flow in Butte Basin was about one-third of the total peak flow of 225,000 ft^3/s measured at the latitude of Butte City on January 24, 1970 (Blodgett and Pearce, 1971). Because most bridges on State Highway 162 in Butte Basin lack the capacity to convey floods, excess floodflows cross the highway between bridges at eleven sites.

FLOOD DATA

Floodflows were measured at the following sites (figs. 2 and 3) to define flow distribution:

1. Sacramento River at Butte City (11389000)

2. Angel Slough at Ord Ferry Road (11390140)

3. Fifteen bridges and eleven road-overflow sites on State Highway 162, including Butte Creek (11390020) and Campbell Slough (11390027).

Bridges and road-overflow sites are considered miscellaneous measuring sites, except at Butte Creek and Campbell Slough (fig. 3), where streamflow gaging stations are operated. Peak stages were measured at streamflow gaging stations, crest-stage gaging stations, and historical high-water mark sites (fig. 2). Peak stage data at selected sites are used to define water-surface profiles and indicate locations where peak stages are encroaching on the levee freeboard. Freeboard is that part of the levee 3 ft below the top (U.S. Army Corps of Engineers, 1991).

PEAK FLOWS

The possibility of flooding at Butte City can be estimated by using the California Department of Water Resources and California-Nevada forecast center, which provides hourly stage and flow data for the Sacramento River at Ord Ferry (11388700) (fig. 2) and other stations in the study reach. During the floods of February 1980, December 1981, January and March 1983, and February 1986, flow measurements were made in the Sacramento River at Butte City and in Butte Basin at selected locations on State Highway 162 (fig. 3) to determine the rates of flow in the river and in Butte Basin. Flows were not measured on State Highway 162 during the flood of December 1983. Measurements were made at the latitude of Butte City because the gaging stations Sacramento River at Butte City (11389000), Campbell Slough (11390027), and Butte Creek (11390020) are the only stations upstream from Moulton Weir that record the total flow of the river between the levees and overland flow in Butte Basin. During the flood of February 18-19, 1986, peak flow in Butte Basin east of Butte City including Butte Creek was 73,800 ft^3/s, which, when combined with 145,000 ft^3/s in the river, indicates total flow of 219,000 ft^3/s at Butte City. Peak flows and peak stages for years 1980-86, for the Sacramento River at Butte City and Angel Slough at Ord Ferry Road are given in table 1.

Flows at bridges were measured by suspending current meters with weights from the bridge, and road overflows were measured by using a wading rod placed along the highway centerline. Descriptions and a map of the overflow areas and bridges (fig. 3) were first prepared by Blodgett and Pearce (1971). Floodflows not obtained by field measurement were determined using streamflow rating curves, which were developed for each bridge and each road-overflow area. Revisions of the rating curves for different floods were required at some sites after

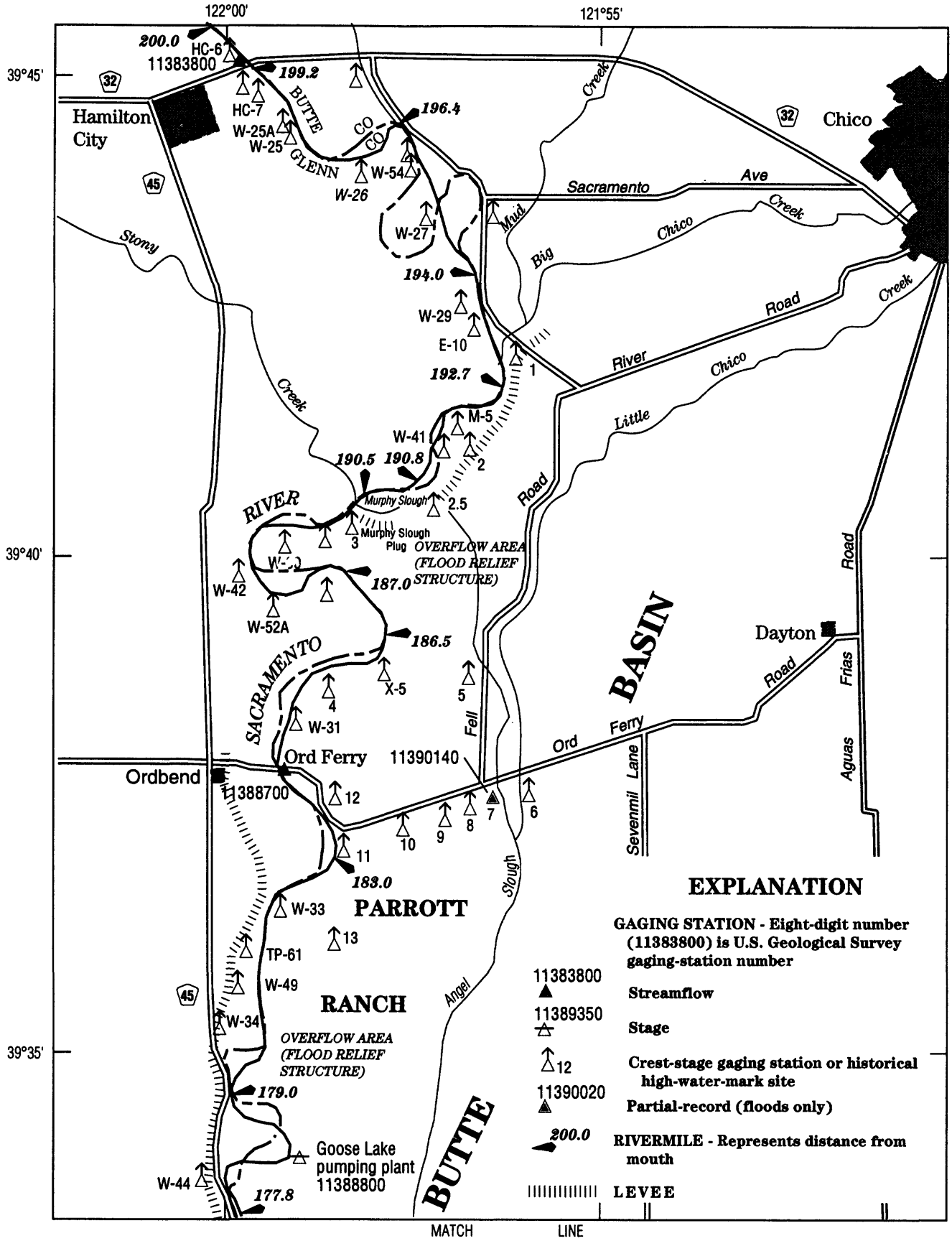
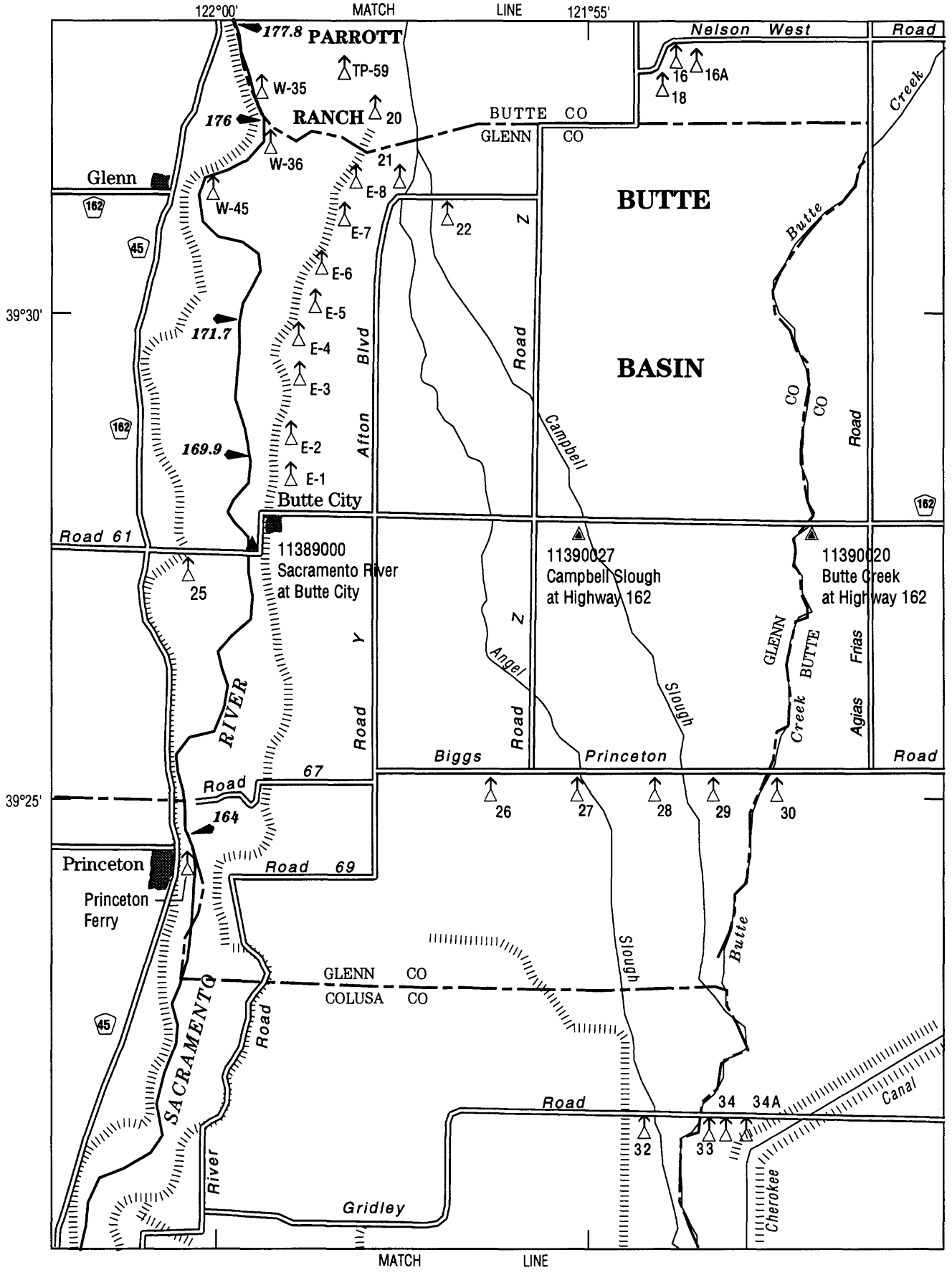


Figure 2. Locations of streamflow gaging stations, crest-stage gaging stations, and historical high-water-mark sites for the Sacramento River and Butte Basin. (Modified by Simpson, 1978).



