Omang, R.J., Water-surface profile and flood boundaries for the computed 100-year flood, Lame Deer Creek, Northern Cheyenne Indian Reservation, Montana

WATER-SURFACE PROFILE AND FLOOD BOUNDARIES FOR THE COMPUTED 100-YEAR FLOOD, LAME DEER CREEK, NORTHERN CHEYENNE INDIAN RESERVATION, MONTANA

By

R.J. Omang

INTRODUCTION

Areas that would be inundated by a peak discharge having a recurrence interval of 100 years (the 100-year flood) along streams in the Northern Cheyenne Indian Reservation are of interest to the Northern Cheyenne Tribe because of the potential for development of the land. Knowledge of the extent of the flood plain also is needed to control flood damage in the Northern Cheyenne Reservation. An area of concern is the flood plain of Lame Deer Creek (fig. 1).

One approach for decreasing flood damage is controlling land use adjacent to the stream by planned development and management of flood-hazard areas. Delineation of flood-hazard areas will allow selection of the type of desired development that is compatible with the flood risk.

The U.S. Geological Survey, in cooperation with the Northern Cheyenne Tribe, conducted a hydrologic and hydraulic analysis of Lame Deer Creek to identify areas along the creek subject to flooding. The specific objective of the study was to determine the extent of flooding that would result from a 100-year flood. This report presents the results of the study.

The magnitude of the 100-year flood was determined using techniques described in reports by Omang (1992) and by Parrett and others (1987). Sixty-six channel and flood-plain cross sections were surveyed and 25 cross sections were synthesized along a 9.5-mi reach. Physical dimensions of hydraulic structures were measured. Manning's roughness coefficients were determined at each cross section. Field survey data and a computer model were used to calculate water-surface elevations for the 100-year flood at each cross section. These elevations were used to determine the inundated area for the 100-year flood.

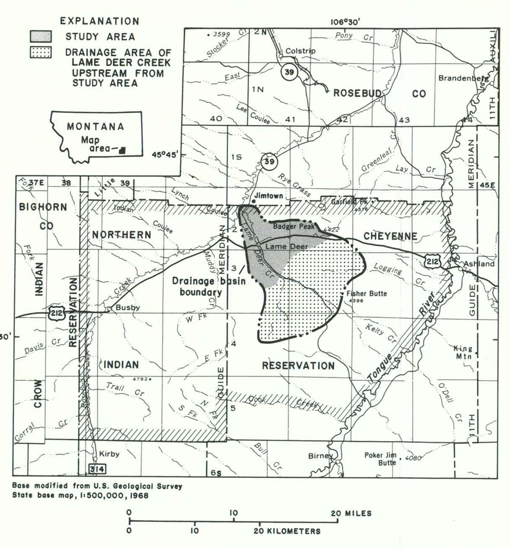


Figure 1.--Location of study area.

General Description of the Area

From its origin 4.5 mi southeast of the town of Lame Deer, Lame Deer Creek flows northwesterly through the town of Lame Deer and joins Rosebud Creek 3.5 mi downstream from Lame Deer. The study area includes Lame Deer Creek from the confluence of the East and South Forks downstream to near the mouth. The Lame Deer Creek Basin is sparsely populated and consists of gently rolling hills and narrow, steep valleys. Areas of the valley adjacent to the stream are densely vegetated with bushes and trees. The elevations of the land surface range from about 3,180 to 4,420 ft in the study area.

The climate is semiarid with cold winters and warm summers. Mean daily temperatures in the area range from 90 °F in July to 8 °F in January. Average annual precipitation is about 15 in. with about half occurring from April through July. June is the wettest month, with an average of about 2.9 in. of precipitation; December, January, and February are the driest, with an average of 0.6 in. (U.S. Environmental Data Service, 1971, p. 10).

Streamflow Conditions and Flooding

Lame Deer Creek has perennial flow, whereas all tributaries are intermittent or ephemeral. Most runoff results from snowmelt in the spring and from rainfall from thunderstorms during the summer. Occasionally, snowmelt and rain combine to produce runoff.

Lame Deer Creek had large discharges in May 1978 and in the 1940's, according to local residents. The magnitudes of the discharges are not known because the stream was not gaged during that period. A streamflow-gaging station is currently (1993) being operated on Lame Deer Creek by the Northern Cheyenne Tribe, but no large flow has occurred since stream gaging began.

