FLOOD ANALYSIS ALONG THE LITTLE MISSOURI RIVER WITHIN AND ADJACENT TO THEODORE ROOSEVELT NATIONAL PARK, NORTH DAKOTA

By Douglas G. Emerson and Kathleen M. Macek-Rowland

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DONALD PAUL HODEL, Secretary

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SELECTED FACTORS FOR CONVERTING INCH-POUND UNITS TO THE INTERNATIONAL SYSTEM (SI) OF UNITS

For those readers who may prefer to use the International System (SI) of Units rather than inch-pound units, the conversion factors for the terms used in this report are given below.

Multiply inch-pound unit	By	To obtain SI unit
Cubic foot per second (ft^3/s)	0.02832	cubic meter per second
Foot (ft)	0.3048	meter
Mile (mi)	1.609	kilometer
Square mile (mi^2)	2.590	square kilometer

National Geodetic Vertical Datum of 1929 (NGVD of 1929): A geodetic datum derived from a general adjustment of the first-order nets of both the United States and Canada, formerly called "mean sea level." NGVD of 1929 is referred to as sea level in this report.

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ABSTRACT

The Little Missouri River flows through Theodore Roosevelt National Park, which consists of three separate units: South Unit, Elkhorn Ranch Site, and North Unit. The park is located in the Little Missouri badlands. Discharges and water-surface elevations for 100- or 500-year floods or both were computed for selected reaches along the Little Missouri River and three of its tributaries (Knutson Creek, Paddock Creek, and Squaw Creek) within and adjacent to Theodore Roosevelt National Park. The 100- and 500-year flood discharges for the Little Missouri River were determined from streamflow records. The 100-year flood discharges for the three creeks were estimated using a multiple-regression equation based on drainage area and soil-infiltration index. Water-surface elevations were determined by the step-backwater method. The effects of ice jams on water-surface elevations were estimated from streamflow records.

INTRODUCTION

Theodore Roosevelt National Park--an area of geologic, historic, and scenic interest--is located in western North Dakota (fig. 1) in the Little Missouri badlands. The park consists of three separate units: South Unit, Elkhorn Ranch Site, and North Unit. The Little Missouri River, a tributary of the Missouri River, flows north through the South Unit and Elkhorn Ranch Site and then turns in the North Unit and flows east. The Little Missouri badlands are described by Bluemle (1977) as a "Rugged, deeply-eroded, hilly area along the Little Missouri River; gentle slopes characterize 20 to 50 percent of the area and local relief is commonly over 500 feet."

The National Park Service needed information on flood potential as part of a general management plan for the park. They requested and funded a study to determine water-surface elevations along the Little Missouri River and three of its tributaries (Knutson Creek, Paddock Creek, and Squaw Creek) within and adjacent to Theodore Roosevelt National Park. The water-surface elevations will be used by the National Park Service as a basis for planning visitor activities and selecting structure sites.

The objectives of the study were to: (1) Determine water-surface elevations for 100- and 500-year flood discharges for selected reaches of the Little Missouri River; (2) determine water-surface elevations for 100-year

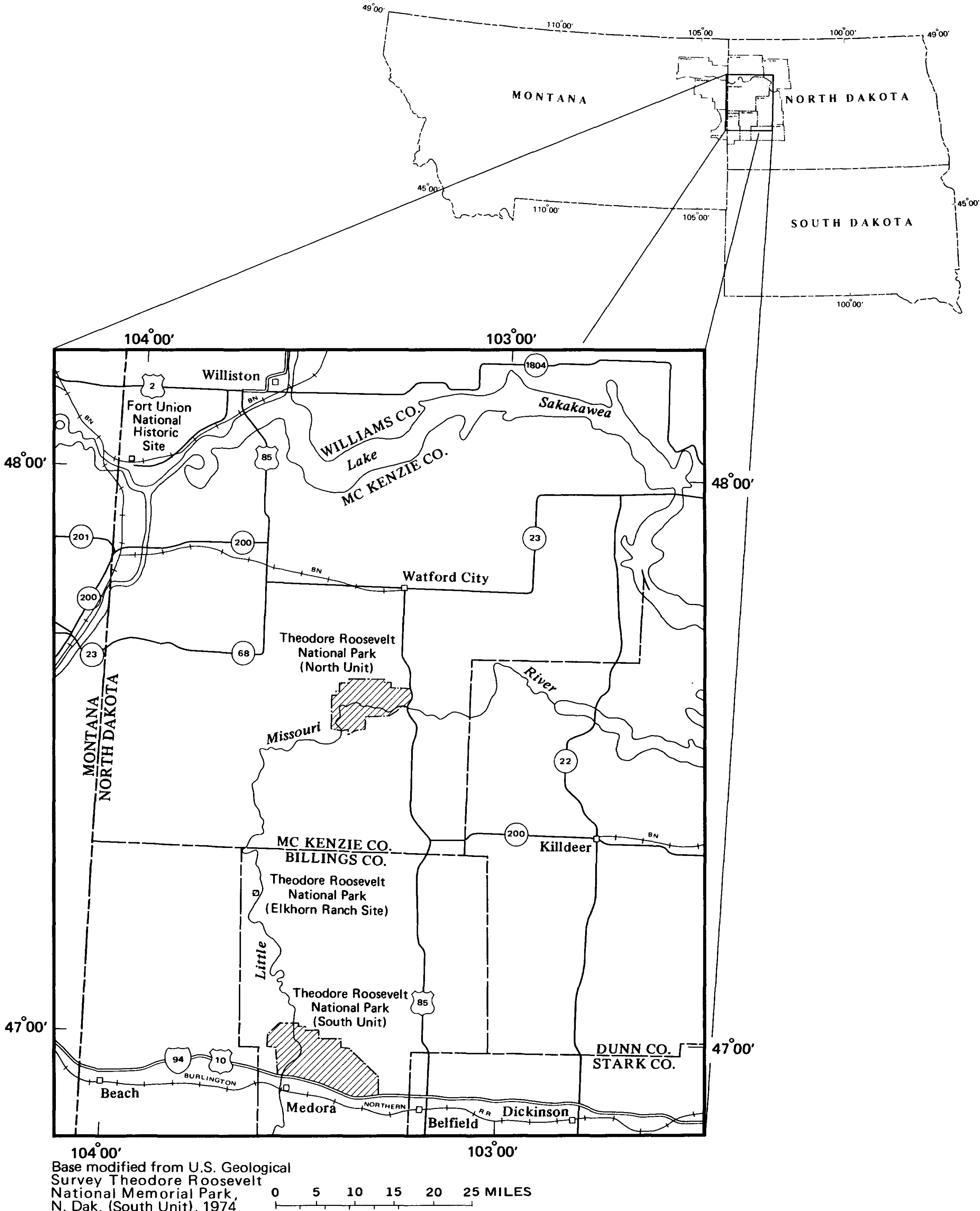


Figure 1.—Location of Theodore Roosevelt National Park.

flood discharges for the areas near the mouths of Knutson, Paddock, and Squaw Creeks; and (3) evaluate the effects of ice jams on water-surface elevations.

The study reach for the South Unit (fig. 2) is about 8 river miles long and includes the area along the Little Missouri River from about 0.1 mi south of Medora to about 1 mi downstream from Beef Corral Bottom. The study reach for the Elkhorn Ranch Site (fig. 3) is about 3 river miles long and includes the area from about 0.5 mi south of the south boundary of the site to about 0.05 mi north of the north boundary of the site. The study reach for the North Unit (fig. 4) is about 7 river miles long and includes the area from about 1 mi upstream from Squaw Creek Campground to the bridge on U.S. Highway 85.

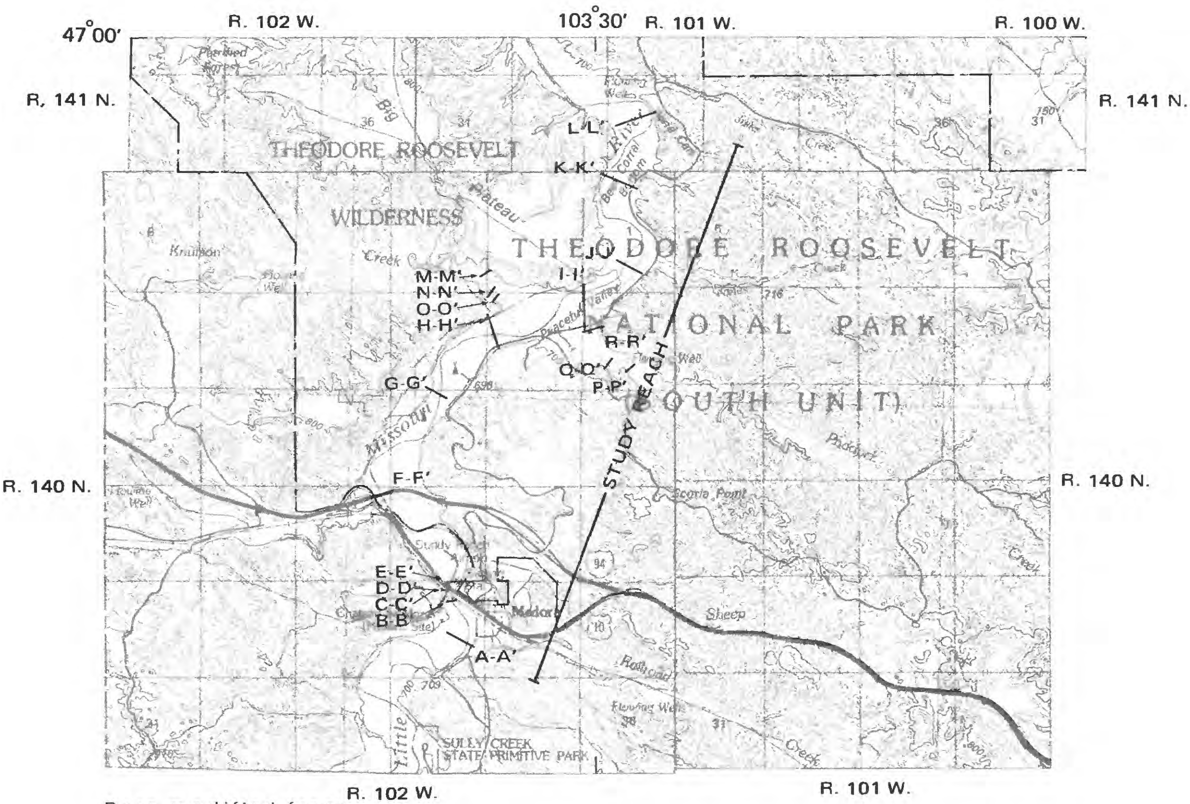
FLOOD FREQUENCY

The annual peak discharge data for the streamflow station Little Missouri River at Medora (06336000), which has a drainage area of about 6,190 mi^2, were used to determine the 100- and 500-year flood discharges for the Little Missouri River along the South Unit reach. The flood discharges determined are considered to be applicable for the entire South Unit reach. The procedures described by the U.S. Geological Survey (1982) were used to determine flood-flow frequency. The station has a discontinuous record from May 1903 to September 1934 and a continuous record from October 1945 to September 1976. The records include 50 annual peak discharges and 50 annual peak elevations (table 1).

Discharge data are not available for the Little Missouri River near the Elkhorn Ranch Site reach. Therefore, annual peak discharge data for the streamflow stations Little Missouri River at Marmarth (06335500), Little Missouri River at Medora (06336000), and Little Missouri River near Watford City (06337000) were used to determine the 100- and 500-year flood discharges for these stations. The 100- and 500-year flood discharges determined at these stations were then plotted against the station drainage areas (fig. 5) and a curvilinear line drawn through the points. The 100-year flood discharge for the Little Missouri River near the Elkhorn Ranch Site reach, which has a drainage area of about 6,680 mi^2, was determined from the plot to be 69,000 ft^3/s, and the 500-year discharge was determined from the plot to be 103,000 ft^3/s. Flood discharges determined in this analysis are considered to be applicable for the entire Elkhorn Ranch Site reach.

The annual peak discharge data for the streamflow station Little Missouri River near Watford City (06337000), which is located near the downstream end of the North Unit and has a drainage area of about 8,310 mi^2, were used to determine the 100- and 500-year flood discharges for the Little Missouri River along the North Unit reach. Flood discharges determined in this analysis are considered to be applicable for the entire North Unit reach. The station has a continuous record from September 1934 to the present. The record includes 48 annual peak discharges and 48 annual peak elevations (table 2).