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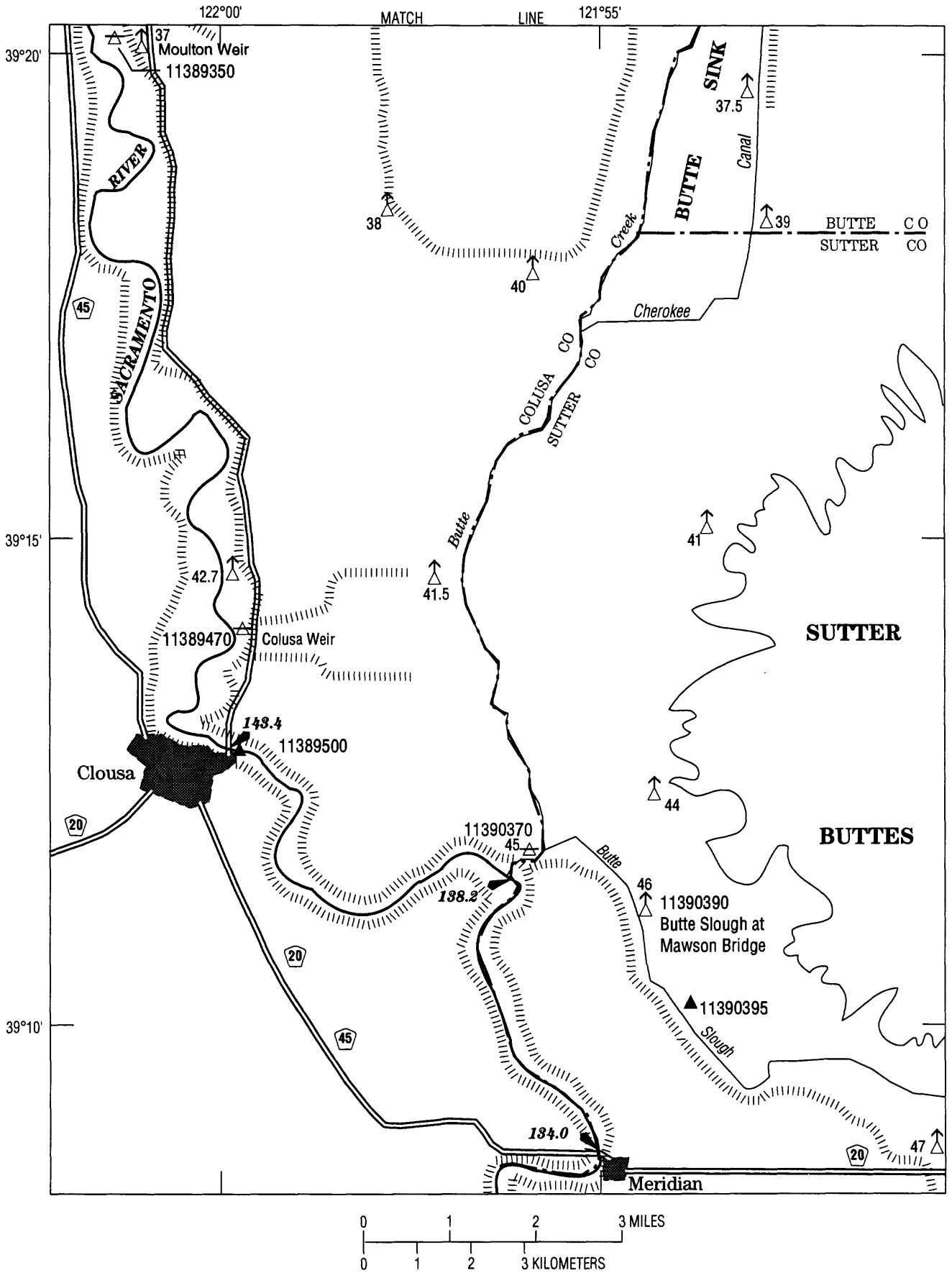

Figure 2. *Continued.*

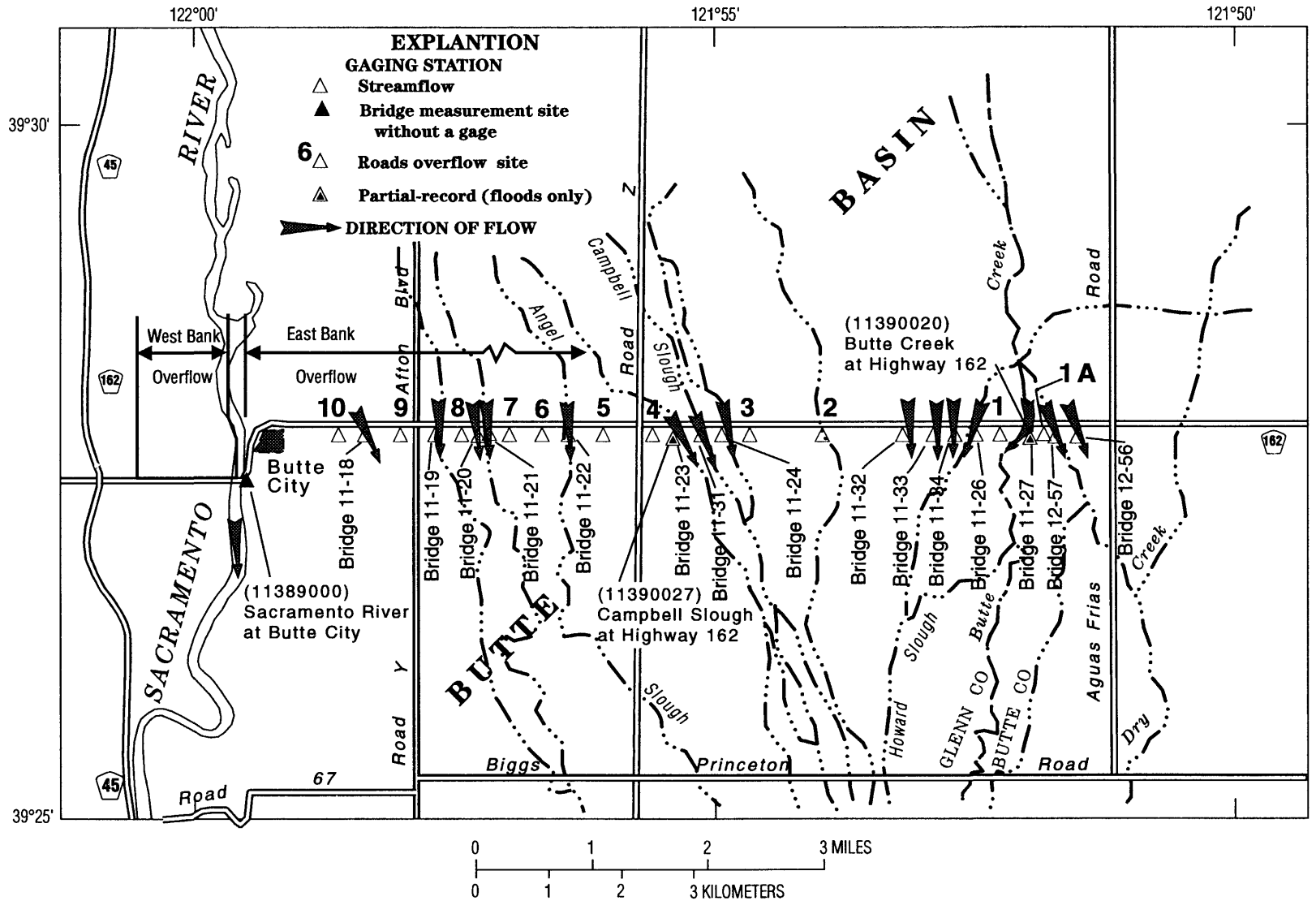

Figure 3. Locations of floodflow-measuring sites on State Highway 162 near Butte City.

Table 1. Peak flows and peak stages for Sacramento River at Butte City and Angel Slough at Ord Ferry Road

[ft, foot above sea level; ft^3/s, cubic foot per second. Location of stations shown in figure 2]

Date	Sacramento River at Butte City 11389000		Angel Slough at Ord Ferry Road 11390140 (Partial-record station 7)	
	Peak flow (ft^3/s)	Peak stage (ft)	Peak flow (ft^3/s)	Peak stage (ft)
February 20, 1980	124,000	90.16	13,100	112.79
December 20-21, 1981	102,000	88.36	9,000	111.75
January 27-28, 1983	130,000	90.67	15,000	113.20
March 2, 1983	157,000	92.97	18,500	113.85
December 25-26, 1983	129,000	90.61	15,700	113.30
February 18-19, 1986	145,000	91.99	19,500	114.00

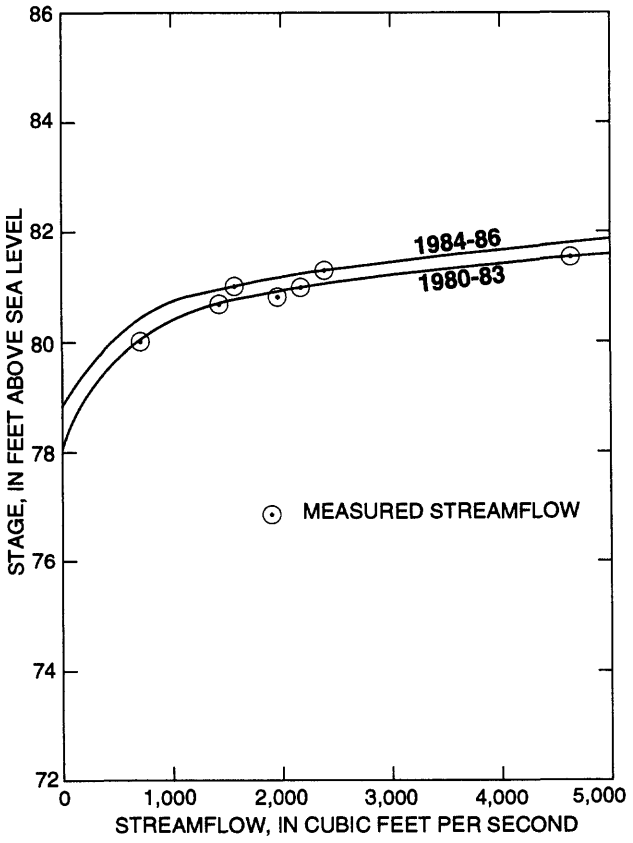

Figure 4. Streamflow ratings for bridge 11-24 on State Highway 162 near Butte City for two flood periods.

channel changes, such as scour or vegetative growth, occurred. Different streamflow ratings for bridge 11-24 for two flood periods are shown in figure 4.

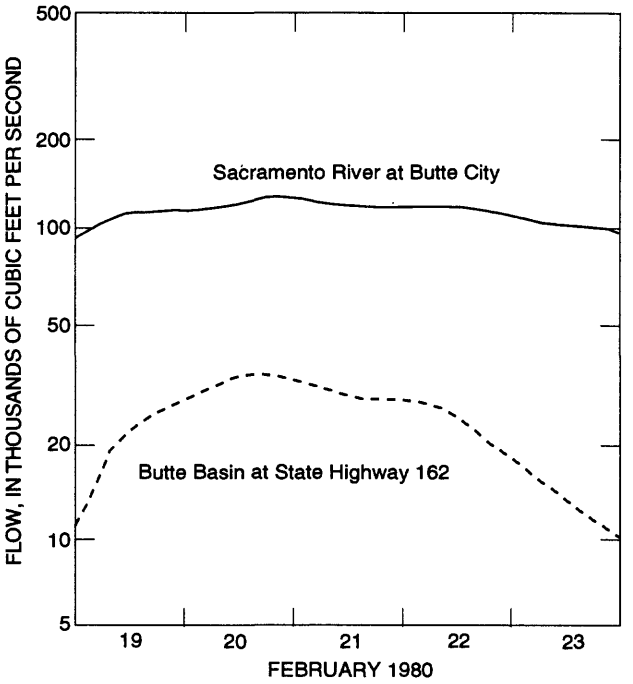

Figure 5. Peak flow for Sacramento River and in Butte Basin at the latitude of Butte City, February 1980.