METHODS OF ANALYSIS

Standard hydrologic and hydraulic methods were used to analyze the flood hazard for Lame Deer Creek. The magnitude of a flood that is expected to be equaled or exceeded once on the average during any 100-year period (recurrence interval) was selected by the Northern Cheyenne Tribe for analysis. The "100-year flood" has a 1-percent chance of being equaled or exceeded in any given year. Although the recurrence interval represents the long-term average period between floods of a specific magnitude, rare floods could occur at shorter intervals or even within the same year. The analyses reported herein reflect flooding potentials based on conditions in the basin in 1991.

Hydrologic Analysis

Flood-discharge values for Lame Deer Creek are based on techniques developed to estimate flood-frequency information using basin characteristics and channel geometry. The 100-year flood discharge was determined using techniques described by Omang (1992), which relate the 100-year flood discharge to basin characteristics. This discharge was computed to be 1,730 ft^3/s. The 100-year flood discharge also was determined by using techniques described by Parrett and others (1987), which relates the 100-year flood to channel width. This discharge was computed to be 1,300 ft^3/s. The two 100-year flood discharges were weighted using methods described by Parrett and others (1987, p. 25), and the resultant 100-year flood was computed to be 1,560 ft^3/s. This discharge was used to determine the water-surface elevation at each cross section.

Hydraulic Analysis

The hydraulic characteristics of the cross sections along Lame Deer Creek were analyzed to determine the water-surface elevations of the 100-year flood. The method used to define hydraulic characteristics requires cross-section geometry data and estimates of the roughness coefficient (Manning's "n").

Cross-section data were obtained from field surveys conducted during the summer of 1991. Sixty-six cross sections were surveyed and 25 were synthesized. The synthesized cross sections (sections 7, 9, 15, 17, 22, 42, 46, 48, 54, 55, 57, 61, 63, 64, 66, 68, 73, 75, 76, 79, 81, 82, 84, 87, and 90 on the principal map) were estimated from adjacent surveyed sections and topographic maps. Structural geometry data also were obtained for one bridge and four culverts. Cross sections were located upstream and downstream from the bridge and culverts to permit computation of the backwater effects of the bridge and culverts. Cross sections typical of channel and flood-plain conditions in the upstream and downstream parts of the study area are shown in figures 2 and 3, respectively. Figure 4 shows the channel condition at the bridge.

The roughness coefficient represents the resistance to flow. Factors that affect the roughness coefficient include the type and size of materials that compose the bed and banks of the channel and flood plain, shape of the channel, variation in dimensions of adjacent cross sections, vegetation, structures, and degree of meandering. Roughness coefficients (Manning's "n") used in the hydraulic computations were based on engineering judgment of onsite observations. Roughness values used range from 0.035 to 0.150 for the main channel and from 0.035 to 0.160 for the flood-plain areas.

Water-surface elevations for the 100-year flood were computed using a water-surface-profile computation model (WSPRO) developed by the U.S. Geological Survey for the Federal Highway Administration (Shearman and others, 1986; Shearman, 1990). WSPRO is a computer program that is used to analyze one-dimensional, gradually varied, steady flow in open channels with fixed boundaries. With this computer program, the surveyed and synthesized cross-section data were used to define the hydraulic characteristics of the channel. The location of each cross section was selected to represent the hydraulic characteristics of that part of the reach, and each section was surveyed to define its shape. The model uses the standard step method (Chow, 1959, p. 265) to determine changes in water-surface elevation from a downstream cross section with a known water-surface elevation to an upstream cross section by balancing the total energy head at the sections. To compute the 100-year flood profile for Lame Deer Creek, the starting water-surface elevation at cross section 1 at the downstream end of the study area was determined from a slope-conveyance computation of normal depth. Starting water-surface elevations upstream from the culverts (sections 4, 27, 37, and 51) were determined using techniques developed by Bodhaine (1968) and Hulsing (1967).

WATER-SURFACE PROFILE

The water-surface profile for the 100-year flood (fig. 5) was drawn for the entire reach within the study area. The profile shows the computed water-surface elevations, the streambed elevations, and the location of the bridge, culverts, and cross sections used in the hydraulic analysis.

The hydraulic analysis was based on unobstructed flow. The water-surface elevations shown on the profile thus are considered to be valid only if hydraulic structures remain unobstructed and do not fail.

For the WSPRO assumption of gradually varied, steady flow to be valid, the distance between cross sections (subreach) needs to be short. As described by Davidian (1984, p. 20), no cross-section subreach should be longer than about 75-100 times the mean depth for the modeled discharge, nor longer than about twice the width of the subreach flood plain. The number of surveyed cross sections for this study was limited by surveying costs to 66. Therefore, 25 additional cross sections were synthesized and added to the WSPRO input data set to decrease possible step-backwater computation errors. If the synthesized cross-section data are replaced with surveyed data, the computed water-surface elevations at cross sections could change.