Discharge data are not available for Knutson and Paddock Creeks, which are located in the South Unit (fig. 2), or for Squaw Creek, which is located in



Base modified from
U.S. Geological Survey
Belfield, 1980

0 1 2 3 MILES

0 1 2 3 KILOMETERS

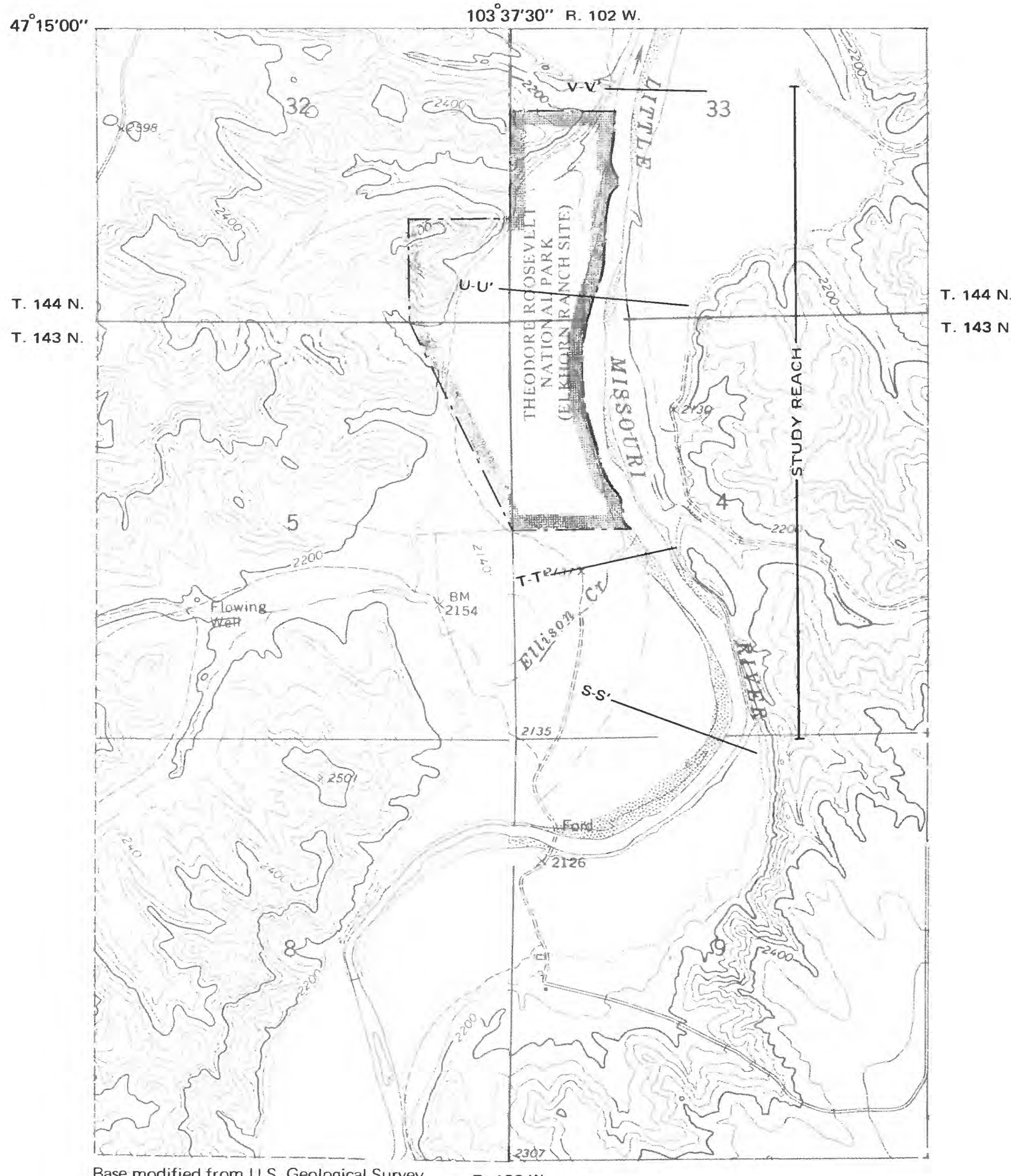
CONTOUR INTERVAL 65.6 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

EXPLANATION

G-G' ——— CROSS SECTION

—·——·— PARK BOUNDARY

Figure 2.—South Unit study reach and location of cross sections A-A' through R-R'.



Base modified from U.S. Geological Survey
Roosevelt Creek West, 1974
Roosevelt Creek East, 1970

0 1/4 1/2 1 MILE

0 1/4 1/2 1 KILOMETER

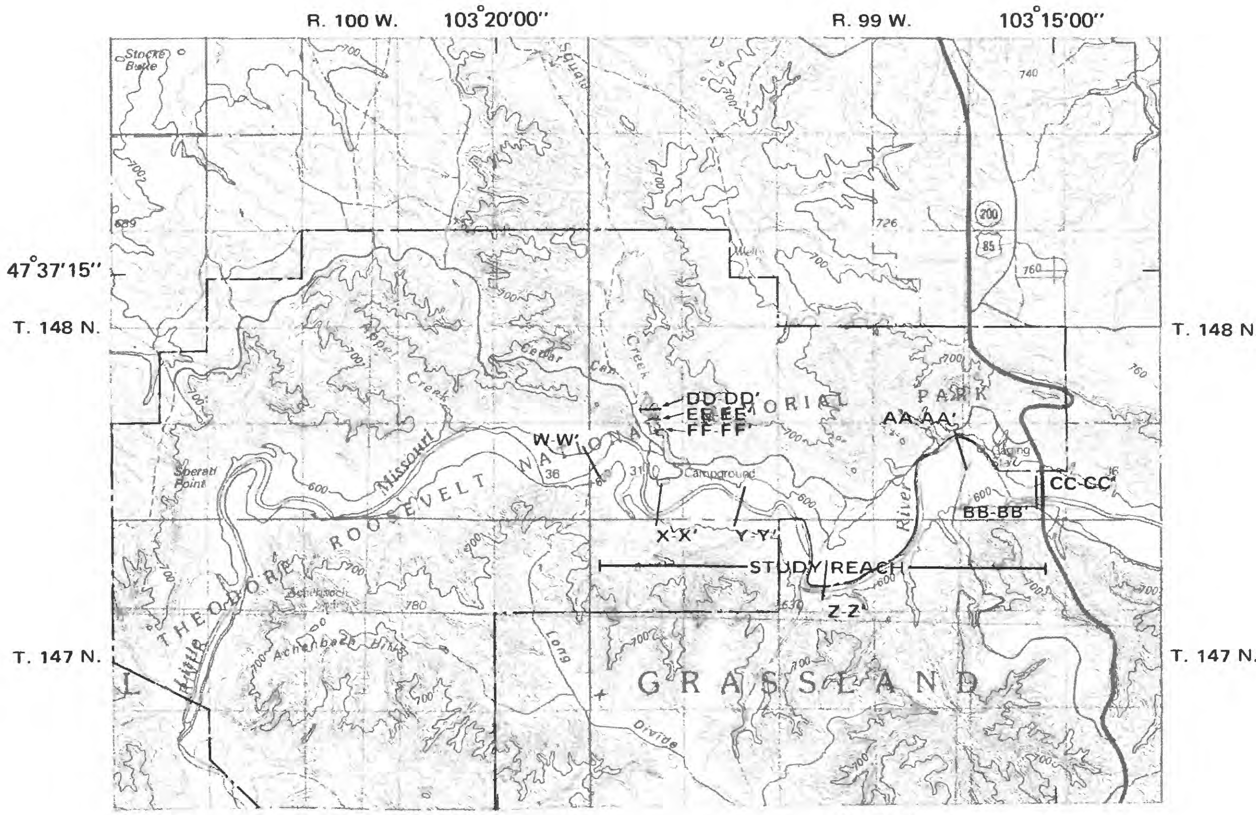
CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

EXPLANATION

S-S' ———— CROSS SECTION

—·——·— PARK BOUNDARY

Figure 3.—Elkhorn Ranch Site study reach and location of cross sections S-S'.through V-V'.



Base modified from
U.S. Geological Survey
Watford City, 1982

0 1 2 3 MILES
0 1 2 3 KILOMETERS

CONTOUR INTERVAL 65.6 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

EXPLANATION

W-W' ———— CROSS SECTION

—·———·— PARK BOUNDARY

Figure 4.—North Unit study reach and location of cross sections W-W' through FF-FF'.

Table 1.--*Annual peak discharges and annual maximum water-surface elevations for the streamflow station Little Missouri River at Medora (06336000)*

Date	Peak discharge (cubic feet per second)	Maximum water-surface elevation (feet above sea level)
June 9, 1904	11,600	2,257.95
July 2, 1905	8,500	2,256.95
June 8, 1906	13,900	2,258.75
June 24, 1907	29,000	2,262.75
June 6, 1908	10,800	2,257.45
May 31, 1909	12,400	2,258.25
Mar. 16, 1910	7,550	2,256.25
May 17, 1911	5,540	2,255.35
July 8, 1912	5,750	2,255.45
Apr. 3, 1914	1,850	2,253.05
June 16, 1915	24,700	2,260.75
Mar. 16, 1916	6,630	2,255.85
Apr. 4, 1924	18,500	2,260.55
June 7, 1929	38,700	2,263.95
Feb. 25, 1930	--	2,255.15
Sept. 13, 1930	4,700	--
June 22, 1931	1,610	2,251.27
Apr. 28, 1932	12,500	2,256.41
May 24, 1933	20,800	2,259.19
June 12, 1934	1,850	2,251.25
June 24, 1946	9,310	2,255.50
Mar. 23, 1947	65,000	2,267.25
Mar. 23, 1948	24,100	2,260.25
Mar. 21, 1949	--	2,259.75
Mar. 27, 1949	14,600	--
Apr. 8, 1950	25,600	2,259.75
Mar. 22, 1951	5,200	2,255.75
Apr. 1, 1952	--	2,265.10
Apr. 8, 1952	42,500	--
June 21, 1953	8,820	2,254.96

Table 1.--*Annual peak discharges and annual maximum water-surface elevations for the streamflow station Little Missouri River at Medora (06336000)*--Continued

Date	Peak discharge (cubic feet per second)	Maximum water-surface elevation (feet above sea level)
Apr. 7, 1954	4,320	2,252.74
June 27, 1955	25,600	2,260.65
Mar. 20, 1956	--	2,251.51
Mar. 27, 1956	2,030	--
June 22, 1957	7,900	2,254.20
July 4, 1958	5,050	2,252.65
Mar. 20, 1959	6,650	2,254.22
Mar. 22, 1960	8,100	2,255.47
May 24, 1961	3,540	2,251.97
May 30, 1962	10,800	2,256.60
Mar. 3, 1963	11,000	2,261.05
June 10, 1964	9,170	2,255.86
Apr. 3, 1965	15,000	2,259.30
Mar. 14, 1966	6,800	2,254.73
May 11, 1967	15,700	2,258.48
Mar. 7, 1968	3,000	2,252.10
Mar. 23, 1969	11,200	2,256.75
May 9, 1970	6,550	2,254.06
June 6, 1971	21,200	2,259.57
Mar. 11, 1972	40,000	2,265.43
Mar. 1, 1973	--	2,254.45
June 20, 1973	3,820	--
May 21, 1974	5,230	2,253.65
May 9, 1975	22,800	2,260.75
June 21, 1976	6,000	2,253.81

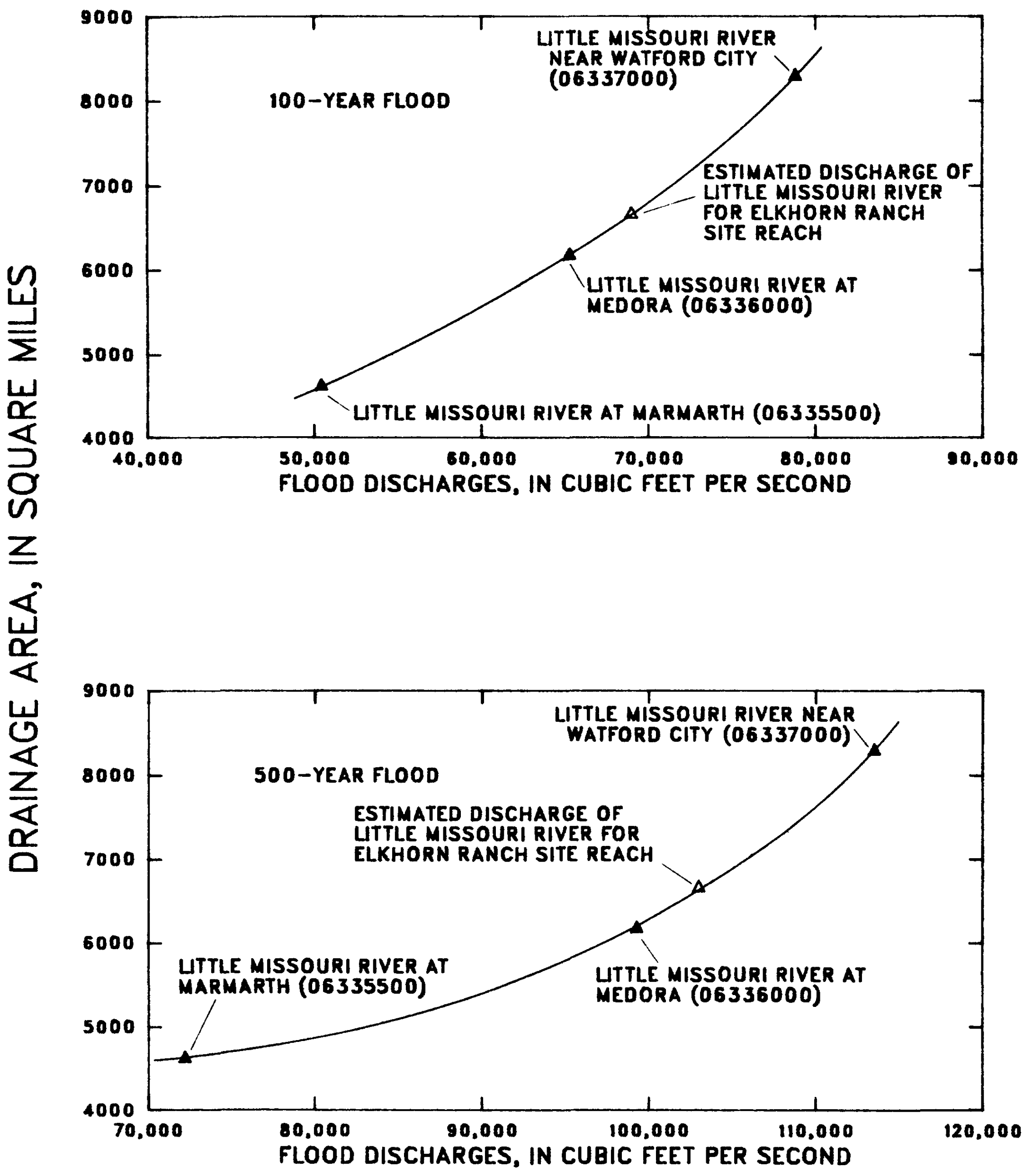


Figure 5.—Relation between the 100- and 500-year flood discharges and drainage area for the Little Missouri River.