The distribution of peak flows during 1980-86 at the latitude of Butte City during selected floods is given in table 2. The duration of flooding in Butte Basin is based on data obtained at the two gaging stations (Campbell Slough, 11390027, and Butte Creek, 11390020) on State Highway 162 near Butte City. The total volume of the flood of February 19-23, 1980, at the latitude of Butte City, computed from hydrographs shown in figure 5, was 1.37 million acre-ft.

Table 2. Distributions of peak flows at the latitude of Butte City during selected floods, 1980-86

[Overflow sites described by Blodgett and Stiehr (1974). Location of overflow sites and bridges shown in figure 3. ft^3/s, cubic foot per second; --, no measurement]

Road overflow site	Bridge No.	Flow during time of current-meter measurement (ft^3/s)	Peak flow during time of peak stage (ft^3/s)
		February 1980	
	12-56	156	170
	12-57	1,070	1,100
1A		174	190
	11-27	4,240	4,400
1		1,030	1,050
	11-26	1,750	1,800
	11-34	564	630
	11-33	915	990
	11-32	1,620	1,800
2		28; 149	160
3		30; 64	75
	11-24	1,940	2,300
	11-31	2,260	2,700
	11-23	3,140	3,300
4		780; 1,220	1,310
5		1,450; 1,830	2,400
	11-22	1,900	2,500
6		1,670; 1,790	2,100
7		80; 161	330
	11-21	821	970
	11-20	1,670	1,810
8		640; 800	1,150
	11-19	345	430
9		--	0
	11-18	292	315
10		--	0
Instantaneous peak flow			
Butte Basin			34,000
Sacramento River			124,000
		December 1981	
	12-56	--	0
	12-57	--	0
1A		--	0
	11-27	--	3,100
1		--	0
	11-26	--	1,200
	11-34	--	590
	11-33	--	790
	11-32	--	1,150
2		--	0
3		--	0
	11-24	958	1,400
	11-31	1,230	1,740
	11-23	2,360	2,600
4		539; 872	1,030
5	11-22	0; 1,520	1,750
	11-22	1,340	1,690
6		1,020; 1,580	1,760
7		266; 462	515
	11-21	--	770
	11-20	--	940
8		224; 669	870
	11-19	--	0
9		--	0
	11-18	--	0
10		--	0
Instantaneous peak flow			
Butte Basin			20,900
Sacramento River			102,000
		January 1983	
	12-56	20	770
	12-57	1,180	1,270
1A		5; 350	660
	11-27	2,890; 4,250	4,400
1		360	980
	11-26	1,800	2,000
	11-34	456	1,000
	11-33	1,380	2,300
	11-32	656	1,350
2		--	0
3		22	30
	11-24	1,450; 2,140	2,900
	11-31	1,350; 1,450	1,600
	11-23	3,250; 4,100	4,350
4		2,610; 2,880	3,000
5		3,720	3,900
	11-22	1,400; 1,800	2,000
6		3,510; 4,530	4,650
7		1,540; 1,850	1,930
	11-21	1,900	2,140
	11-20	210; 462	600
8		4,210; 4,510	4,600
	11-19	119; 1,020	1,100
9		2,330; 2,440	2,500
	11-18	734	810
10		650	740
Instantaneous peak flow			
Butte Basin			51,600
Sacramento River			130,000

Table 2. Distributions of peak flows at the latitude of Butte City during selected floods, 1980-86--*Continued*

Road overflow site	Bridge No.	Flow during time of current-meter measurement (ft^3/s)	Peak flow during time of peak stage (ft^3/s)
		March 1983	
	12-56	--	200
	12-57	2,450	2,550
1A		1,720; 2,290	2,800
	11-27	--	5,400
1		6,250	7,500
	11-26	1,860	2,100
	11-34	960	1,200
	11-33	2,500	2,700
	11-32	810	900
2		2,030	2,800
3		--	0
	11-24	4,640	5,000
	11-31	3,320	3,400
	11-23	5,820	5,850
4		5,950	6,300
5		6,500	6,600
	11-22	--	2,300
6		7,300	7,650
7		5,200	5,800
	11-21	360	450
	11-20	2,640	3,100
8		6,760	6,800
	11-19	1,340	1,650
9		9,320	9,500
	11-18	960	1,280
10		2,690	2,700
Instantaneous peak flow			
Butte Basin			96,500
Sacramento River			157,000
		February 1986	
	12-56		
	12-57		
1A			
	11-27		
1			
	11-26		
	11-34		
	11-33		
	11-32		
2			
3			
Cumulative flow for the above sites is 26,000 ft^3/s, based on a stage-flow relation			
Total for bridge 12-56 through overflow site 3			26,000
	11-24	1,570; 2,360	2,400
	11-31	1,460; 1,760	1,800
	11-23	3,100; 3,320	3,400
4		5,580	5,800
5		6,350	6,500
	11-22	1,510; 1,840	2,000
6		7,600	7,750
7		2,870	3,180
	11-21	552; 654	700
	11-20	1,320; 1,730	1,800
8		5,430	5,600
	11-19	512	570
9		4,400	4,750
	11-18	749	980
10		552	600
Instantaneous peak flow			
Butte Basin			73,800
Sacramento River			145,000

PEAK STAGES

Water-surface elevations (stage) of floods exceeding 80,000 ft^3/s at the Butte City gage (11389000) were documented at selected sites along both banks of the Sacramento River and in Butte Basin. Peak stage data can be used to determine flood profiles, indicate amount of freeboard in leveed reaches, and compute slopes of the water surface between selected locations. Data-collection sites (fig. 2) include streamflow gaging stations, crest-stage gaging stations and locations of historical high-water marks, mostly near the banks of the river. Elevations of all marks were referenced to sea-level datum, using National Geodetic Survey benchmarks and a vertical control network established in Butte Basin during 1970-73 (Blodgett and Stiehr, 1974; Blodgett, 1981).

Elevations of peak stages obtained at selected sites during 1980-86 are included in table 3. Hydrographs of selected peak stages of the Sacramento River at the gaging stations at Ord Ferry (11388700), Goose Lake

Table 3. Elevations of peak stages in the Sacramento River and Butte Basin, 1980-86

[HWM, historical high-water mark; CSG, crest-stage gage; SGS, streamflow gaging station; --, no measurement. Location of sites shown in figure 2]

Site designation	Type of site	Rivermile or latitude, longitude	Elevation, in feet above sea level					
			1980	1981	1983			1986
			February	December	January	March	December	February
HC-6:								
Left bank	HWM	199.5	145.2	--	148.1	148.6	--	148.6
Right bank	CSG	199.5	145.0	--	--	--	--	--
11383800 Sacramento River near Hamilton City	SGS	199.3	144.6	143.8	147.7	148.4	145.9	148.2
Gianella Bridge, downstream:								
Left bank	HWM	199.2	144.4	--	147.2	147.7	--	147.6
Right bank	HWM	199.2	144.4	--	147.4	147.4	--	147.3
HC-7	HWM	199.1	143.7	--	--	147.0	--	--
W-25A, Dunning Slough	HWM	198.2	--	--	144.4	144.2	--	145.1
W-25	HWM	198.1	141.2	--	143.3	143.9	142.5	143.8
W-26	HWM	197.0	--	--	141.6	--	--	--
Pine Creek:								
At State Highway 32	HWM	--	140.2	--	142.4	143.1	--	141.4
At mouth	HWM	196.4	139.2	--	141.0	142.2	--	141.3
W-54, Scotty's Landing	HWM	196.1	139.1	--	140.6	140.7	--	141.1
Sacramento Avenue	HWM	195.2	--	--	--	--	--	137.8
W-27	HWM	195.1	--	--	136.4	--	135.3	136.6
W-29, St. John Road	HWM	194.1	133.7	--	134.6	135.0	134.8	134.3
E-10, Chico Landing	HWM	193.7	134.1	--	134.5	--	--	136.0
1, Big Chico Creek	CSG	39°42'16", 121°56'18"	133.0	132.3	134.0	135.4	133.6	135.2
Chico sewer outfall	HWM	192.7	--	130.7	132.4	133.5	132.1	--
M-5	HWM	192.3	130.8	--	--	--	--	--
W-41	HWM	192.0	--	--	130.6	132.4	--	131.1
2	CSG	39°41'05", 121°56'35"	129.0	128.3	130.1	131.6	129.9	130.9
2.5	CSG	191.0	128.0	127.7	129.0	129.8	128.8	129.3
Murphy Slough plug, upstream	HWM	190.5	128.0	127.6	129.1	130.1	--	129.4
3	CSG	189.6	126.4	126.0	126.8	127.6	126.0	126.9
W-30	HWM	189.2	--	--	128.1	128.7	127.1	128.4
W-42	HWM	188.4	--	--	125.2	--	123.5	125.8
W-42A	HWM	188.2	--	--	124.4	--	--	--
W-52A, Road 29	HWM	187.5	123.5	122.8	123.7	--	123.4	124.0
Murphy Slough plug, downstream	HWM	187.0	120.9	120.0	121.6	--	--	123.9
X-5	HWM	186.5	118.7	117.9	119.7	--	118.9	120.9
4	CSG	186.0	117.0	116.0	--	--	117.3	118.1
5	CSG	39°38'54", 121°56'42"	117.2	115.8	--	--	--	--
W-31	HWM	185.4	--	--	116.8	118.7	116.7	117.0
11388700 Sacramento River at Ord Ferry, right bank	SGS	184.1	114.1	112.8	115.2	116.7	114.8	115.6

Table 3. Elevations of peak stages in the Sacramento River and Butte Basin, 1980-86--*Continued*