Sea-level elevation was transferred from either U.S. Geological Survey or U.S. Coast and Geodetic Survey bench marks to cross sections and to reference marks established at convenient locations along Lame Deer Creek. Reference-mark locations are shown on the principal map and reference-mark descriptions are given in table 1.

FLOOD BOUNDARIES

The flood boundaries along the stream define an area that would be inundated by a 100-year flood. For this study, the 100-year flood boundaries were delineated using water-surface elevations computed at each cross section. Between cross sections, where survey data were unavailable, the flood boundaries were interpolated using the contour lines on topographic maps.

The 100-year flood boundaries are shown on the principal map. Small flood-plain areas within the flood boundaries may lie above the water-surface elevation, but cannot be shown owing to limitations of the map scale or lack of detailed topographic data.

SUMMARY

Standard hydrologic and hydraulic methods were used to determine the flood-hazard area for Lame Deer Creek. The 100-year flood was selected as having special significance for flood-plain management.

The magnitude of the 100-year flood was determined for the reach of Lame Deer Creek extending from the confluence of the East and South Forks downstream to the mouth, 3.5 mi north of Lame Deer. The flood discharge for this reach of stream was determined to be 1,560 ft^3/s.

Geometry and roughness coefficients used for 66 channel and flood-plain cross sections were obtained from field surveys of a 9.5-mi reach of the stream. Twenty-five additional cross sections were synthesized from adjacent surveyed sections and topographic maps. These data were used to compute the water-surface elevation for the 100-year flood at each cross section using WSPRO, a computer program.

The water-surface profile was drawn showing computed water-surface elevations of a 100-year flood. The profile also shows the streambed elevations and location of the bridge, culverts, and cross sections used in the hydraulic analysis. Flood boundaries were delineated using the water-surface elevation computed at each cross section. Between cross sections, the flood boundaries were interpolated using the contour lines on topographic maps.

REFERENCES CITED

Bodhaine, G.L., 1968, Measurement of peak discharge at culverts by indirect methods: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chap. A3, 60 p.

Chow, V.T., 1959, Open-channel hydraulics: New York, McGraw-Hill, 680 p.

Davidian, Jacob, 1984, Computation of water-surface profiles in open channels: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chap. A15, 48 p.

Hulsing, Harry, 1967, Measurement of peak discharge at dams by indirect methods: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 3, Chap. A5, 29 p.

Omang, R.J., 1992, Analysis of the magnitude and frequency of floods and the peak-flow gaging network in Montana: U.S. Geological Survey Water-Resources Investigations Report 92-4048, 70 p.

Parrett, Charles, Hull, J.A., and Omang, R.J., 1987, Revised techniques for estimating peak discharges from channel width in Montana: U.S. Geological Survey Water-Resources Investigations Report 87-4121, 34 p.

Shearman, J.O., 1990, User's manual for WSPRO--a computer model for water surface profile computations: U.S. Department of Transportation, 177 p. [Available from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161 as Report FHWA-IP-89-027.]

Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model--research report: U.S. Department of Transportation, 112 p. [Available from the National Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161 as Report FHWA/RD-86/108.]

U.S. Environmental Data Service, 1971, Climate of Montana: Department of Commerce, National Oceanic and Atmospheric Administration, Climatography of the United States No. 60-24, 21 p.