Table 2.--*Annual peak discharges and annual maximum water-surface elevations for the streamflow station Little Missouri River near Watford City (06337000)*

Date	Peak discharge (cubic feet per second)	Maximum water-surface elevation (feet above sea level)
July 11, 1935	20,500	1,939.63
Mar. 10, 1936	8,800	1,937.03
June 15, 1937	8,990	1,936.88
Mar. 15, 1938	14,600	1,938.43
Mar. 22, 1939	26,500	1,942.08
Sept. 23, 1940	4,270	1,935.86
June 11, 1941	13,000	1,938.03
Mar. 11, 1942	12,600	1,938.62
Feb. 22, 1943	25,000	1,947.03
Apr. 8, 1944	32,600	1,943.43
Mar. 14, 1945	30,000	1,943.43
Feb. 24, 1946	8,000	1,937.78
Mar. 25, 1947	110,000	1,953.03
Mar. 17, 1948	--	1,943.63
Mar. 24, 1948	16,000	--
Mar. 28, 1949	26,000	1,942.73
Apr. 9, 1950	60,000	1,950.45
Mar. 25, 1951	--	1,942.97
Mar. 27, 1951	18,000	--
Apr. 10, 1952	42,000	1,944.56
Mar. 25, 1953	--	1,937.58
June 22, 1953	7,650	--
June 14, 1954	10,200	1,937.40
June 28, 1955	17,600	1,938.99
July 30, 1956	2,770	1,935.03
June 23, 1957	6,890	1,936.83
Mar. 25, 1958	12,000	1,938.97
Mar. 20, 1959	12,800	1,939.16
Mar. 22, 1960	18,900	1,938.86
May 24, 1961	2,920	1,932.79

Table 2.--*Annual peak discharges and annual maximum water-surface elevations for the streamflow station Little Missouri River near Watford City (06337000)*--Continued

Date	Peak discharge (cubic feet per second)	Maximum water-surface elevation (feet above sea level)
May 31, 1962	12,100	1,935.74
Mar. 5, 1963	10,000	1,938.93
July 5, 1964	12,000	1,936.85
Apr. 8, 1965	--	1,946.96
Apr. 10, 1965	20,000	--
Mar. 12, 1966	12,000	1,936.36
Mar. 22, 1967	30,000	1,945.10
Mar. 1, 1968	7,900	1,935.41
Mar. 23, 1969	15,300	1,937.07
May 9, 1970	13,400	1,936.33
Mar. 28, 1971	31,000	1,944.30
Mar. 13, 1972	52,800	1,943.71
Feb. 28, 1973	7,500	1,935.45
Feb. 2, 1974	--	1,935.33
May 21, 1974	6,750	--
May 11, 1975	17,500	1,937.43
Mar. 19, 1976	--	1,938.42
June 24, 1976	7,600	--
June 17, 1977	6,400	1,934.43
Mar. 30, 1978	31,500	1,940.11
Mar. 18, 1979	--	1,935.70
Apr. 17, 1979	10,000	--
Mar. 23, 1980	--	1,932.84
June 14, 1980	865	--
Oct. 23, 1980	1,390	--
Feb. 18, 1981	--	1,933.31
Feb. 21, 1982	11,000	--
Mar. 13, 1982	--	1,942.06

the North Unit (fig. 4). The 100-year flood discharges were estimated using a multiple-regression equation based on drainage area and soil-infiltration index (O. A. Crosby, U.S. Geological Survey, written commun., 1984). The equation,

$$Q_{100} = 927A^{0.65}Si^{-1.00},$$

where Q_{100} = the 100-year flood discharge, in cubic feet per second;
A = the drainage area, in square miles; and
Si = the soil infiltration index, in inches;
is based on 47 streamflow stations with most of the stations having 18 years of record. The average standard error of estimate is 98 percent.

A summation of the 100- and 500-year flood discharges for the Little Missouri River and the 100-year flood discharges for the three creeks is listed in table 3. The 100-year flood discharges on the Little Missouri River range from 65,300 to 78,800 ft^3/s, whereas the 500-year flood discharges range from 99,300 to 113,500 ft^3/s. The 100-year flood discharges on the three creeks range from 18,500 to 31,800 ft^3/s.

FLOOD PROFILES

The water-surface profiles for the flood discharges listed in table 3 for the various reaches were computed using the U.S. Geological Survey's E431 program (Shearman, 1976). The program computes water-surface profiles for gradually varied, subcritical flow by the step-backwater method. The computations that were used to define water-surface elevations are based on hydraulic equations that depend on the following assumptions: (1) Stream discharge remains constant in the subreach defined by the two cross sections; (2) the flow regime in the subreach is entirely critical, critical and subcritical, or subcritical; (3) the longitudinal water-surface and channel slopes are small enough that normal depths and vertical depths may be considered equal; (4) the water surface is level across each individual cross section; (5) effects from sediment and air entrainment are negligible; and (6) all losses are correctly evaluated.

Starting elevations for downstream ends of the South Unit reach, the Elkhorn Ranch Site reach, and the three creeks were obtained using a slope-conveyance technique together with computed 100- or 500-year discharges or both discharges. The starting elevations for the downstream end of the North Unit reach were obtained using the relationship between elevation and discharge for the streamflow station Little Missouri near Watford City (06337000), which is located at the downstream end of the North Unit reach. Gradually varied flow does not exist where the creeks enter the Little Missouri River flood plain. Because of this, the flood profile for the creeks cannot be computed using this method for the area within the Little Missouri River flood plain. The computed flood profiles for the three creeks are for reaches upstream of the Little Missouri flood plain.

Roughness coefficients (Mannings "n") used in the computations were chosen from experience and by using results of coefficient-verification studies by Barnes (1967). Limited cross-sectional data were obtained from field surveys.

Table 3.--*Flood discharges for selected reaches*

Reach	Recurrence interval (years)	Probability (percent)	Discharge (cubic feet per second)
Little Missouri River South Unit	100	1	65,300
	500	0.2	99,300
Little Missouri River Elkhorn Ranch Site	100	1	69,000
	500	0.2	103,000
Little Missouri River North Unit	100	1	78,800
	500	0.2	113,500
Knutson Creek	100	1	31,800
Paddock Creek	100	1	18,500
Squaw Creek	100	1	24,600

The locations of the field-surveyed cross sections are shown in figures 2-4. These cross sections and computed water-surface elevations for the various reaches are shown in figures 6-11. Limited resources dictated the number of field-surveyed cross sections. Additional intermediate cross sections required for computational purposes were synthesized from the field-surveyed data and topographic maps. The average velocities for the 100-year flood for the Little Missouri River are about 4.8 ft/s for the South Unit reach, 4.9 ft/s for the Elkhorn Ranch Site reach, and 3.6 ft/s for the North Unit reach. The average velocities for the 500-year flood are about 0.2 ft/s higher than the average velocities for the 100-year flood. The average velocities for the 100-year floods on the three creeks are about 7.8 ft/s for Knutson Creek, 4.6 ft/s for Paddock Creek, and 6.6 ft/s for Squaw Creek. The flood profiles of the various reaches are shown in figures 12-17. The average water-surface slope for the floods on the Little Missouri River is about 0.0005 ft/ft, and the difference between the 100- and 500-year flood elevations averages about 3.5 ft.

ICE JAMS

"An ice jam may be defined as an accumulation of ice in a stream which reduces the cross sectional area available to carry the flow and increase the water-surface elevation. The accumulation of ice is usually initiated at a natural or manmade obstruction or a relatively sudden change in channel slope, alignment, or cross section shape or depth. In northern regions of the United States, where rivers can develop relatively thick ice covers during the winter, ice jamming can contribute significantly to flood hazards. When historical records are examined, ice jams are typically found to occur in the same locations. This is because the necessary conditions for genesis of an adequate ice supply and obstruction of its downstream transport determine the specific areas where ice jams will occur." (Federal Emergency Management Agency, 1982, p. A 3-1).

An analysis of ice jams is subjective. The Little Missouri River at Medora (06336000) and the Little Missouri River near Watford City (06337000) are the only streamflow stations having data available for analysis. The backwater due to ice versus the water-surface elevations for discharge measurements was plotted for these two stations (fig. 18). All discharge measurements for the Little Missouri River at Medora (06336000) were used to develop a maximum observed backwater envelope curve. Cross section C-C' of the Little Missouri River, South Unit reach, is located at this site. From September 1934 to October 1959, the streamflow station Little Missouri River near Watford City (06337000) was located about 1 mi upstream from its present location. Only the measurements made during that period were used to develop a maximum observed backwater envelope curve. Cross section AA-AA' of the Little Missouri River, North Unit reach, is located about 200 ft upstream from this site. A maximum observed backwater envelope curve was not developed for the present streamflow-station location because of the lack of high-flow measurements.

Although the curves represent only maximum observed backwater and the number of measurements decreases at higher flows, the curves represent a trend

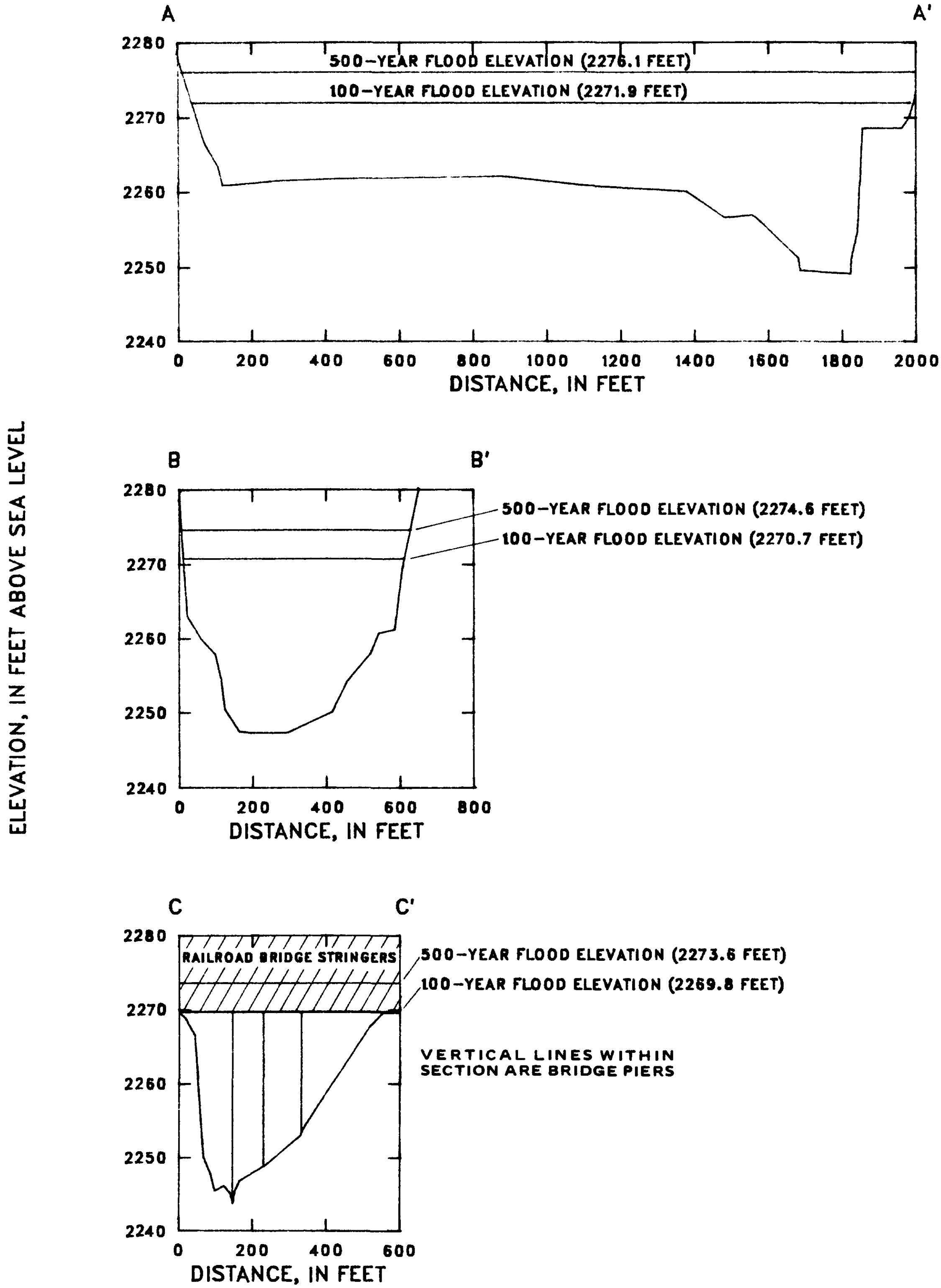


Figure 6.—Cross sections A-A' through L-L' and water-surface elevations for 100- and 500-year floods, Little Missouri River, South Unit reach.