Site designation	Type of site	Rivermile or latitude, longitude	Elevation, in feet above sea level					
			1980	1981	1983			1986
			February	December	January	March	December	February
Ord Ferry, left bank	HWM	184.1	114.4	--	115.2	--	--	--
6	CSG	39°37'44", 121°56'16"	111.9	110.9	--	115.0	113.2	114.1
11390140 (site 7) Angel Slough at Ord Ferry Road	SGS	--	112.8	111.8	113.2	113.8	113.3	114.0
8	CSG	30°37'34", 121°56'53"	114.1	113.8	115.0	115.4	114.6	115.0
9	CSG	39°37'29", 121°57'14"	110.6	110.6	114.0	115.0	113.4	114.5
10	CSG	39°37'20", 121°57'47"	112.1	111.5	112.6	114.8	112.4	114.0
11	CSG	39°37'09:, 121°58'30"	113.6	112.8	114.1	114.8	113.7	114.3
12	CSG	39°37'28", 121°58'51'	114.0	113.2	114.8	116.1	114.6	--
13	CSG	39°36'13", 121°58'35"	110.2	108.7	--	113.4	111.3	112.3
W-33, SR-81	HWM	182.1	110.7	109.3	111.4	112.7	111.0	111.6
TP-61	HWM	181.9	--	107.8	110.0	111.3	--	110.0
W-49, SR-80	HWM	181.5	--	--	--	110.2	--	108.8
W-34, milepost 9	HWM	180.9	107.2	105.7	108.1	108.9	107.3	108.1
Hawaiian Gardens	HWM	179.9	106.5	105.3	107.4	108.4	106.7	107.1
Levee protection site	HWM	179.0	--	103.7	106.8	108.2	--	--
P-7, Parrot plug	CSG	--	--	--	--	107.2	105.0	106.9
P-7B	HWM	178.7	--	102.6	--	--	105.5	--
11388800 Sacramento River at Goose Lake Pump P-7B	SGS	178.7	--	--	--	--	--	105.7
W-44, Sidd's Landing	HWM	178.0	101.9	99.8	104.2	105.7	104.5	104.7
Bertopelli Ranch	HWM	177.8	100.5	98.8	101.0	103.5	101.9	--
TP-59, side levee:								
Shoreward	HWM	177.0	--	--	--	101.2	--	--
Streamward	HWM	177.0	--	--	--	100.4	--	--
W-35, Reference Y	HWM	176.9	99.0	98.2	100.0	101.4	101.0	101.2
20, End levee, left bank	CSG	39°32'01", 121°58'12"	99.6	98.5	99.4	100.1	--	101.0
W-36, Road 48	HWM	176.3	98.5	97.2	99.1	100.6	99.3	100.2
E-8	HWM	175.5	99.0	98.5	--	--	--	--
W-45	HWM	174.1	97.8	96.3	98.1	99.8	98.0	98.8
E-7	HWM	174.0	97.3	95.4	97.8	99.1	97.5	98.8
E-6	HWM	173.0	96.7	95.1	97.4	99.0	96.5	97.9
E-5	HWM	172.1	95.6	93.9	96.0	97.6	95.8	97.0
E-4	HWM	171.9	94.6	93.2	--	97.3	95.2	96.2
X-171.7:								
Left bank	HWM	171.7	--	93.1	94.8	97.0	94.9	96.1
Right bank	HWM	171.7	--	92.0	94.5	96.4	94.3	96.0
E-3	HWM	171.2	93.6	--	--	--	--	--
E-2	HWM	170.3	92.1	90.2	92.8	94.6	92.5	93.9
X-169.9	HWM	169.9	--	90.1	--	--	92.0	--
E-1	HWM	169.5	--	89.8	92.0	94.0	91.5	92.3

Table 3. Elevations of peak stages in the Sacramento River and Butte Basin, 1980-86--*Continued*

Site designation	Type of site	Rivermile or latitude, longitude	Elevation, in feet above sea level					
			1980	1981	1983			1986
			February	December	January	March	December	February
11389000 Sacramento River at Butte City, left bank	SGS	168.6	90.2	88.4	90.7	93.0	90.6	92.0
25, Butte City, right bank	CSG	168.5	89.5	87.4	90.2	92.4	--	--
Princeton Ferry	HWM	164.3	--	--	87.0	89.5	--	88.1
16	CSG	39°33'04", 121°53'53"	--	--	--	100.1	--	99.1
16A	CSG	39°33'04", 121°53'47"	--	--	98.8	100.1	--	--
18	CSG	39°32'49", 121°54'07"	--	--	98.5	--	98.0	--
21	CSG	39°31'20" 121°57'43"	94.0	92.8	95.8	96.8	94.8	96.5
22	CSG	39°31'20", 121°57'23"	93.6	92.9	95.3	96.8	94.9	--
26	CSG	39°25'12", 121°56'24"	72.9	71.0	73.6	74.4	73.6	75.0
27	CSG	39°25'12", 121°55'11"	73.1	72.8	74.0	74.5	74.1	--
28	CSG	39°25'12", 121°54'16"	72.0	71.8	72.2	72.9	72.1	--
29	CSG	39°25'12", 121°53'29"	72.1	72.0	--	72.0	72.2	--
30	CSG	39°25'10", 121°53'49"	71.8	71.4	--	71.9	72.0	--
30A	CSG	39°25'10", 121°53'47"	71.6	--	--	--	--	--
32	CSG	39°21'44", 121°54'09"	64.1	63.8	65.3	--	65.2	--
33, Butte Creek at Gridley Road	CSG	--	64.2	63.7	64.9	--	--	--
34	CSG	39°21'44", 121°53'01"	63.7	62.3	64.4	66.2	64.7	--
34A	CSG	39°21'44", 121°52'46"	63.8	62.1	64.1	66.1	64.7	--
37, Moulton Weir	CSG	158.1	72.2	70.4	--	73.9	70.8	--
37.5	CSG	39°19'43", 121°52'51"	61.4	59.7	60.7	64.5	61.4	63.9
38	CSG	39°18'41" 121°57'43'	61.4	--	--	64.3	--	63.8
39	CSG	39°18'23", 121°52'56'	61.0	57.5	59.4	--	--	--
40	CSG	39°18'03" 121°55'53"	61.2	--	--	64.3	--	63.8
41	CSG	39°15'13" 121°53'25"	60.5	56.5	59.4	63.9	60.3	63.1
41.5	CSG	39°14'48" 121°57'14"	60.7	56.7	--	64.0	61.6	63.4
42.7	CSG	147.4	69.5	68.5	--	71.1	70.1	70.4
11389470 Colusa Weir near Colusa	SGS	146.0	64.5	63.9	--	66.1	65.3	65.4

Table 3. Elevations of peak stages in the Sacramento River and Butte Basin, 1980-86--*Continued*

Site designation	Type of site	River mile or latitude, longitude	Elevation, in feet above sea level					
			1980	1981	1983			1986
			February	December	January	March	December	February
11389500 Sacramento River at Colusa	SGS	143.3	63.6	63.0	--	65.6	64.7	65.0
44	CSG	39°12'54", 121°54'09"	60.4	56.4	59.3	63.7	60.3	62.9
11390370 (site 45) Butte Slough near outfall	SGS	138.2	60.4	56.1	59.1	63.6	60.2	62.7
46, Butte Slough at Mawson Bridge	CSG	--	59.3	55.2	58.4	62.7	59.4	--
47, Sutter Bypass at Long Bridge	CSG	--	50.5	47.3	49.8	53.7	51.1	54.0

pumping plant (11388800), and Butte City (11389000) for the flood of February 18-19, 1986, are shown in figure 6.

Peaks at crest-stage gaging stations were documented by lines of floating particles of cork that cling to wood sticks placed inside vertical steel pipes with holes to admit water and air.

Peaks at historical high-water-mark sites were determined by level surveys to high-water marks. These marks consist of grass particles, seeds, debris, mud stains, and washlines left at the highest (peak) stage.

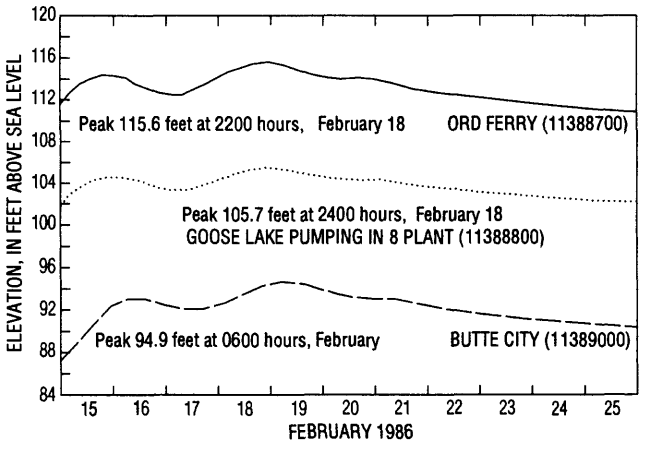

Figure 6. Selected peak stages of the Sacramento River, February 1986.

FLOODS OF 1980-86

Water-surface elevation and floodflow data were collected in the study reach during floods of February 1980, December 1981, January, March, and December 1983, and February 1986. Peak flows for the floods in the Sacramento River at Butte City ranged from 102,000 to 157,000 ft^3/s (table 1). Flooding did not occur between 1987 and 1990.

Tropical storms that began in January 1980 brought heavy rainfall at elevations as high as 9,000 ft in the mountains of northern California, which resulted in snowmelt and excessive runoff. Butte Basin was flooded during February 19-24, 1980. The peak flow of the river at Butte City was 124,000 ft^3/s.

Runoff during the 1982 water year was 151 percent of the 1951-80 median based on representative streamflow records (Fogelman and others, 1983) for an area that includes Butte Basin and the Sacramento River. Minor flooding in Butte Basin occurred December 21-22, 1981, concurrent with the peak flow at Butte City of 102,000 ft^3/s.

Runoff during the 1983 water year ranged from 174 to 228 percent of the median based on representative streamflow records in the area (Fogelman and others, 1984). Peak flows were measured during January and March 1983. Maximum flows for the 1983 water year occurred on March 2, 1983, when the peak flow in the river at Butte City was 157,000 ft^3/s. The stage at this flow was 93.0 ft where the elevation of the top of the left bank levee is 98.0 ft. Flooding of Butte Basin continued for 20 days, February 28 to March 19, 1983. Flows were not measured on State Highway 162 during the flood of December 25-28, 1983, but peak stages were documented.

Heavy rains fell on northern and Central California for more than a week in February 1986, resulting in extensive flooding. The flood of February 1986 had a longer duration than the flood of March 1983, but the peak flow of 145,000 ft^3/s in the Sacramento River at Butte City was less. Flooding in Butte Basin at State Highway 162 began on February 15 and continued until March 1, when flows on the flood plain were confined to the overflow channels.

The California Department of Water Resources, the California State Reclamation Board, and the U.S. Army Corps of Engineers developed a flood-control plan during 1980-87 which recommended that Sacramento River flows above a designated amount should enter Butte Basin at locations of historical overbank flow (Clifford L. Gregory, Jr., California Department of Water Resources, written commun., 1990). The three selected major overflow sites to Butte Basin are at rivermiles 190.8, 186.5, and 179.0 (fig. 2). During 1986, overbank flow eroded two scour holes at the flood relief structure upstream from Murphy Slough near rivermile 190.8. More than 12,000 tons of rock and 500,000 yd^3 of soil were required to fill the holes (Clifford L. Gregory, Jr., California Department of Water Resources, written commun., 1990). A part of the 1980-87 flood-control plan included a flood-relief structure to replace a raised roadway known as the Parrott Plug near rivermile 179 (Woodward-Clyde, 1986). Construction was completed in 1988 (fig. 2).

CHANNEL GEOMETRY

Cross sections at fixed monumented locations of the Sacramento River were surveyed annually during 1981-84 and 1986-90 to determine the extent of channel migration and scour caused by channel erosion. These surveys supplement surveys made between 1971 and 1980. Coordinate data for six cross sections between rivermiles 193.7 near Big Chico Creek and 183.3 near Ordbend (fig. 7 and table 4, at back of report) were obtained by level surveys and fathometer. All elevations for these cross sections are referenced to sea-level datum. Because initial points (station 0 ft) on the left bank were the same for all surveys at each cross section, the surveys can be used to indicate changes in channel geometry and location. Cross sections are located where bank protection (rock riprap) was placed before 1980 (sections 1, 2, 4, and 6), where rock riprap was placed in 1988 (section 3), and where no riprap has been placed (section 5).

SUMMARY

Peak flows and peak stages of floods were measured and channel cross sections were surveyed at sites along the Sacramento River and in Butte Basin during 1980-90 to document magnitudes of flooding and channel changes. The study reach extends from rivermile 200 near Hamilton City to rivermile 134 near Meridian.