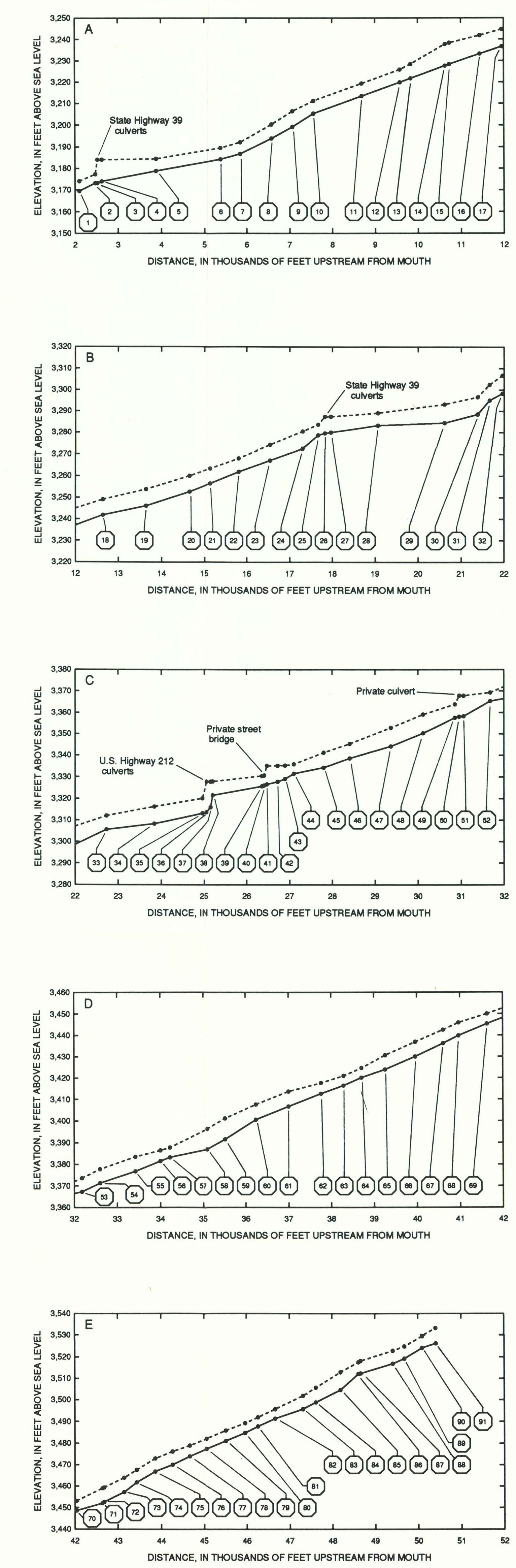


Figure 5.--Profile of computed water-surface elevations for the 100-year flood, streambed elevations, and location of cross sections.

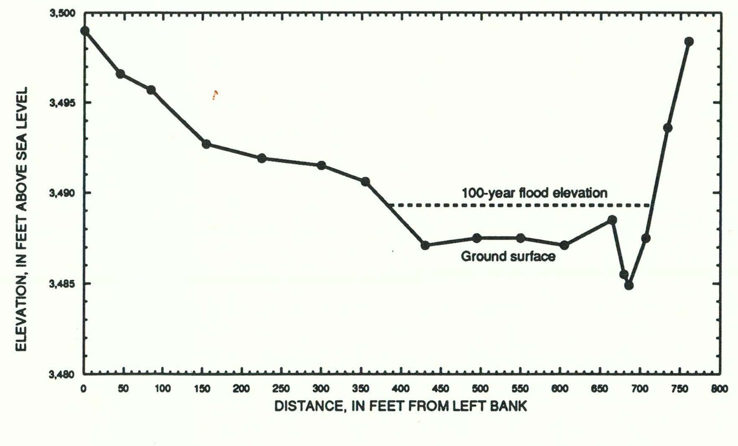


Figure 2.--Cross section 80, which is typical of channel and flood-plain conditions in the upstream part of the study area.

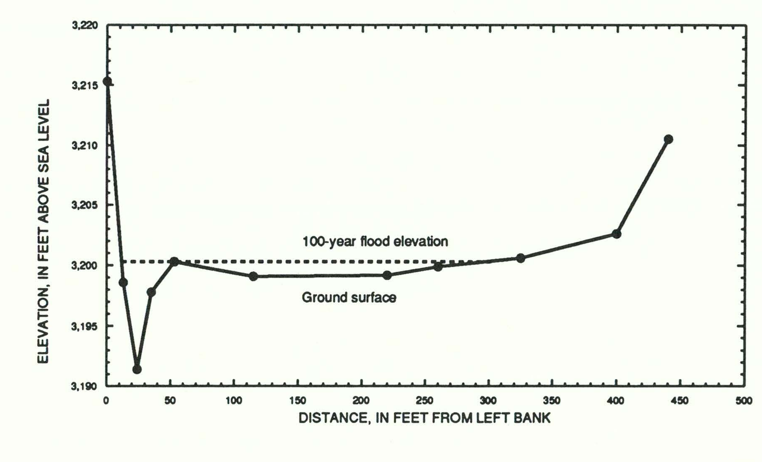


Figure 3.--Cross section 8, which is typical of channel and flood-plain conditions in the downstream part of the study area.