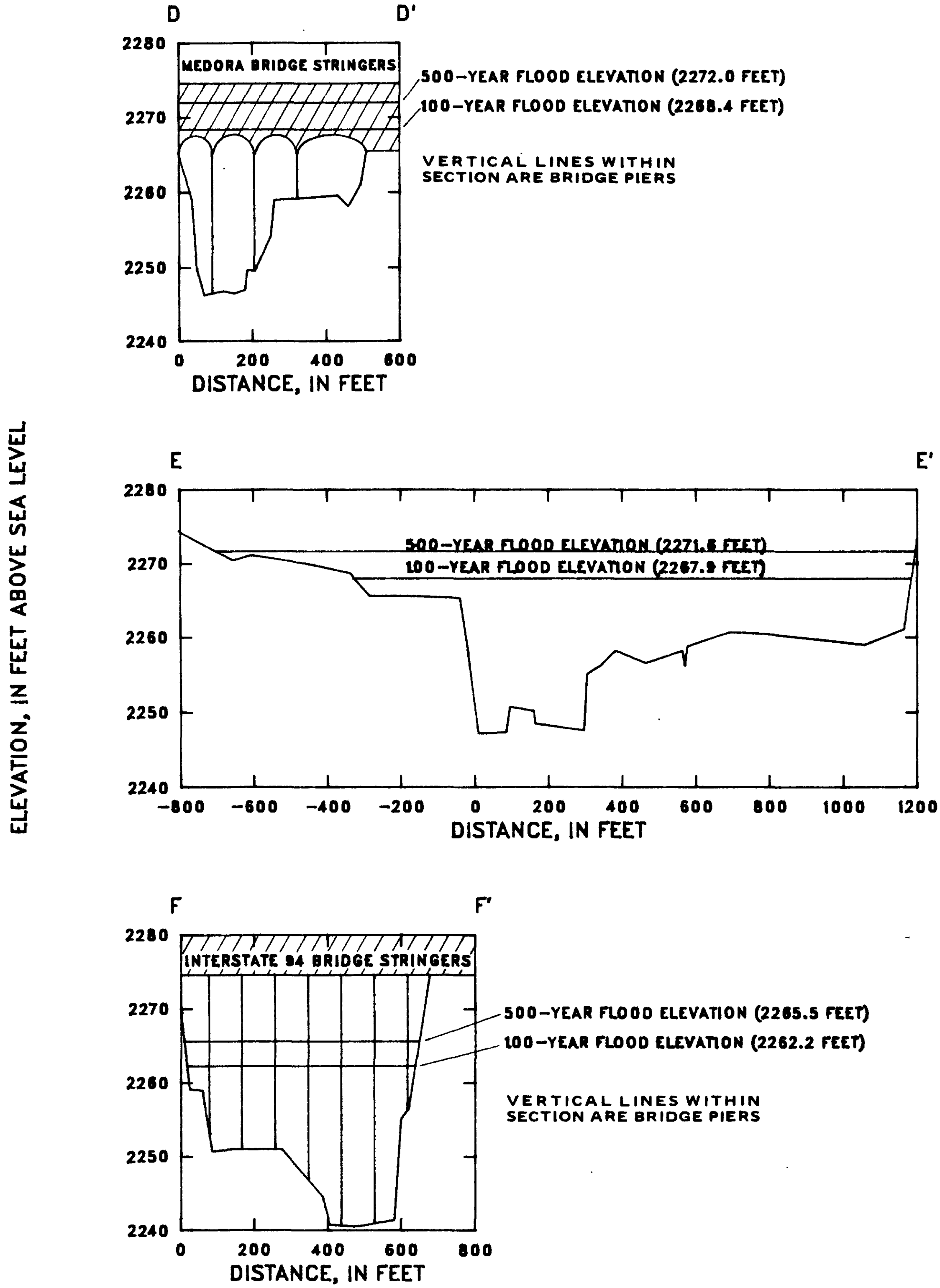


Figure 6.—Cross sections A-A' through L-L' and water-surface elevations for 100- and 500-year floods, Little Missouri River, South Unit reach—Continued.

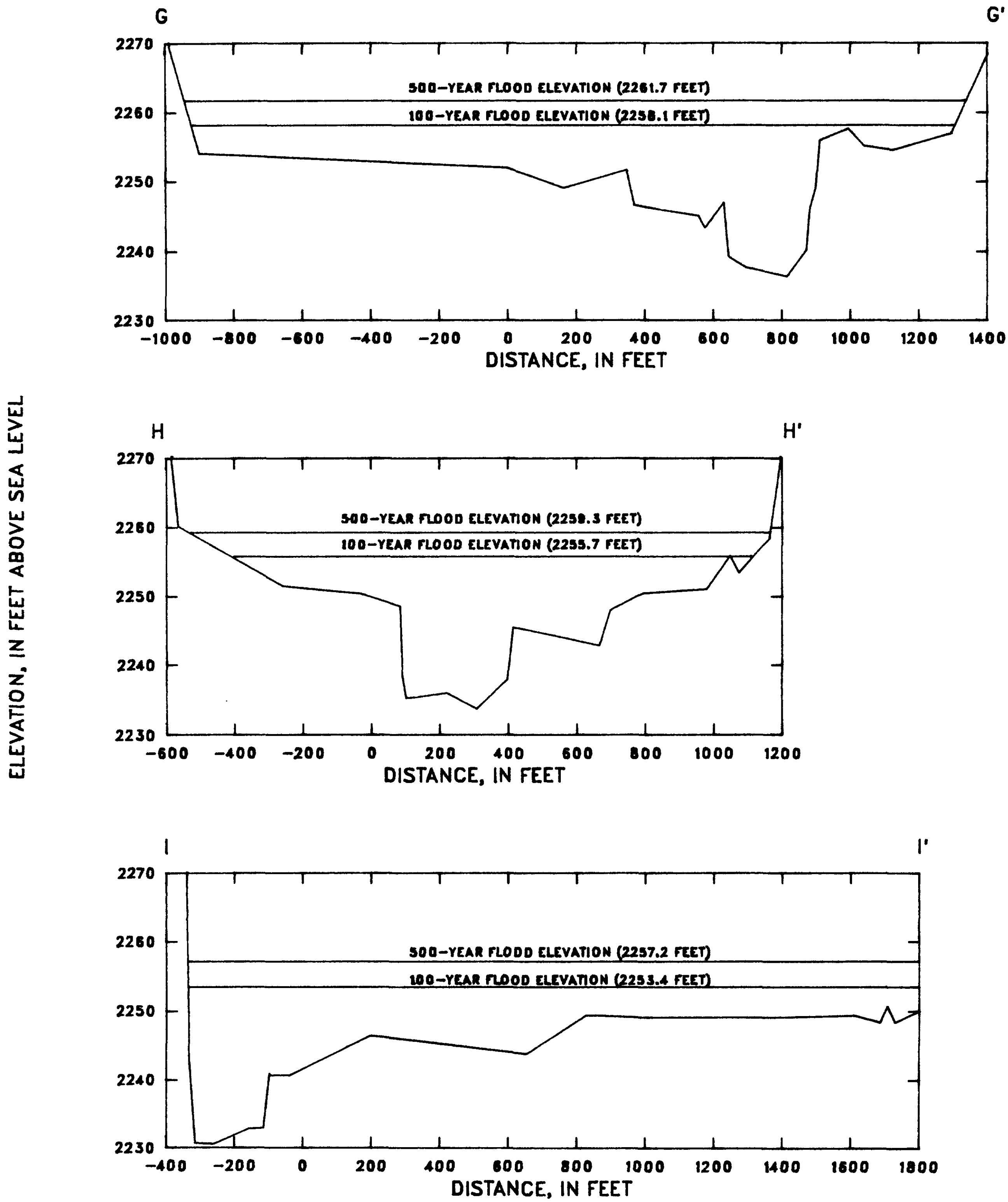


Figure 6.—Cross sections A-A′ through L-L′ and water-surface elevations for 100- and 500-year floods, Little Missouri River, South Unit reach—Continued.

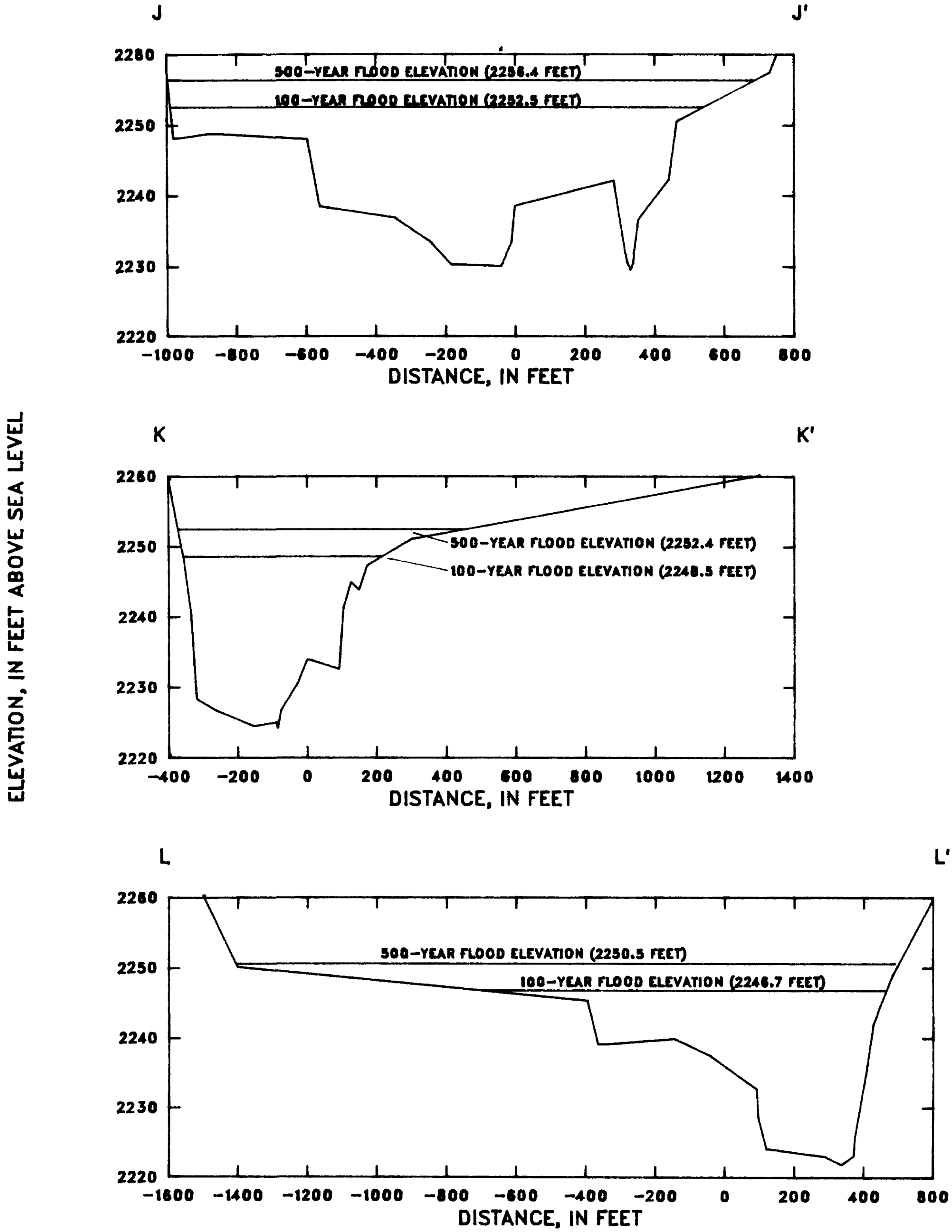


Figure 6.—Cross sections A-A′ through L-L′ and water-surface elevations for 100- and 500-year floods, Little Missouri River, South Unit reach—Continued.

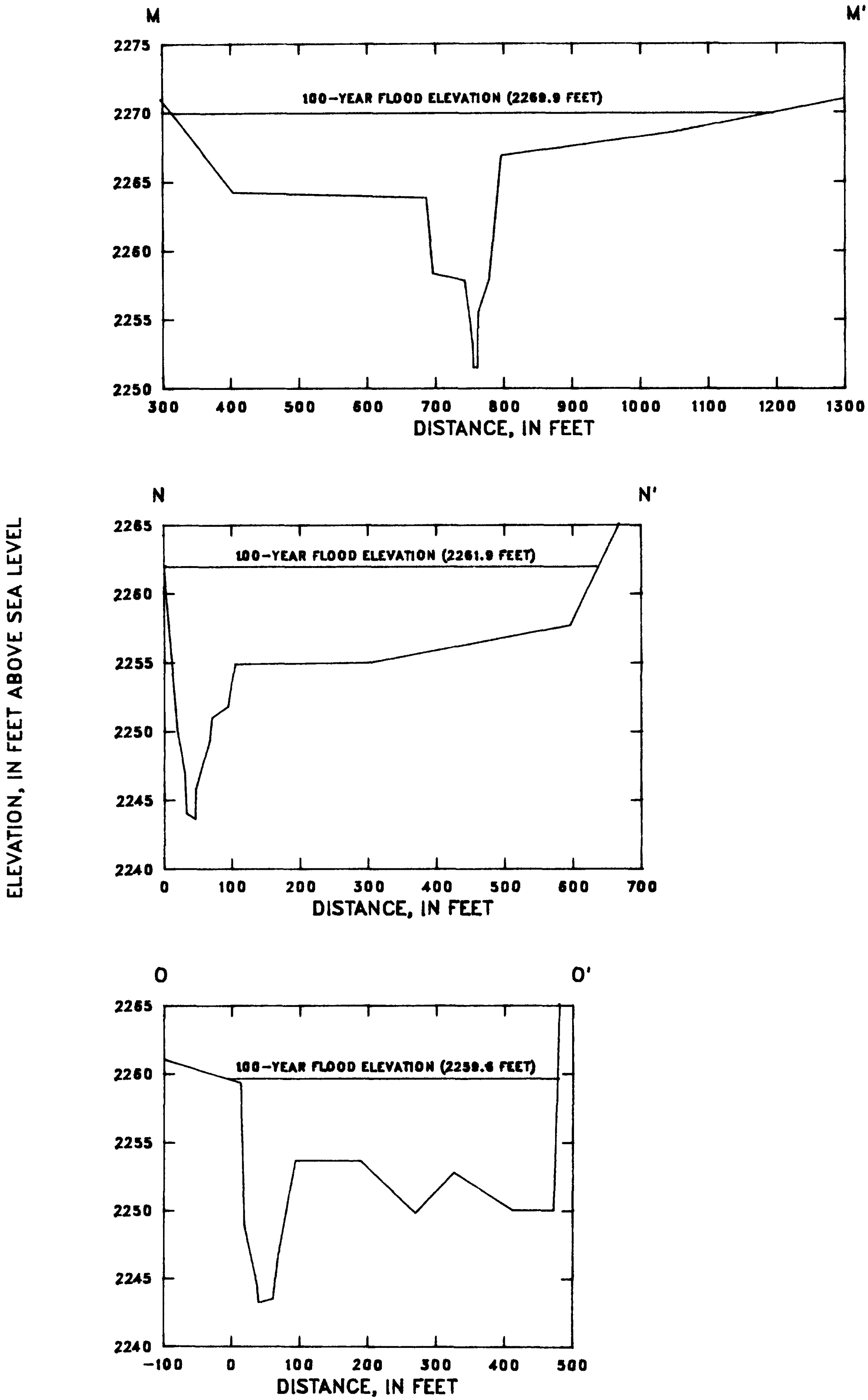


Figure 7.—Cross sections M-M′ through O-O′ and water-surface elevations for 100-year flood, Knutson Creek reach.