Levees on the left bank of the Sacramento River between rivermile 176 near Glenn and rivermile 134 near Meridian prevent flows from entering Butte Basin except controlled overbank flow at Moulton and Colusa Weirs. When river flows exceed about 80,000 cubic feet per second, flows begin to inundate Butte Basin between rivermile 194 near Chico and rivermile 176 near Glenn by overtopping the riverbank and by entering sloughs and swales near the river channel. Overflow into Butte Basin between Chico and Glenn decreases the total flow of the river entering the leveed channel downstream from Glenn. Overland flow in Butte Basin was about one-third of the total peak flow of 225,000 cubic feet per second measured at the latitude of Butte City on January 24, 1970.

Data were collected in the study reach during floods of February 1980, December 1981, January, March, and December 1983, and February 1986. These data were collected at about 70 sites for each flood. Peak flows in the Sacramento River at Butte City ranged from 102,000 to 157,000 cubic feet per second.

Flows were measured at the Sacramento River at Butte City, Angel Slough at Ord Ferry Road, and 15 bridges and 11 road-overflow sites on State Highway 162. Peak stages were documented at streamflow gaging stations, crest-stage gaging stations, and historical high-water-mark sites. Six cross sections of the Sacramento River between rivermiles 193.7 and 183.3 were surveyed annually during calendar years 1981-84 and 1986-90 to determine the extent of channel migration and scour caused by channel erosion.

References Cited

Blodgett, J.C., 1981, Flood data for the Sacramento River and Butte Basin, 1875 to 1978, Sacramento Valley, California: U.S. Geological Survey Open-File Report 80-971, 193 p.

Blodgett, J.C., and Pearce, V.F., 1971, Determination of floodflow of the Sacramento River at Butte City, California, January 1970: U.S. Geological Survey open-file report, 29 p.

Blodgett, J.C., and Stiehr, P.L., 1974, Hydraulic analysis of floodflows in Butte Basin at State Highway 162, Glenn and Butte Counties, California: U.S. Geological Survey open-file report, 48 p.

Fogelman, R.P., Mullen, J.R., Shelton, W.F., and Simpson, R.G., 1983, Water resources data--California, water year 1982. Volume 4. Northern Central Valley basins and the Great Basin from Honey Lake basin to Oregon State line: U.S. Geological Survey Water-Data Report CA-82-4, 319 p.

Fogelman, R.P., Mullen, J.R., Shelton, W.F., Simpson, R.G., and Grillo, D.A., 1984, Water resources data--California, water year 1983. Volume 4. Northern Central Valley basins and the Great Basin from Honey Lake basin to Oregon State line: U.S. Geological Survey Water-Data Report CA-83-4, 291 p.

Simpson, R.G., 1978, Flood hydrology of Butte Basin, 1973-77 water years, Sacramento Valley, California: U.S. Geological Survey Water-Resources Investigations Report 78-86, 69 p.

U.S. Army Corps of Engineers, 1984, Sacramento River, California, Aerial Atlas: Corps of Engineers, Sacramento, California, 41 p.

U.S. Army Corps of Engineers, 1991, Hydraulic design of flood control channels: U.S. Army Corps of Engineers, Engineer Manual 1110-2-1601, 4 chapters [variously paged].

Woodward-Clyde, 1986, Environmental impact report for the Butte Basin overflow area: Woodward-Clyde, Consultants, 106 p.

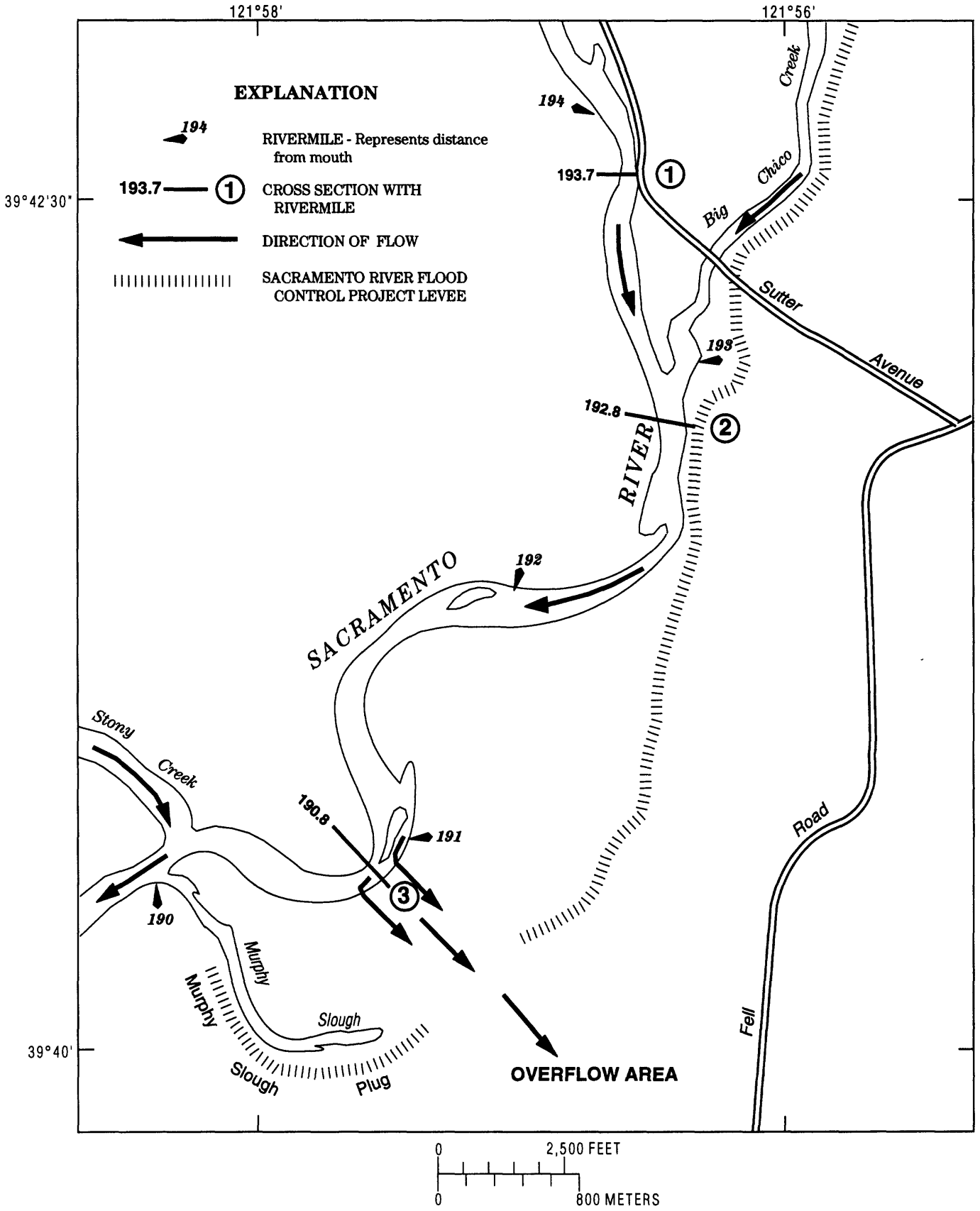

Figure 7. Locations of cross sections that are surveyed annually.

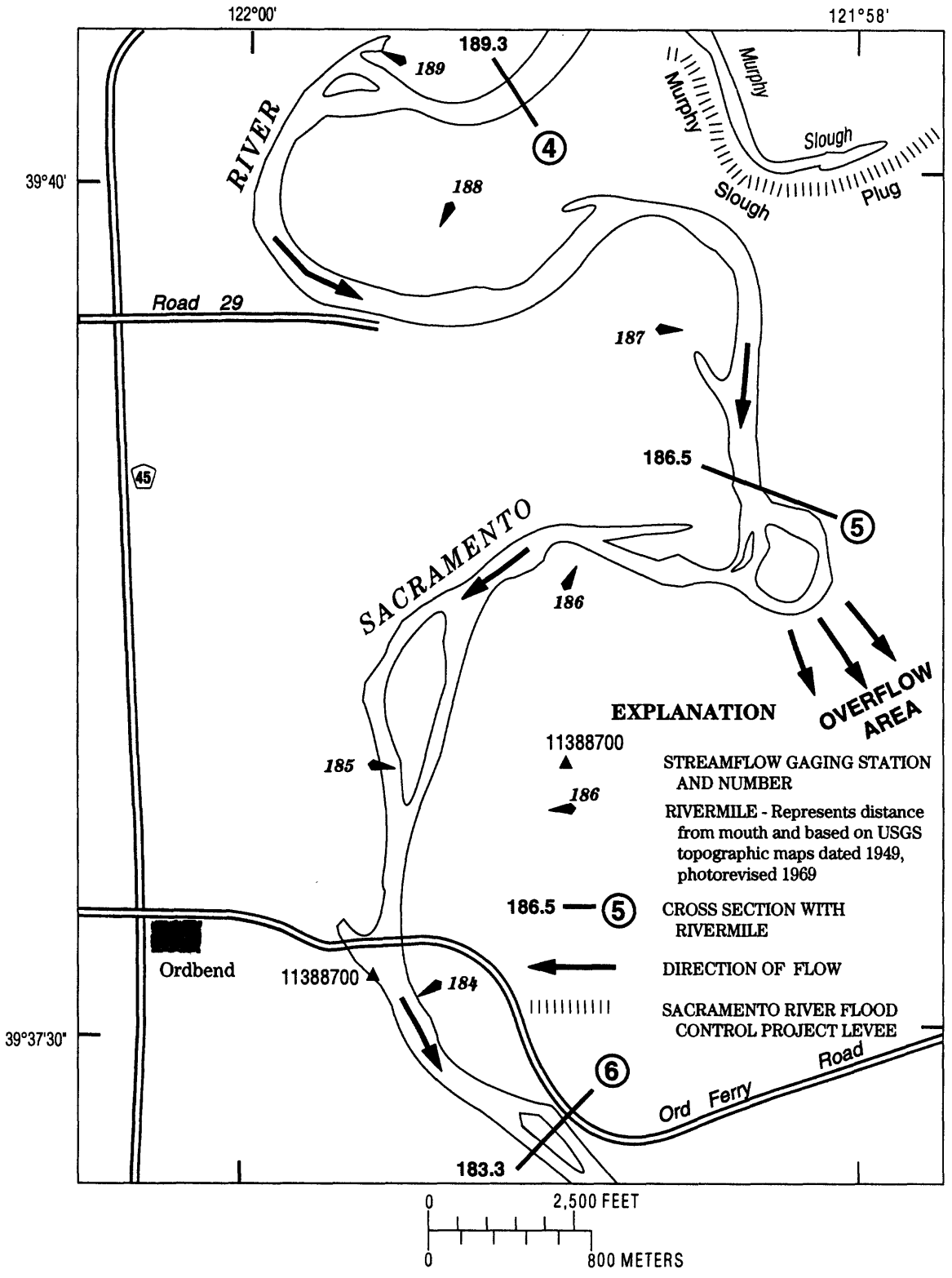

Figure 7. *Continued.*

Table 4. Coordinate data for six cross sections of the Sacramento River

[All values are in feet. Elevation in feet above sea level. See figure 7 for location of cross sections]

Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation
				Rivermile 193.7, October 1981--Cross section 1					
0	127.1	35	114.5	132	101.4	321	114.5	710	121.8
10	127.0	43	106.3	181	104.5	476	120.0	730	124.8
13	127.2	60	101.5	217	106.8	548	120.3	755	124.8
21	123.9	75	100.0	241	109.3	616	118.5		
34	117.9	101	100.9	296	111.1	699	119.9		
				Rivermile 192.8, September 1981--Cross section 2					
0	137.6	94	122.8	337	105.1	579	123.1	863	123.7
8	137.0	94	112.1	376	107.1	620	122.4	871	124.4
20	132.9	104	104.6	397	109.1	708	122.4	882	124.2
38	128.9	125	99.9	409	109.6	726	124.5	920	126.2
58	128.1	155	89.1	419	112.2	787	123.4	936	127.8
72	129.0	173	92.1	458	115.2	794	122.8	1,007	128.5
85	129.2	242	97.1	484	122.1	827	123.3	1,031	129.6
88	128.8	307	101.1	519	121.9	841	124.3		
				Rivermile 190.8, September 1981--Cross section 3					
0	125.0	352	102.4	496	96.7	874	114.5	1,149	119.5
148	124.0	376	98.5	517	96.6	928	117.7	1,199	121.8
172	121.8	392	97.4	601	100.0	954	117.0	1,262	122.3
204	119.6	416	97.2	689	106.5	990	116.1	1,301	121.0
234	124.3	436	98.0	697	106.7	1,018	115.3	1,372	120.3
310	125.0	452	99.5	712	109.1	1,043	121.7	1,456	123.1
313	125.0	464	97.2	752	110.0	1,086	120.2	1,518	123.7
328	109.0	472	97.5	785	114.1	1,095	120.6	1,520	124.4
336	102.8	480	95.5	804	115.9	1,108	116.6	1,540	123.5
				Rivermile 189.3, August 1981--Cross section 4					
0	125.	147	97.8	363	103.3	804	119.0	1,191	118.6
40	124.6	173	96.8	371	105.2	858	119.2	1,218	116.7
54	123.8	203	98.1	413	107.3	923	115.0	1,227	116.8
88	105.3	237	96.2	600	111.3	932	117.4	1,233	117.9
97	101.3	260	96.5	610	115.3	939	115.7	1,260	118.3
114	101.3	293	98.3	620	113.3	1,050	115.0		
130	99.9	310	98.5	774	109.9	1,123	117.6		
137	100.1	346	101.3	780	109.1	1158	117.6		

Table 4. Coordinate data for six cross sections of the Sacramento River--*Continued*

Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation
				Rivermile 186.5, September 1981--Cross section 5					
0	119.5	327	95.2	772	100.4	1,402	108.9	1,963	113.5
49	119.2	394	89.0	811	103.2	1,429	109.8	2,033	115.7
60	118.9	434	93.2	975	110.4	1,451	116.6	2,127	113.3
69	112.0	488	97.3	1,101	108.5	1,472	116.1	2,152	107.0
105	113.3	502	97.2	1,172	111.5	1,486	111.6	2,259	107.1
169	110.6	528	97.7	1,233	111.3	1,547	114.1	2,284	111.4
228	111.6	555	97.7	1,253	114.2	1,618	115.4	2,303	112.4
240	103.2	605	95.4	1,269	114.8	1,710	114.2	2,373	114.9
255	110.1	685	97.2	1,329	113.6	1,801	112.0		
264	97.7	726	96.7	1,344	110.0	1,819	113.8		
286	94.7	748	97.7	1,363	110.8	1,858	114.7		
309	94.5	757	97.7	1,373	114.1	1,913	114.2		
				Rivermile 183.3, August 1981--Cross Section 6					
0	112.4	166	86.2	398	91.9	723	96.3	939	106.0
18	113.0	186	85.6	477	94.5	786	95.7	961	106.6
32	112.0	249	87.3	500	94.8	834	100.7	993	107.4
63	92.1	262	87.3	627	96.0	854	96.6	1,057	108.7
73	88.0	305	89.7	634	97.8	883	102.8	1,122	109.6
106	80.0	338	90.0	648	96.2	898	102.6		
				Rivermile 193.7, January 1982--Cross section 1					
0	127.1	54	104.4	128	100.1	269	111.6	414	118.0
13	127.2	65	97.8	136	100.9	276	111.5	429	118.4
24	122.1	70	97.9	158	103.3	323	114.2	469	120.1
30	116.4	91	98.2	164	103.8	327	114.3	710	122.1
32	115.6	94	98.3	204	105.0	370	116.7	730	124.8
45	109.3	97	98.1	208	106.1	372	117.0		
				Rivermile 192.8, September 1982--Cross section 2					
0	137.5	97	103.5	156	92.2	475	122.7	1,292	129.0
6	137.3	101	99.2	160	92.2	507	122.4	1,355	126.5
20	132.9	105	99.2	190	94.6	559	123.2	1,373	127.6
34	129.2	108	97.0	210	96.1	668	122.3	1,411	124.3
51	128.0	116	96.5	245	98.0	705	124.2	1,429	125.4
75	129.1	122	94.0	288	100.0	799	122.6	1,461	123.7
79	129.5	130	92.5	353	103.5	945	128.3	1,486	125.9
84	114.0	131	93.4	429	109.3	1,021	129.7	1,547	126.0
89	104.4	135	92.0	439	114.0	1,065	130.1	1,620	126.5
96	103.6	137	91.3	455	115.4	1,156	129.9	1,741	132.5

Table 4. Coordinate data for six cross sections of the Sacramento River--*Continued*

Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation
			Rivermile 190.8, September 1982--Cross section 3						
0	125.0	334	106.6	465	96.4	602	102.4	1,082	119.1
186	123.9	344	104.7	473	96.1	612	105.5	1,151	120.2
222	123.5	363	100.3	483	96.4	617	108.5	1,230	120.8
261	118.8	380	98.4	487	95.3	632	112.7	1,288	118.6
300	123.9	389	97.7	494	96.7	738	111.6	1,363	120.1
307	124.2	409	97.1	506	96.8	839	116.0	1,394	121.2
312	116.7	428	96.2	531	96.6	924	114.7	1,445	122.0
315	112.4	448	95.8	566	99.0	1,015	116.4	1,499	123.4
326	108.5	455	95.9	588	101.0				
			Rivermile 189.3, August 1982--Cross section 4						
0	125.0	122	100.9	324	97.8	631	113.4	1,047	115.7
40	124.6	173	96.8	407	104.1	773	110.4	1,124	117.8
50	124.7	187	97.2	422	106.0	773	111.5	1,209	118.8
89	106.2	233	93.6	492	110.8	794	111.1	1,233	117.1
94	102.9	269	96.9	613	113.0	813	120.2	1,244	118.5
111	102.3	297	96.3	623	116.1	824	118.3		
			Rivermile 186.5, September 1982--Cross section 5						
0	119.1	414	97.7	967	94.6	1,515	108.1	2,025	113.4
21	119.1	426	98.1	972	96.6	1,560	112.4	2,073	115.8
135	110.5	443	97.2	990	96.7	1,573	111.0	2,161	116.4
202	113.2	459	98.3	1,000	96.9	1,585	113.6	2,217	114.3
204	113.2	559	98.2	1,078	101.4	1,659	116.6	2,237	108.3
216	104.9	603	97.6	1,111	104.3	1,689	114.5	2,352	106.6
229	100.8	745	97.9	1,144	110.5	1,717	115.5	2,375	110.4
231	99.1	799	97.3	1,253	111.5	1,881	111.3	2,432	115.1
255	96.9	869	95.3	1,346	114.8	1,895	114.6		
293	94.6	909	95.3	1,448	110.2	1,912	116.0		
352	94.6	928	91.2	1,460	111.9	1,935	114.6		
392	92.7	940	90.1	1,483	111.8	2,013	115.8		
			Rivermile 183.3, August 1982--Cross section 6						
0	112.2	65	85.6	200	77.8	440	93.6	1,028	105.8
16	112.8	81	82.0	217	77.9	614	96.6	1,047	107.3
26	111.9	102	76.4	242	80.7	734	96.1	1,080	105.6
36	111.1	112	77.4	297	82.9	865	97.7	1,092	109.2
49	100.2	153	80.7	346	86.8	967	103.0	1,146	109.0
59	93.7	187	79.0	420	89.4	1,000	102.2	1,191	110.2

Table 4. Coordinate data for six cross sections of the Sacramento River--*Continued*

Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation
				Rivermile 193.7, May 1983--Cross section 1					
0	127.1	43	107.8	114	97.8	282	113.7	616	118.5
10	127.0	49	103.7	128	100.0	312	115.3	699	119.9
13	127.2	56	99.5	144	101.1	342	116.4	710	121.8
22	121.5	64	95.4	162	103.9	372	117.4	730	124.8
25	119.1	72	93.6	182	106.8	402	118.7		
29	117.3	82	94.5	204	108.4	432	120.2		
33	114.1	92	95.5	228	110.5	456	121.5		
38	110.2	102	96.9	254	112.0	548	122.5		
				Rivermile 192.8, September 1983--Cross section 2					
0	137.6	87	100.8	244	99.8	472	122.7	842	128.0
5	137.6	124	90.8	267	99.6	537	122.5	907	128.5
18	133.1	141	93.0	289	100.2	616	124.5	936	129.8
37	128.9	163	93.8	370	104.8	657	123.7	1,150	130.0
54	128.4	220	97.8	395	106.0	707	125.8		
69	129.0	231	99.0	462	113.6	744	125.7		
82	115.9	237	97.8	472	115.8	773	123.7		
				Rivermile 190.8, September 1983--Cross section 3					
0	124.8	313	105.0	571	95.0	1,041	121.2	1,558	120.4
64	124.0	347	97.8	601	101.0	1,110	122.4	1,564	122.7
119	124.2	373	95.6	651	108.0	1,153	120.8	1,658	120.5
194	123.9	425	95.8	661	109.9	1,214	123.7	1,697	119.8
261	123.7	431	95.0	881	111.4	1,300	121.1	1,727	122.9
273	120.6	497	95.3	954	113.6	1,400	122.1	1,740	121.9
303	110.0	538	95.9	1,034	118.3	1,479	121.6	1,785	121.4
				Rivermile 189.3, August 1983--Cross section 4					
0	124.9	149	99.3	340	93.8	717	111.8	1,128	120.9
40	124.6	158	97.3	375	100.8	781	112.5	1,239	118.8
52	124.5	225	93.1	432	105.8	791	115.7	1,287	117.8
85	108.3	255	94.6	452	108.2	821	120.0	1,317	120.6
90	104.6	280	95.5	555	111.9	892	119.8	1,385	123.1
120	100.7	296	93.5	627	116.8	951	116.4		
131	100.9	320	92.3	672	115.6	1,081	121.3		
				Rivermile 186.5, September 1983--Cross section 5					
0	119.0	214	102.0	753	100.6	1,701	96.7	2,021	114.2
13	118.7	219	100.3	863	100.0	1,724	99.4	2,084	116.8
50	113.5	260	94.6	948	98.6	1,729	102.9	2,025	116.8
93	111.1	272	96.9	1,235	98.4	1,747	106.6	2,223	106.9
146	113.4	344	97.0	1,313	95.4	1,767	114.8	2,270	104.1
160	112.2	372	97.9	1,505	93.0	1,865	114.1	2,349	106.1
165	108.9	393	97.5	1,635	87.4	1,893	115.8	2,362	110.1
171	107.1	541	97.4	1,658	89.4	1,916	115.9	2,385	110.4
176	104.4	718	97.5	1,671	88.9	1,969	112.8		

Table 4. Coordinate data for six cross sections of the Sacramento River--*Continued*

Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation
				Rivermile 183.3, August 1983--Cross section 6					
0	112.4	90	76.1	315	89.5	644	96.9	939	93.2
16	112.9	120	80.0	344	89.9	673	95.9	949	95.9
25	111.8	180	83.3	380	90.9	698	93.9	1,050	107.6
31	111.9	200	81.4	435	92.7	723	93.3	1,088	106.3
54	94.9	226	83.7	465	94.8	781	91.9	1,111	109.3
58	92.8	250	84.2	498	96.1	833	91.2	1,227	110.3
76	84.9	305	87.9	523	95.2	888	91.9	1,237	110.1
				Rivermile 193.7, December 1984--Cross section 1					
0	127.7	55	108.9	143	97.1	278	111.2	619	119.8
18	127.1	71	101.1	175	100.5	324	113.8	665	121.8
24	123.4	90	94.3	214	104.9	371	115.9	720	124.9
30	118.9	113	96.0	233	106.6	401	118.8		
40	110.0	135	97.9	251	107.1	493	123.3		
				Rivermile 192.8, September 1984--Cross section 2					
0	137.5	101	104.0	279	100.4	469	115.3	962	129.2
19	132.9	119	95.6	310	102.9	474	118.1	1,014	130.4
38	128.9	132	92.4	348	105.3	479	120.5	1,044	131.1
66	129.3	141	94.2	400	108.3	584	122.0	1,329	129.1
71	129.1	199	98.0	407	112.0	683	123.3		
82	115.4	251	101.5	430	111.8	814	127.1		
88	105.3	265	101.4	461	112.3	902	124.2		
				Rivermile 190.8, September 1984--Cross section 3					
0	123.5	291	109.5	465	95.7	673	106.0	1,222	123.1
50	124.0	326	103.6	484	97.1	694	107.1	1,282	121.2
117	124.3	356	96.3	532	94.1	715	109.4	1,397	122.2
214	123.9	375	95.4	576	93.2	823	115.7	1,512	121.3
249	124.0	404	97.2	602	94.9	932	119.3	1,624	121.9
264	122.9	436	96.9	626	97.1	1,022	121.0		
282	111.3	455	95.6	653	103.0	1,155	122.3		
				Rivermile 189.3, August 1984--Cross section 4					
0	124.9	169	96.1	359	97.0	715	114.3	1,082	120.6
30	124.5	205	94.0	374	98.5	769	112.1	1,144	120.8
55	124.3	226	94.2	390	100.5	787	113.0	1,266	119.6
84	107.9	244	94.7	417	102.7	791	112.0	1,334	119.0
90	103.0	256	95.5	444	104.5	812	119.9	1,390	120.0
103	101.5	282	94.5	456	107.8	823	120.7		
112	100.5	294	93.1	601	114.8	905	120.4		
123	101.0	311	93.6	623	117.5	925	114.8		
143	97.1	333	95.2	664	113.4	1,064	118.4		

Table 4. Coordinate data for six cross sections of the Sacramento River--*Continued*

Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation
				Rivermile 186.5, September 1984--Cross section 5					
0	119.0	278	94.8	563	99.2	1,091	102.7	1,758	96.1
15	119.1	303	97.7	576	99.2	1,263	99.9	1,773	97.4
23	114.6	308	100.5	583	98.5	1,298	99.1	1,818	99.6
95	112.3	313	99.8	591	99.3	1,341	98.8	1,826	102.8
152	114.7	316	98.6	619	100.0	1,389	96.9	1,851	112.2
161	114.6	321	100.8	629	98.6	1,446	94.5	1,895	116.8
182	108.2	362	100.3	650	98.7	1,475	94.2	2,014	115.7
201	102.6	367	98.5	714	99.6	1,500	92.3	2,161	116.8
234	99.5	373	99.4	732	99.2	1,587	91.7	2,189	105.8
246	97.6	409	99.0	743	100.1	1,624	92.2	2,346	107.1
267	95.9	511	98.9	779	99.9	1,657	93.0	2,360	109.8
272	98.5	543	99.6	944	102.7	1,728	93.1	2,385	112.7
				Rivermile 183.3, August 1984--Cross section 6					
0	112.3	137	80.0	242	87.9	667	92.9	912	92.7
27	111.9	144	81.9	248	88.8	684	92.5	954	95.7
36	113.1	148	85.2	277	89.5	704	92.4	1,036	103.8
57	94.8	153	83.8	317	90.1	735	91.5	1,054	107.9
67	89.2	164	87.8	356	91.3	762	90.3	1,085	106.9
78	86.0	181	80.3	421	94.6	786	89.9	1,098	106.9
89	79.5	188	80.5	512	96.5	832	90.7	1,103	109.5
94	79.1	218	86.2	634	97.8	857	90.9	1,109	109.3
97	76.7	231	86.7	641	95.6	884	91.4	1,227	109.0
				Rivermile 193.7, September 1986--Cross section 1					
0	127.0	28	118.4	102	93.5	227	110.6	470	123.4
8	126.8	37	114.8	109	93.8	275	112.3	493	123.2
13	127.2	45	108.6	118	94.0	291	113.3	532	123.8
17	125.8	57	106.3	155	98.8	316	114.7	617	119.8
21	123.0	79	98.3	197	106.4	398	118.8	714	124.0
				Rivermile 192.8, September 1986--Cross section 2					
0	137.3	85	113.8	185	93.1	471	107.5	794	124.5
8	136.9	95	107.8	197	93.8	481	108.8	847	123.1
20	133.0	119	103.0	214	93.7	485	109.8	871	129.1
31	131.8	128	98.5	227	93.5	500	113.7	887	125.5
44	131.9	135	92.8	270	96.3	523	117.1	912	125.7
52	127.8	141	89.8	310	100.8	568	119.2	942	131.0
59	125.2	146	88.8	404	104.3	619	121.3		
69	120.6	160	88.9	435	104.8	667	122.6		
83	116.8	172	91.6	453	105.6	728	124.3		

Table 4. Coordinate data for six cross sections of the Sacramento River--*Continued*

Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation
				Rivermile 190.8, September 1986--Cross section 3					
0	124.0	141	103.5	271	97.0	434	98.8	1,014	122.8
14	125.1	153	102.0	282	96.6	459	102.7	1,130	118.0
58	124.4	170	99.4	331	95.0	474	108.0	1,151	119.9
103	124.1	198	95.1	355	94.6	547	111.6	1,184	122.8
108	124.3	203	94.9	370	94.8	626	114.6	1,372	123.8
109	118.4	216	95.3	379	94.5	678	116.9	1,502	123.2
116	113.3	232	96.1	369	95.2	738	117.1		
125	109.2	241	96.1	406	95.6	839	117.0		
129	108.0	267	96.8	413	95.8	929	121.8		
				Rivermile 189.3, August 1986--Cross section 4					
0	124.8	106	101.0	248	96.2	396	103.3	603	114.6
36	124.5	118	99.6	260	94.9	403	103.6	613	116.5
49	124.4	126	98.4	265	94.8	417	103.0	618	116.2
52	124.2	146	98.6	282	93.9	440	104.3	797	115.0
62	118.4	153	98.8	290	92.8	455	104.9		
75	111.5	176	96.4	307	94.1	467	104.8		
88	106.6	211	96.6	325	96.4	487	106.5		
98	101.6	233	96.8	350	98.2	553	110.5		
				Rivermile 186.5, September 1986--Cross section 5					
0	119.4	735	101.4	1,447	109.2	2,030	97.2	2,301	109.0
49	119.0	789	101.6	1,516	105.2	2,062	98.6	2,340	105.4
97	114.8	919	101.2	1,624	101.2	2,102	101.5	2,377	104.5
220	114.6	1,019	101.6	1,704	98.4	2,152	104.7	2,387	111.3
284	101.5	1,087	105.8	1,759	97.0	2,164	109.2	2,392	111.7
414	107.4	1,207	104.3	1,878	95.2	2,172	109.4	2,466	116.0
460	106.2	1,245	112.6	1,907	95.8	2,220	107.5		
572	102.0	1,320	112.7	1,955	96.4	2,236	104.8		
673	102.2	1,402	110.5	1,967	96.2	2,297	109.1		
				Rivermile 183.3, September 1986--Cross section 6					
0	112.4	84	83.0	177	85.3	632	94.7	947	91.5
17	112.9	86	80.5	184	86.9	662	93.0	965	91.0
23	112.0	90	78.0	197	89.1	675	92.5	989	93.5
28	112.2	97	77.1	254	92.2	691	92.2	1,004	95.2
37	111.5	108	78.3	354	93.9	708	91.9	1,063	102.7
46	106.1	118	79.8	394	95.7	727	91.3	1,091	106.3
55	100.3	135	81.2	416	96.9	778	90.9	1,113	110.0
61	94.0	157	83.0	456	97.4	840	90.3	1,124	110.1
71	82.5	167	84.2	535	97.6	898	90.6	1,177	110.0
79	83.1	171	86.0	622	96.6	920	91.0	1,252	110.5
				Rivermile 193.7, August 1987--Cross section 1					
0	127.0	47	104.7	148	97.9	260	111.9	493	123.3
13	127.6	62	98.4	180	102.4	291	112.4	630	119.1
32	118.8	77	92.6	204	105.4	341	115.4	708	124.2
35	115.4	124	95.4	240	108.9	412	119.8	750	124.8

Table 4. Coordinate data for six cross sections of the Sacramento River--*Continued*

Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation
			Rivermile 192.8, September 1987--Cross section 2						
0	137.4	80	114.1	140	89.3	384	104.1	522	114.1
8	137.0	95	106.1	150	92.0	440	105.0	681	123.9
20	133.0	107	104.1	180	94.1	478	107.1	868	126.9
25	132.2	117	99.0	220	96.1	490	109.0	1,060	131.6
44	131.3	124	94.1	276	99.1	504	108.1	1,190	129.9
61	125.2	132	91.1	343	103.2	512	109.0		
			Rivermile 190.8, September 1987--Cross section 3						
0	124.1	155	98.3	385	94.3	651	114.8	1,167	121.7
90	124.2	187	95.5	409	98.3	740	116.9	1,331	123.4
106	124.2	216	96.3	426	103.3	871	117.5	1,497	123.2
109	117.2	265	93.8	443	105.3	918	121.1		
123	110.8	295	93.3	474	106.3	981	123.0		
128	108.3	326	91.8	484	108.2	1,017	121.9		
133	102.0	358	93.3	541	112.2	1,093	117.2		
			Rivermile 189.3, August 1987--Cross section 4						
0	124.6	126	99.5	304	93.7	474	104.8	784	112.5
24	124.5	166	99.7	322	95.2	494	106.8	794	115.4
52	124.3	192	97.2	350	96.7	549	111.1	823	120.1
64	117.1	212	96.7	371	99.7	610	116.5		
84	106.8	242	95.4	386	101.7	617	116.5		
89	101.7	260	95.7	412	104.0	702	114.2		
113	100.7	282	94.1	441	103.2	747	116.1		
			Rivermile 186.5, August 1987--Cross section 5						
0	119.1	264	106.3	1,276	111.7	1,795	96.0	2,068	98.0
19	119.1	430	105.3	1,302	111.7	1,858	95.0	2,109	99.0
64	114.2	443	103.0	1,485	108.0	1,900	94.5	2,139	101.0
183	114.4	611	99.8	1,622	101.0	1,929	95.0	2,223	106.7
204	114.5	669	101.2	1,642	99.0	1,963	95.5	2,373	110.4
240	100.9	1,159	101.7	1,665	98.5	1,980	96.5	2,438	104.3
251	100.9	1,234	101.5	1,730	96.5	2,032	97.0	2,502	111.7
			Rivermile 183.3, August 1987--Cross section 6						
0	112.4	104	79.0	175	91.0	661	94.0	969	92.2
36	111.8	114	80.0	182	90.5	722	92.5	1,000	93.0
58	94.0	120	83.5	210	91.5	760	91.0	1,020	95.0
68	89.5	130	87.0	242	93.0	810	90.0	1,076	102.7
73	91.0	134	84.8	267	94.0	840	90.2	1,116	108.7
78	84.0	140	86.0	462	98.0	880	90.5	1,236	110.1
92	77.0	157	89.0	631	95.0	930	91.3		