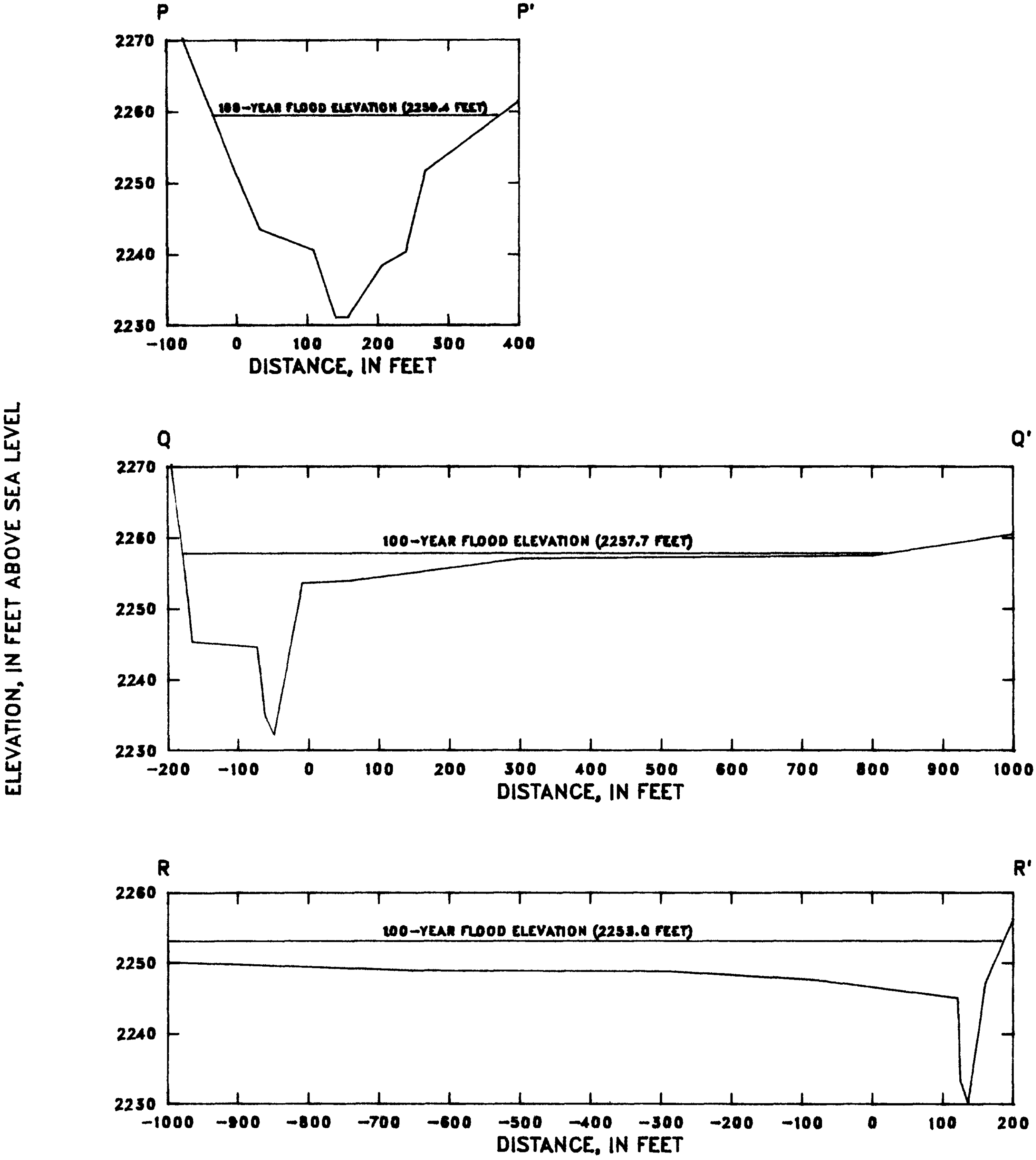


Figure 8.—Cross sections P-P′ through R-R′ and water-surface elevations for 100-year flood, Paddock Creek reach.

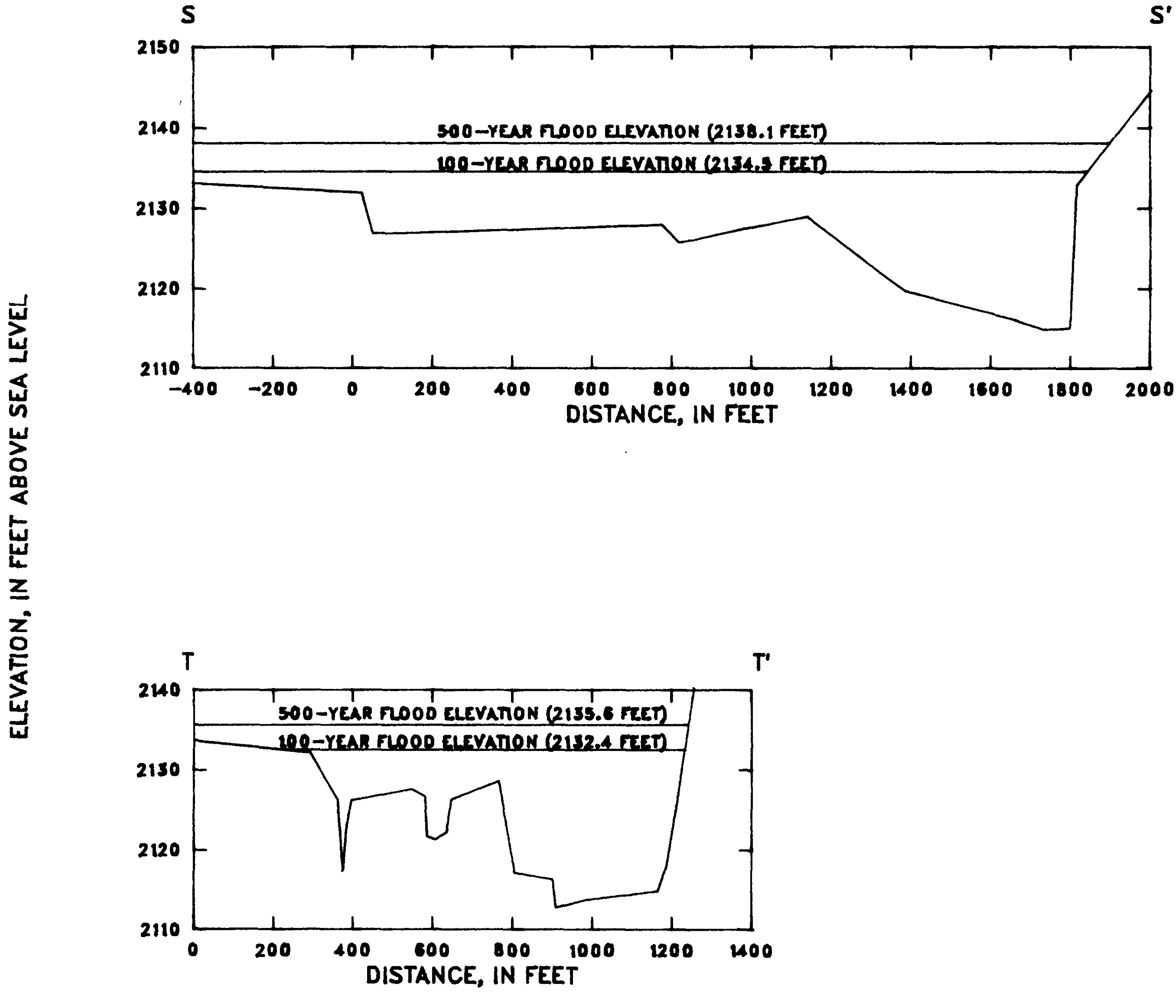


Figure 9.—Cross sections S-S' through V-V' and water-surface elevations for 100- and 500-year floods, Little Missouri River, Elkhorn Ranch Site reach.

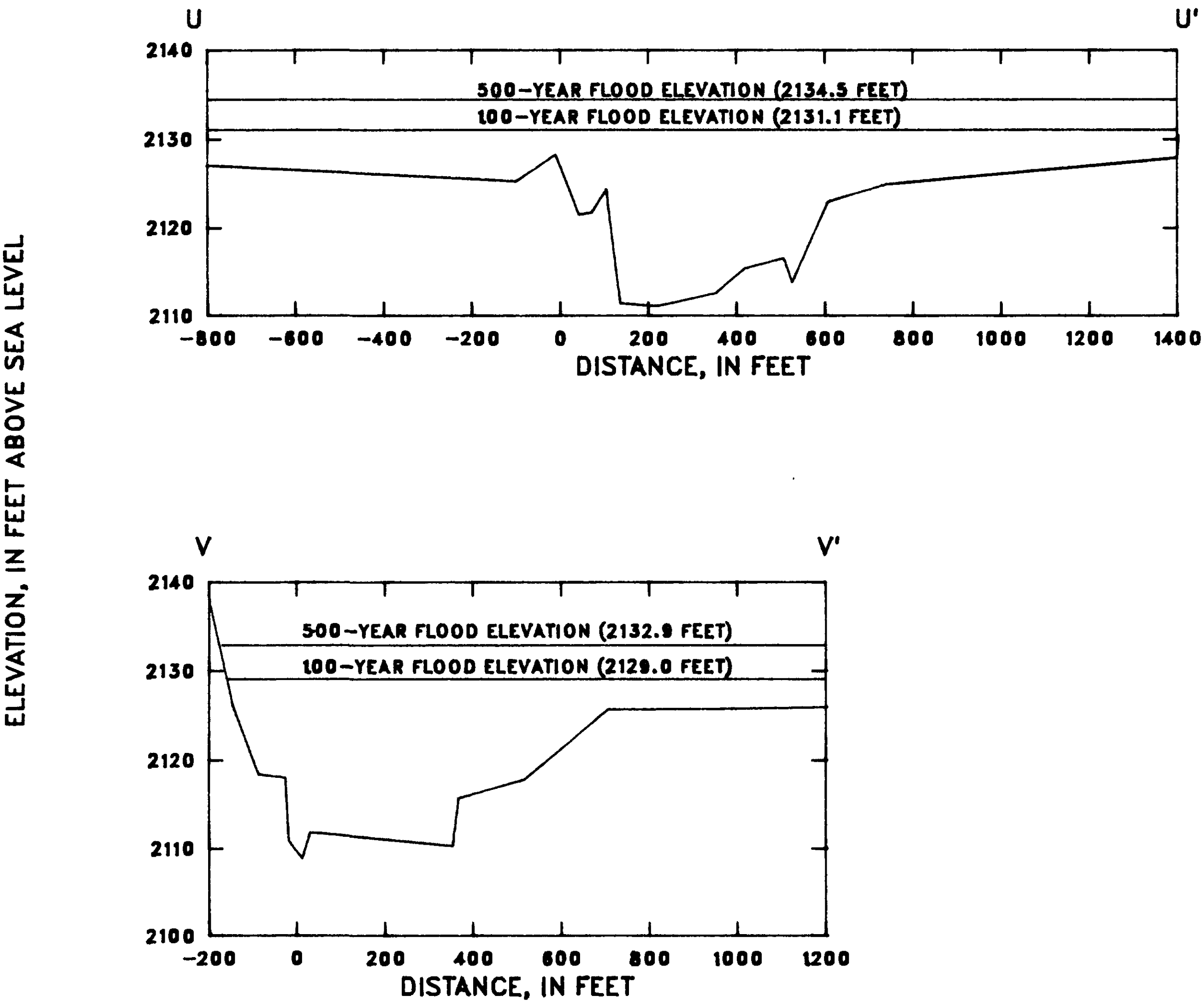


Figure 9.—Cross sections S-S' through V-V' and water-surface elevations for 100- and 500-year floods, Little Missouri River, Elkhorn Ranch Site reach—Continued.

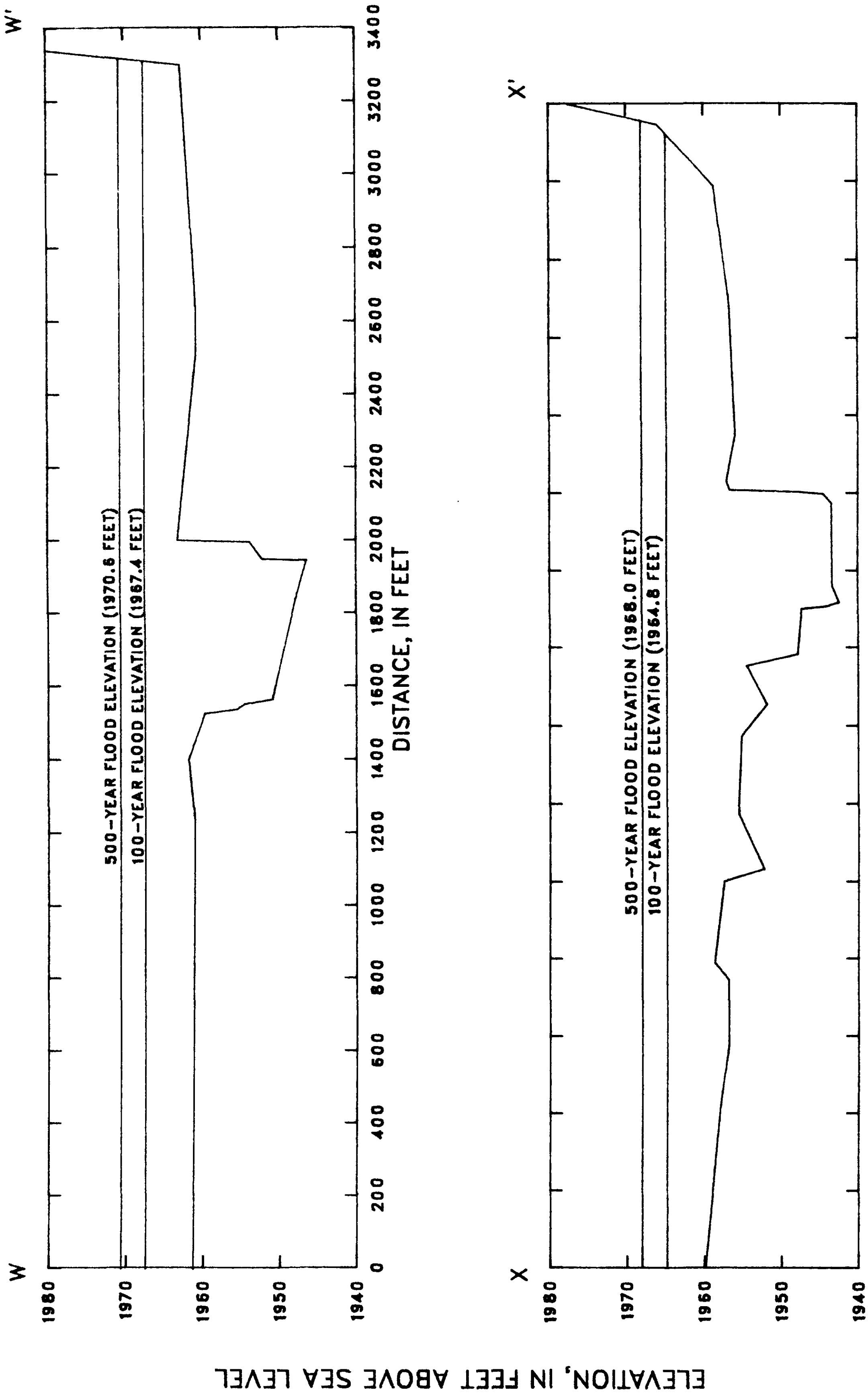


Figure 10.—Cross sections W-W' through CC-CC' and water-surface elevations for 100- and 500-year floods, Little Missouri River, North Unit reach.

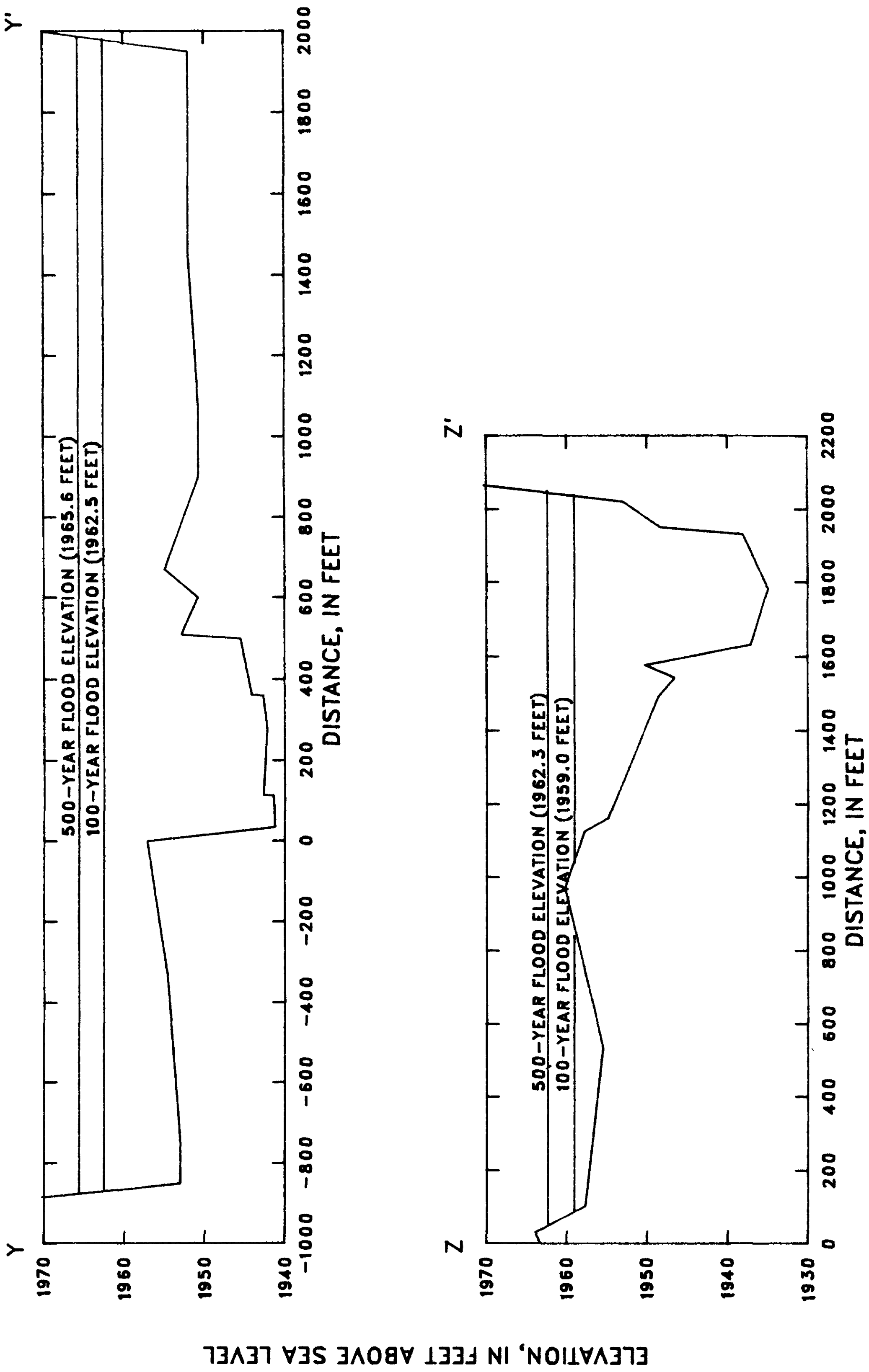


Figure 10.—Cross sections W-W' through CC-CC' and water-surface elevations for 100- and 500-year floods, Little Missouri River, North Unit reach—Continued.

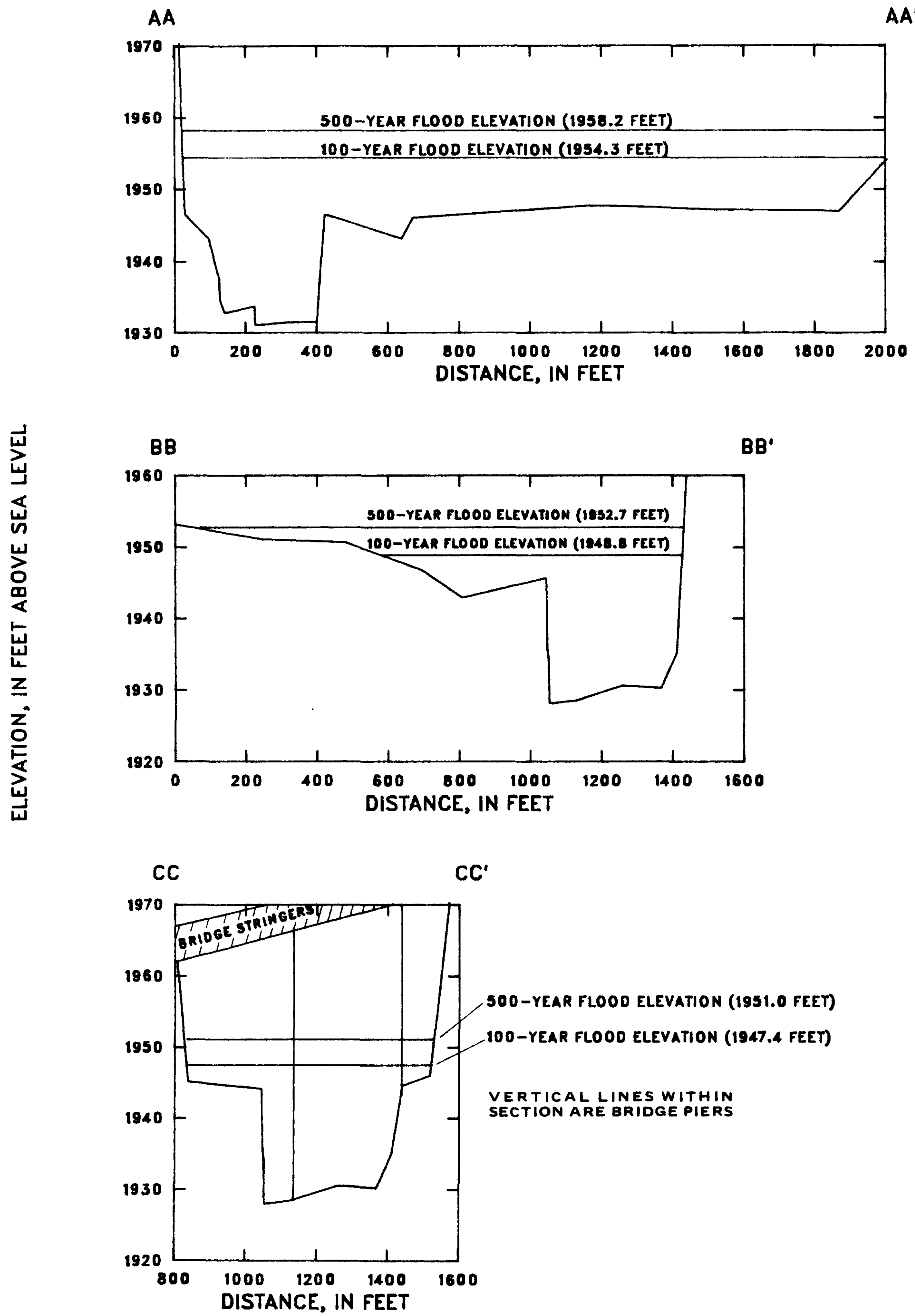


Figure 10.—Cross sections W-W' through CC-CC' and water-surface elevations for 100- and 500-year floods, Little Missouri River, North Unit reach—Continued.

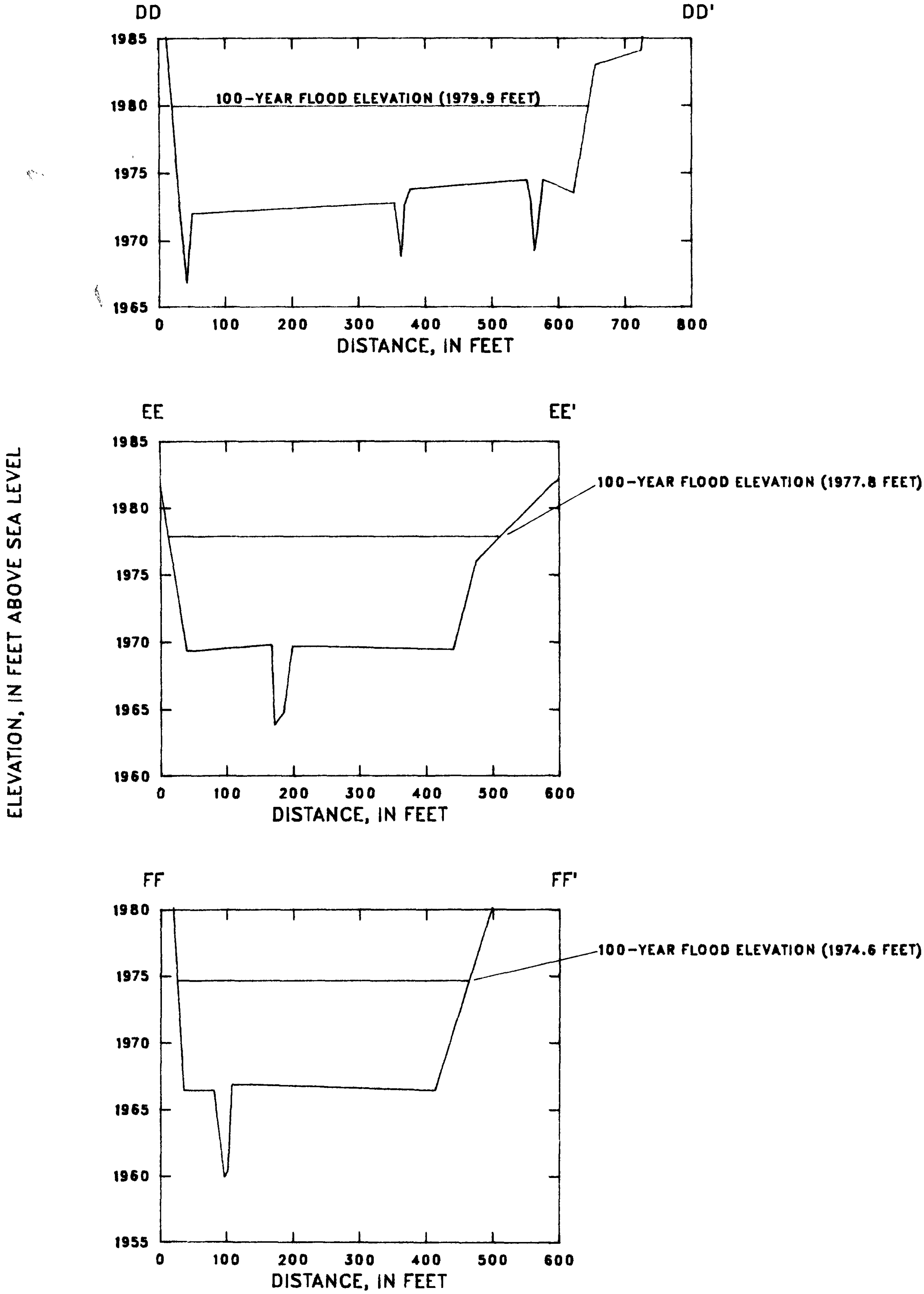


Figure 11.—Cross sections DD-DD′ through FF-FF′ and water-surface elevations for 100-year flood, Squaw Creek reach.