Table 4. Coordinate data for six cross sections of the Sacramento River--*Continued*

Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation
			Rivermile 193.7, August 1988--Cross section 1						
0	127.0	64	102.1	186	101.1	320	112.6	636	119.3
13	127.6	76	96.1	221	105.1	350	116.1	657	121.6
23	123.4	87	93.6	233	106.1	467	123.4	699	124.1
37	116.1	100	92.6	242	108.1	492	123.2	750	124.8
42	109.8	123	94.1	270	110.1	527	124.0		
52	107.1	145	96.1	296	111.1	581	122.0		
			Rivermile 192.8, August 1988--Cross section 2						
0	137.4	100	110.5	234	99.0	479	107.2	942	133.5
6	137.2	124	105.0	270	101.0	485	108.0	992	128.7
20	133.0	136	101.0	324	102.0	515	115.0	1,042	131.6
44	131.2	154	89.5	366	104.0	606	121.0		
62	123.7	160	89.4	411	104.5	693	124.2		
78	115.0	171	95.0	428	105.3	907	126.0		
84	111.2	197	98.0	454	105.0	932	130.4		
			Rivermile 190.8, August 1988--Cross section 3						
0	124.2	167	97.1	294	92.3	391	93.1	986	122.4
94	124.0	188	95.3	306	92.3	406	96.6	1,093	117.2
107	124.0	216	95.1	317	91.9	420	100.1	1,167	121.7
108	118.0	230	94.5	329	92.0	435	103.1	1,331	123.4
120	109.2	246	93.1	338	91.6	470	109.1		
130	104.1	264	92.7	362	93.0	494	111.2		
147	100.2	277	92.8	380	92.6	746	117.2		
			Rivermile 189.3, August 1988, Cross section 4						
0	124.7	108	101.2	203	95.6	274	93.6	438	103.6
35	124.5	114	99.6	212	94.8	295	96.0	468	104.8
52	124.2	121	99.9	226	95.6	318	96.6	505	107.6
65	116.5	131	98.6	237	95.6	341	99.4	615	116.2
83	107.7	152	98.6	245	94.6	359	101.6	701	114.3
89	103.0	168	96.6	255	93.8	383	103.6	791	115.3
99	102.6	189	94.2	265	94.6	411	102.6	820	120.0
			Rivermile 186.5, August 1988--Cross section 5						
0	119.1	264	106.3	1,333	110.8	1,818	96.0	2,103	98.1
20	119.1	430	105.3	1,606	101.7	1,860	95.8	2,163	102.0
64	114.2	611	99.8	1,686	99.8	1,882	95.0	2,201	105.6
85	114.2	669	101.2	1,710	98.1	1,916	94.6	2,293	110.5
204	114.5	1,159	101.7	1,725	98.1	1,980	95.1	2,423	105.0
240	100.9	1,234	101.5	1,760	96.8	2,000	95.1	2,502	111.7
251	100.9	1,244	112.8	1,772	96.6	2,053	97.0		

Table 4. Coordinate data for six cross sections of the Sacramento River--*Continued*

Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation
				Rivermile 183.3, August 1988--Cross section 6					
0	112.4	159	79.2	383	94.6	747	89.1	1,068	99.7
34	111.9	172	82.2	453	98.2	820	89.6	1,078	103.2
37	112.4	190	82.7	587	96.9	833	89.2	1,117	109.3
56	94.7	210	82.2	615	95.6	868	90.1	1,167	109.7
66	75.2	250	89.4	645	92.0	920	91.1	1,244	110.2
96	74.7	300	90.0	700	89.6	1,002	92.2		
128	77.7	363	92.7	723	89.1	1,027	95.6		
				Rivermile 193.7, September 1989--Cross section 1					
0	127.0	72	92.4	175	102.4	285	112.4	531	123.9
14	127.9	80	92.4	190	104.7	331	113.9	647	119.8
30	118.3	95	93.4	202	105.4	341	115.4	676	123.3
35	115.4	110	94.4	216	108.0	169	123.5		
45	103.9	140	98.4	253	110.9	493	123.2		
				Rivermile 192.8, September 1989--Cross section 2					
0	137.4	104	102.5	145	93.0	365	103.5	524	117.8
8	137.0	109	99.5	170	96.0	396	104.9	694	124.4
20	133.0	115	96.5	187	97.5	418	104.5	925	126.4
35	131.7	120	92.5	200	97.8	449	105.0	939	131.2
43	132.0	125	89.5	203	98.9	457	105.5	967	130.3
79	114.5	129	88.8	232	100.5	473	108.0		
94	104.7	135	88.8	265	100.5	489	110.4		
99	104.0	138	90.5	319	103.0	499	114.4		
				Rivermile 190.8, September 1989--Cross section 3					
0	124.4	182	92.9	325	91.1	416	104.6	1,013	123.6
52	124.4	195	92.8	338	91.6	428	106.4	1,051	117.6
85	124.0	212	93.7	356	92.6	433	107.6	1,152	117.2
134	107.6	225	92.9	371	94.1	551	112.2	1,252	122.8
144	100.6	246	92.9	386	97.6	634	117.3		
153	102.0	259	92.6	395	99.6	721	116.4		
161	101.1	275	91.6	400	99.6	863	121.4		
177	97.6	300	91.3	406	102.1	946	121.4		
				Rivermile 189.3, September 1989--Cross section 4					
0	124.7	136	97.9	245	95.3	367	98.0	772	117.6
34	124.6	172	96.7	252	95.1	415	102.6	794	115.8
50	124.5	193	94.5	267	9307	456	102.5	854	120.0
89	105.7	202	93.5	281	93.1	496	105.7		
99	100.7	208	93.5	303	92.2	619	116.4		
110	100.7	214	94.3	335	94.4	706	114.1		

Table 4. Coordinate data for six cross sections of the Sacramento River--*Continued*

Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation
			Rivermile 186.5, September 1989--Cross section 5						
0	119.1	611	99.8	1,726	97.8	1,929	96.0	2,304	108.8
20	119.1	669	101.2	1,742	97.0	1,978	96.9	2,326	105.7
64	114.2	1,159	101.7	1,792	95.8	2,015	97.4	2,380	105.1
85	114.2	1,234	101.5	1,803	95.6	2,056	97.6	2,388	111.2
204	114.5	1,278	109.2	1,832	94.9	2,106	98.8	2,391	111.7
240	100.9	1,294	112.9	1,861	95.3	2,136	100.5	2,429	115.8
251	100.9	1,458	109.2	1,869	95.0	2,165	102.6	2,472	117.6
264	106.3	1,643	100.2	1,886	95.5	2,180	108.0	2,501	114.9
430	105.3	1,693	98.7	1,905	94.9	2,230	109.0		
			Rivermile 183.3, September 1989--Cross section 6						
0	112.4	125	86.9	342	92.8	709	91.2	997	93.9
24	112.0	130	86.9	385	95.4	728	90.4	1,044	97.5
37	112.8	140	83.1	403	99.4	760	89.9	1,118	109.4
60	92.9	146	83.4	473	98.4	770	89.7	1,145	109.8
70	79.4	157	87.4	560	97.1	782	90.1	1,235	109.2
76	76.4	170	89.3	617	97.0	827	89.9	1,252	110.6
81	76.2	178	89.9	624	94.8	844	90.3		
89	78.4	190	90.4	640	93.9	856	90.2		
107	80.7	244	90.9	670	92.4	915	91.9		
115	82.9	302	91.4	683	91.9	967	92.9		
			Rivermile 193.7, August 1990--Cross section 1						
0	127.1	74	100.0	212	106.5	493	123.2		
16	127.0	90	92.5	220	108.3	529	124.0		
35	115.0	113	94.0	296	112.5	650	119.7		
50	103.5	173	102.0	336	115.0	674	123.4		
			Rivermile 192.8, August 1990--Cross section 2						
0	137.4	43	131.0	121	101.9	252	101.9	503	113.9
8	137.0	79	113.9	132	92.4	373	104.9	696	124.3
20	133.0	94	106.9	158	96.4	415	104.9	941	131.4
35	131.7	108	105.9	180	98.2	453	106.4	971	130.4
			Rivermile 190.8, August 1990--Cross section 3						
0	124.3	190	98.5	267	90.5	410	94.5	466	108.0
87	124.1	200	95.5	283	93.0	420	95.5	735	116.9
137	108.0	215	92.8	305	93.5	433	102.0	996	123.2
152	103.5	234	93.5	347	92.5	440	103.5	1,077	116.8
176	101.0	250	93.0	390	93.5	451	106.0	1,187	122.5

Table 4. Coordinate data for six cross sections of the Sacramento River--*Continued*

Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation	Distance from initial point	Elevation
				Rivermile 189.3, August 1990--Cross section 4					
0	124.8	111	99.5	214	94.8	337	92.5	446	102.5
36	124.6	124	99.8	244	95.0	346	97.7	468	103.2
52	124.2	138	98.4	258	95.6	367	99.7	488	106.2
87	106.2	160	98.4	284	93.7	382	101.7	616	116.5
92	101.0	193	95.2	302	93.2	405	102.2	696	114.4
98	101.2	204	95.2	322	92.2	430	102.2	786	115.6
				Rivermile 186.5, August 1990--Cross section 5					
0	119.1	611	99.8	1,813	94.8	2,062	96.7	2,371	104.8
20	119.1	669	101.2	1,837	94.6	2,080	96.6	2,387	111.0
64	114.2	1,159	101.7	1,859	94.3	2,095	97.0	2,392	111.7
85	114.2	1,234	101.5	1,883	94.3	2,107	98.0	2,411	114.5
204	114.5	1,291	112.8	1,908	94.0	2,114	99.0	2,465	117.5
240	100.9	1,455	109.0	1,935	93.3	2,134	101.0		
251	100.9	1,634	101.0	1,968	93.7	2,159	102.9		
264	106.3	1,684	97.8	1,982	93.4	2,179	108.8		
430	105.3	1,772	95.0	2,018	96.5	2,304	108.5		
				Rivermile 183.3, August 1990--Cross section 6					
0	112.4	95	76.5	197	88.0	495	98.0	869	89.6
38	111.6	105	79.0	207	89.0	583	98.3	960	90.4
60	93.5	120	79.8	242	90.5	640	96.3	1,007	92.8
65	84.3	136	80.5	262	90.5	664	94.3	1,057	94.3
70	83.5	159	85.7	336	92.5	684	91.3	1,145	109.7
76	80.0	171	83.5	376	93.5	730	90.3	1,161	109.7
86	76.5	182	84.5	441	97.8	777	89.6	1,202	110.6

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