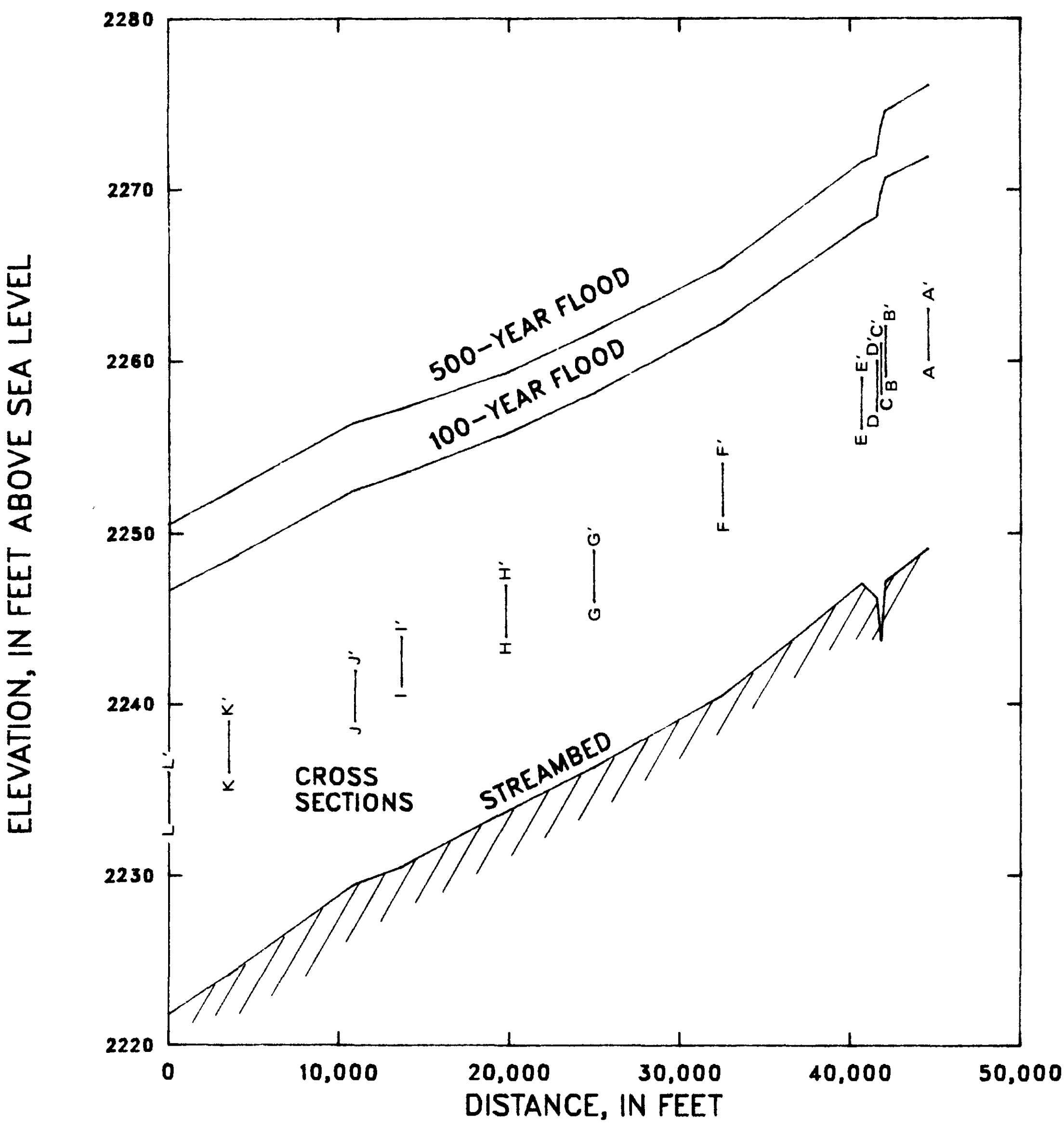


Figure 12.—Profiles for 100- and 500-year floods and streambed, Little Missouri River, South Unit reach.

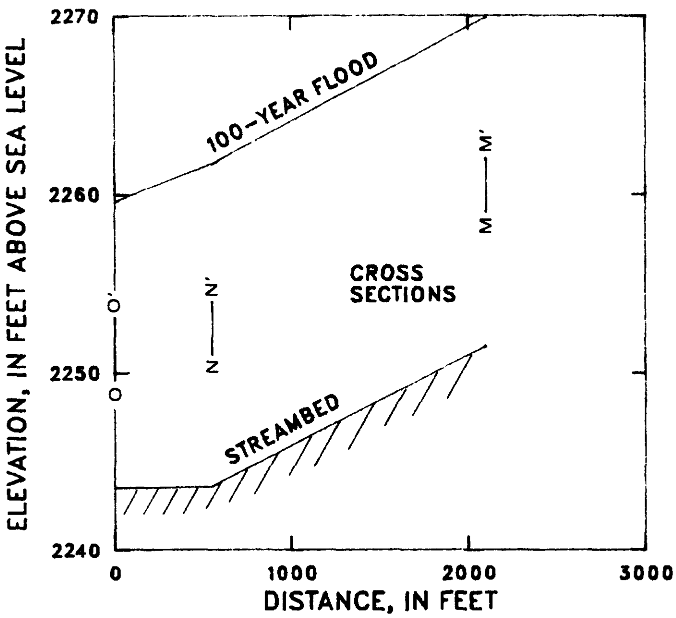


Figure 13.—Profiles for 100-year flood and streambed, Knutson Creek reach.

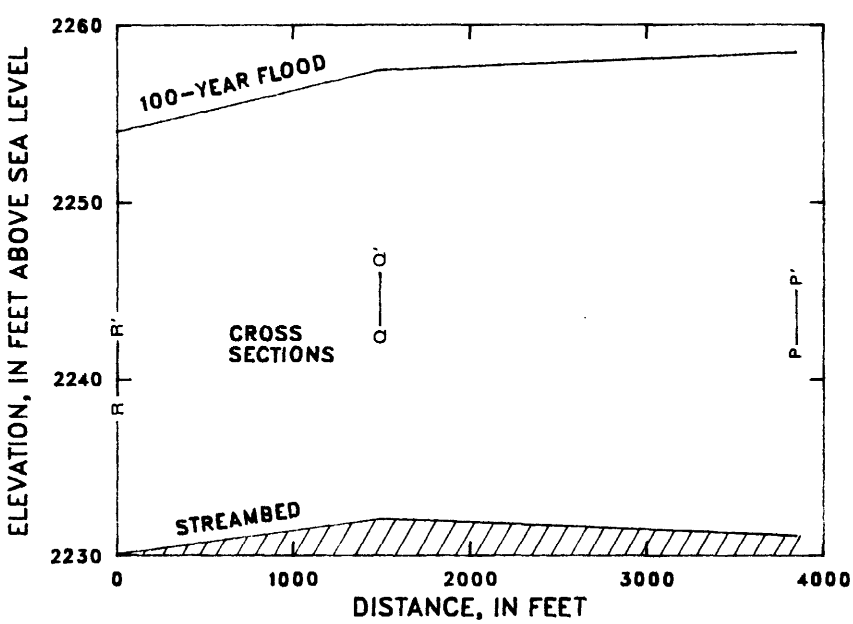


Figure 14.—Profiles for 100-year flood and streambed, Paddock Creek reach.

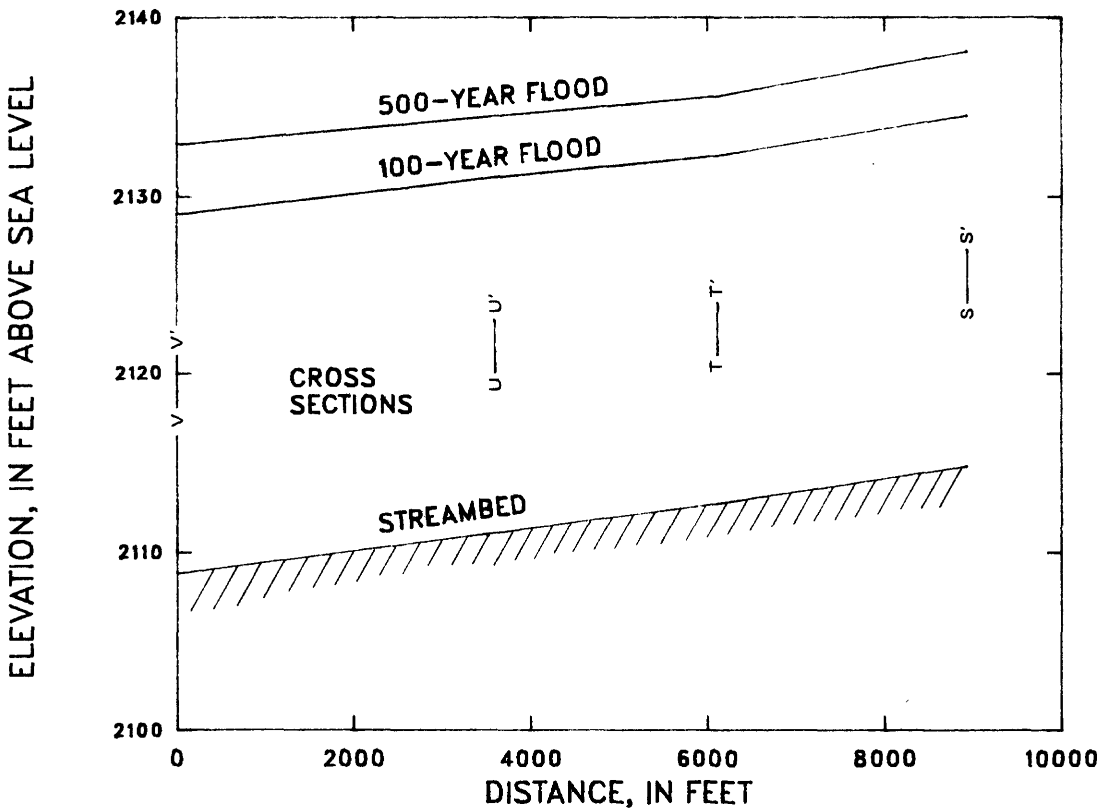


Figure 15.—Profiles for 100- and 500-year floods and streambed, Little Missouri River, Elkhorn Ranch Site reach.

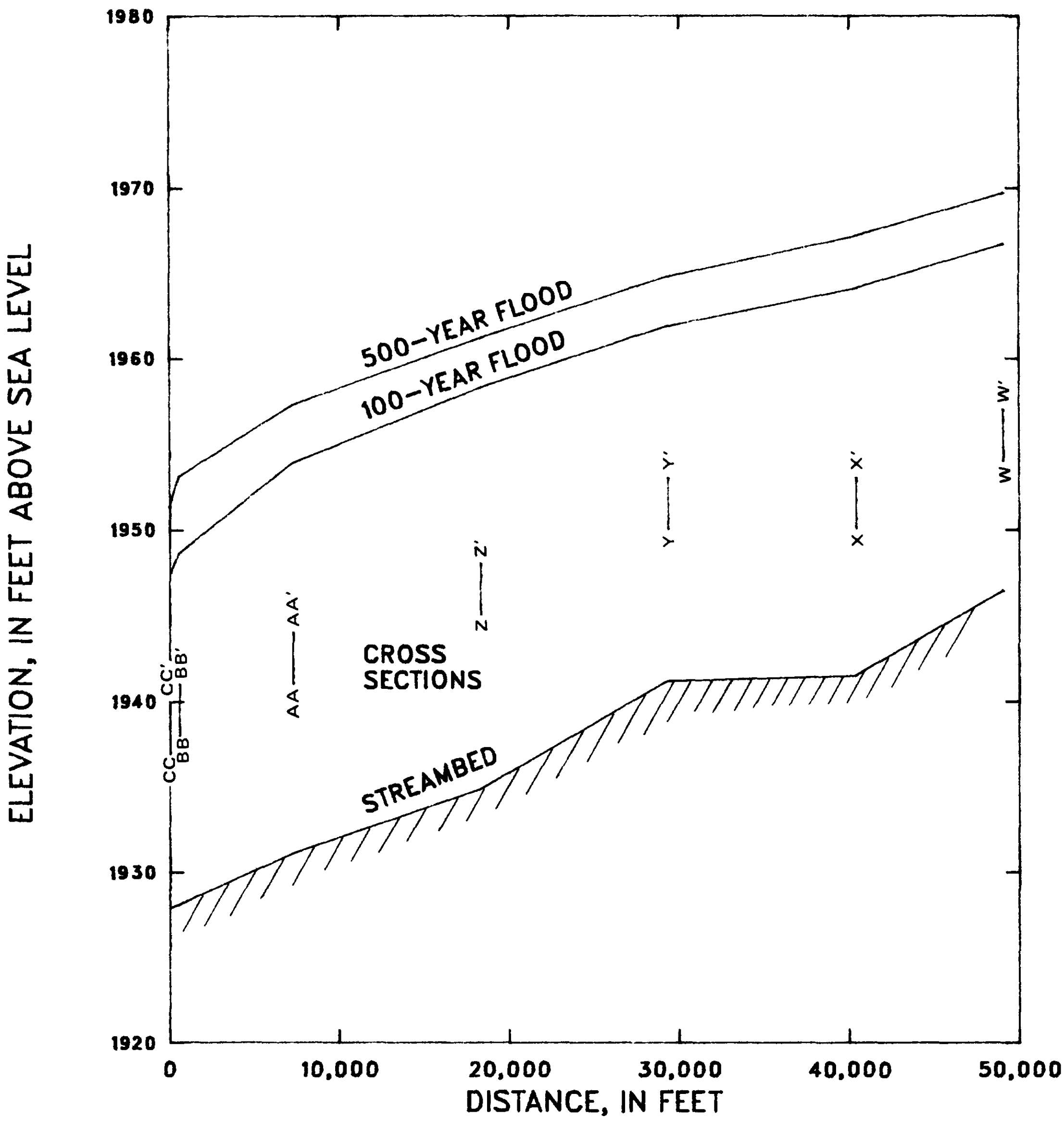


Figure 16.—Profiles for 100- and 500-year floods and streambed, Little Missouri River, North Unit reach.

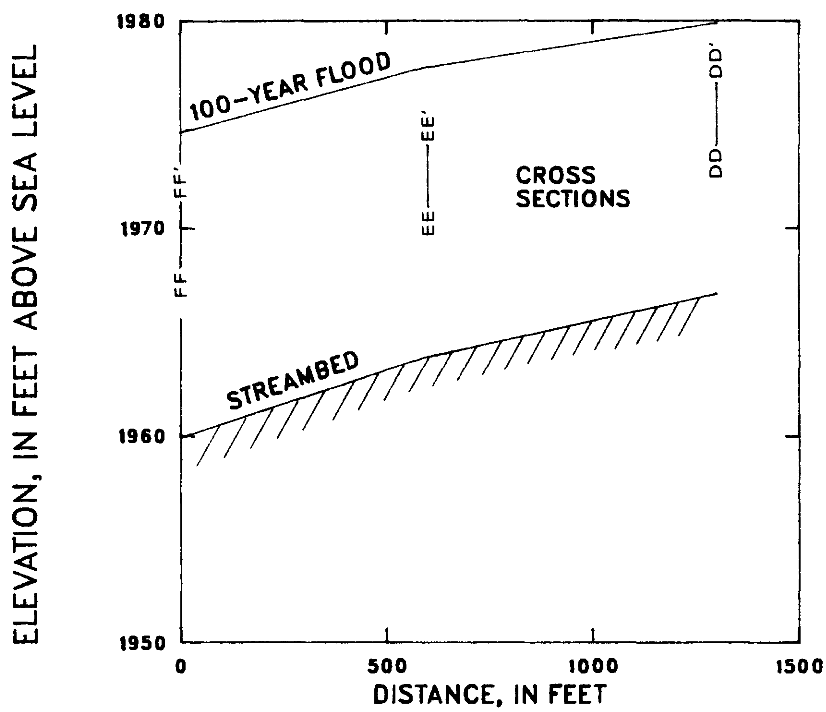


Figure 17.—Profiles for 100-year flood and streambed, Squaw Creek reach.

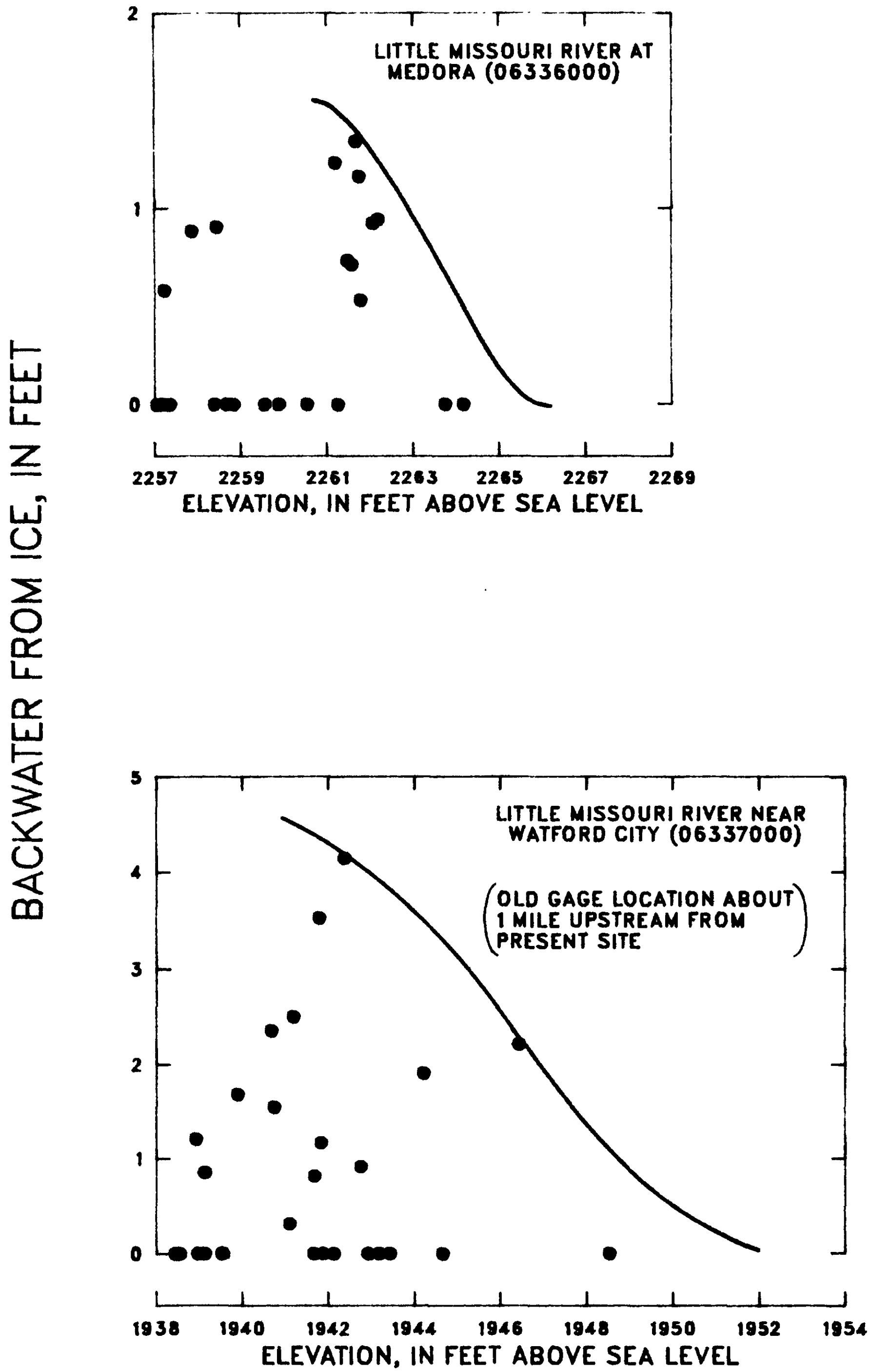


Figure 18.—Relation between backwater due to ice and water-surface elevations, and an envelope curve.

in which the backwater decreases as the discharge increases. For both streamflow stations, the backwater due to ice approaches zero before reaching the elevation computed in the step-backwater computations for the 100-year flood discharge.

The water-surface elevation of a flood causes the most concern whether or not the elevations are during an ice jam or free flow. Elevation frequencies for areas subject to ice-jam flooding can be based on the development of elevation-frequency relationships for two different populations (ice-jam flood elevations and free-flow flood elevations when adequate data are available). These relations can be combined into a single composite curve for flood elevation at a site under study. Because a combined frequency is needed, separating the annual maximum water-surface elevations into values for ice-jam and free-flow conditions, developing separate elevation frequencies, and then combining the two frequencies is not warranted. Therefore, a single elevation-frequency curve was developed by assigning Weibull plotting positions to both ice-jam and free-flow elevations and fitting a curve to these points on log-normal probability paper.

All of the annual maximum water-surface elevations (table 1) for the streamflow station Little Missouri River at Medora (06336000) were used to develop an elevation-frequency curve (fig. 19) for that site. Only the annual maximum water-surface elevations prior to October 1959 (table 2) for the streamflow station Little Missouri River near Watford City (06337000) were used to develop a curve (fig. 19) for that site. The Weibull plotting position was used to plot the elevations and the graphical method was used to fit a curve to the points. Caution must be exercised when comparing the elevations from the elevation-frequency curve to elevations associated with the flood discharges (figs. 6 and 10) because: (1) The graphical method requires no assumptions as to the type or characteristics of the distribution, and (2) only 20 years of elevation record were used to compute the elevation-frequency curve compared to 48 years of discharge record used to compute the discharge-frequency curve for the streamflow station Little Missouri River near Watford City (06337000). Because ice jams normally are location oriented, these ice-jam analyses apply to the specific location of the streamflow stations.

FLOOD-HAZARD ASSESSMENT

Flooding from the Little Missouri River and the three creeks causes a hazard to persons and property. The flood hazard of the Little Missouri River alone is very different from that of the three creeks. The Little Missouri River has a relatively large drainage basin and the threat of a flood may be known days in advance. The velocity of flood flows in the flood plain is considerably less than that in the main channel. In contrast, flooding from the three creeks most likely will be caused by intense, localized thunderstorms, and the threat of a flood may be known only hours in advance. The flood water will fill the flood plain of the creek and will flow at fast velocities. Once the flood water of a creek reaches the flood plain of the Little Missouri River, the water will spread out, reducing the velocities and depths.

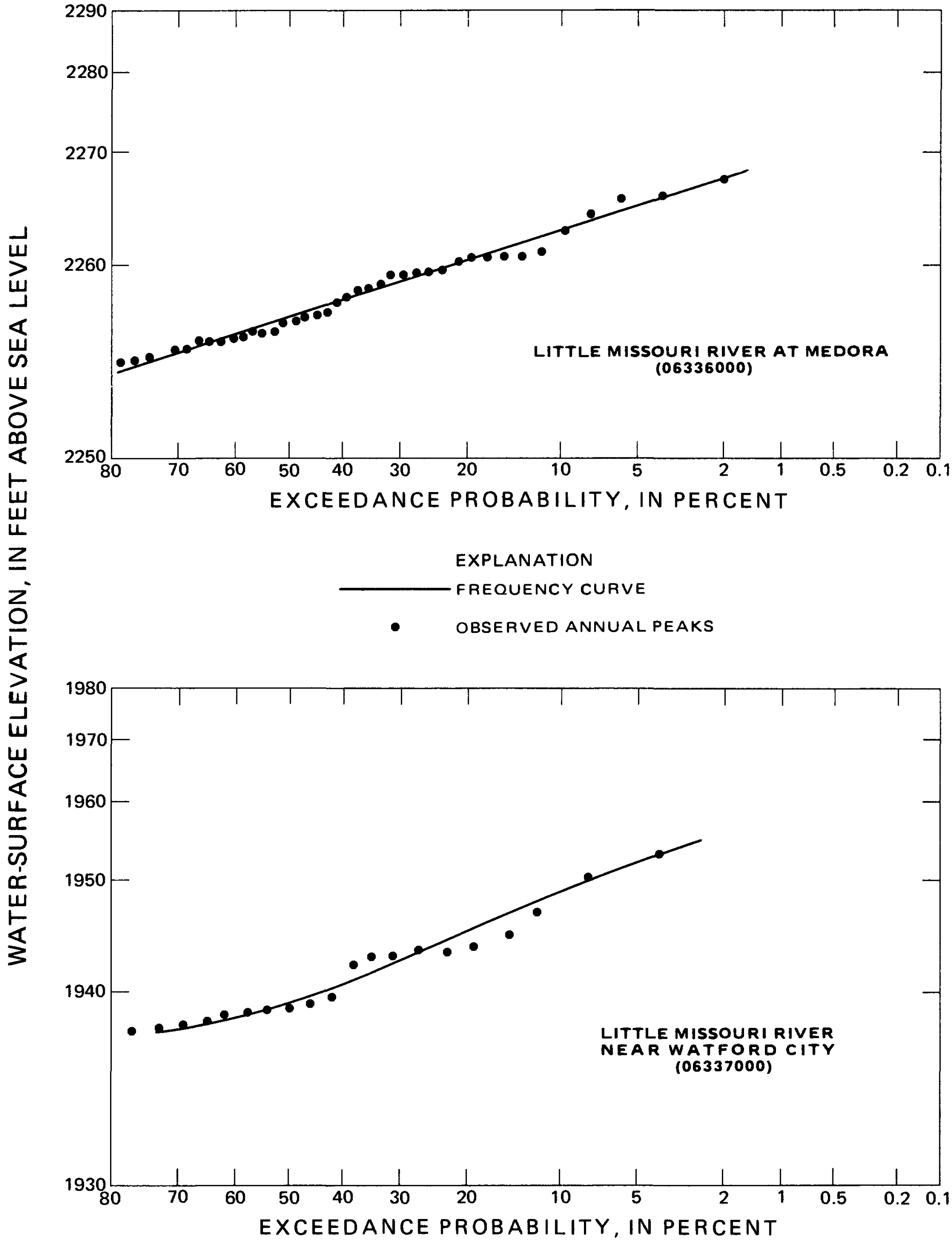


Figure 19.—Water-surface elevation-frequency curves.

SUMMARY

Flood analyses were performed on selected reaches along the Little Missouri River and its tributaries (Knutson, Paddock, and Squaw Creeks). Streamflow records were used in the flood flow frequency analysis for the Little Missouri River. The 100-year flood discharge determined for the Little Missouri River South Unit reach was 65,300 ft^3/s; the discharge determined for the Little Missouri River Elkhorn Ranch Site reach was 69,000 ft^3/s; and the discharge determined for the Little Missouri River North Unit reach was 78,800 ft^3/s. A multiple-regression equation based on drainage area and infiltration index was used in the flood flow frequency analysis for the creeks. The 100-year flood discharge determined for Knutson Creek reach was 31,800 ft^3/s; the discharge determined for Paddock Creek reach was 18,500 ft^3/s; and the discharge determined for Squaw Creek reach was 24,600 ft^3/s. Cross-sectional data were obtained by field surveys. Water-surface elevations were computed using step-backwater methods.

Streamflow records for two stations on the Little Missouri River were used to develop maximum observed backwater envelope curves and elevation frequency curves. The maximum observed backwater envelope curves show a trend in which the backwater decreases as the discharge increases. The backwater due to ice approaches zero before reaching the computed elevations for the 100-year discharges.

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