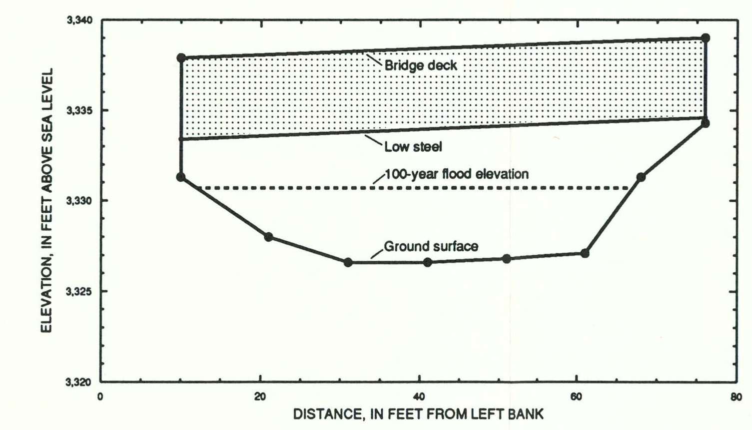
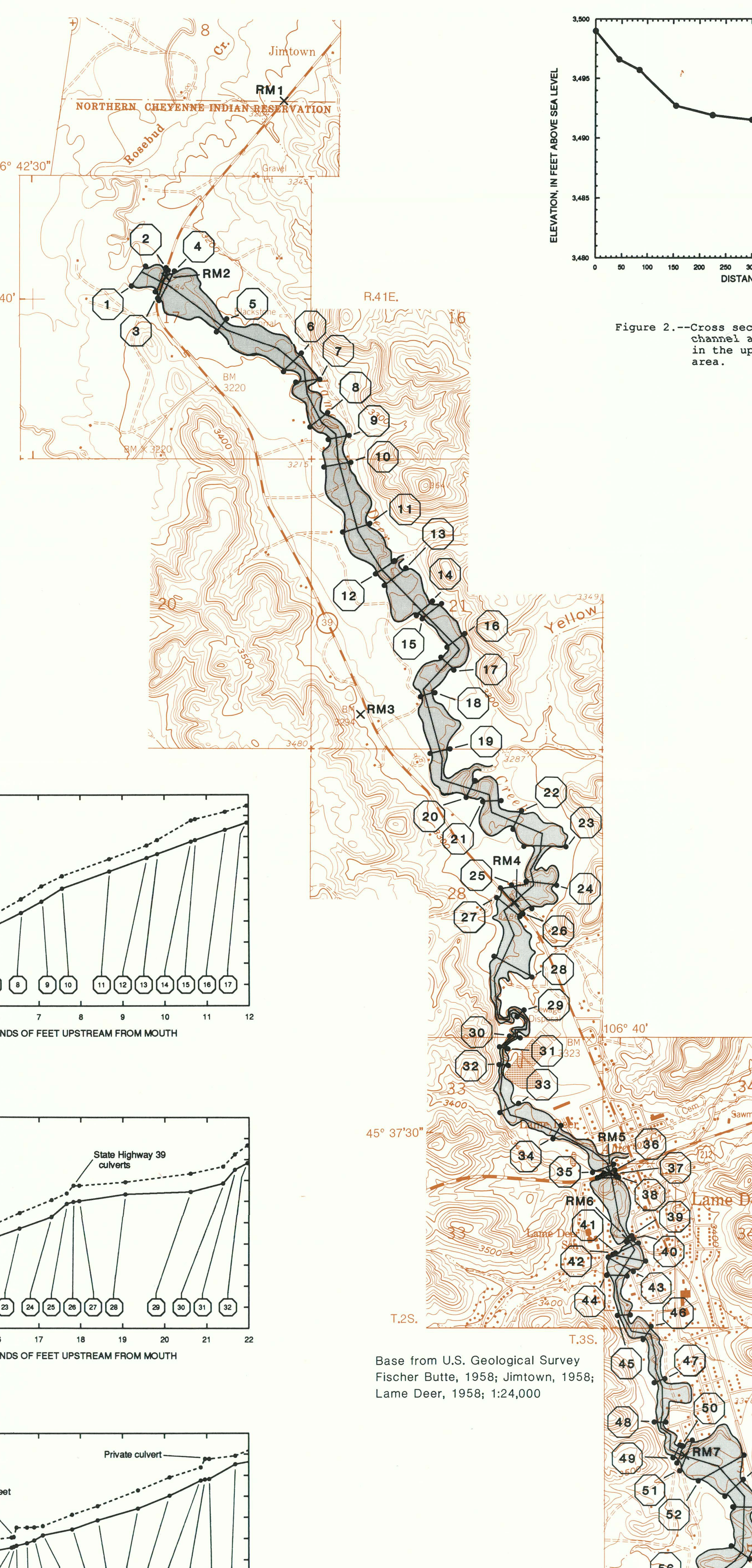
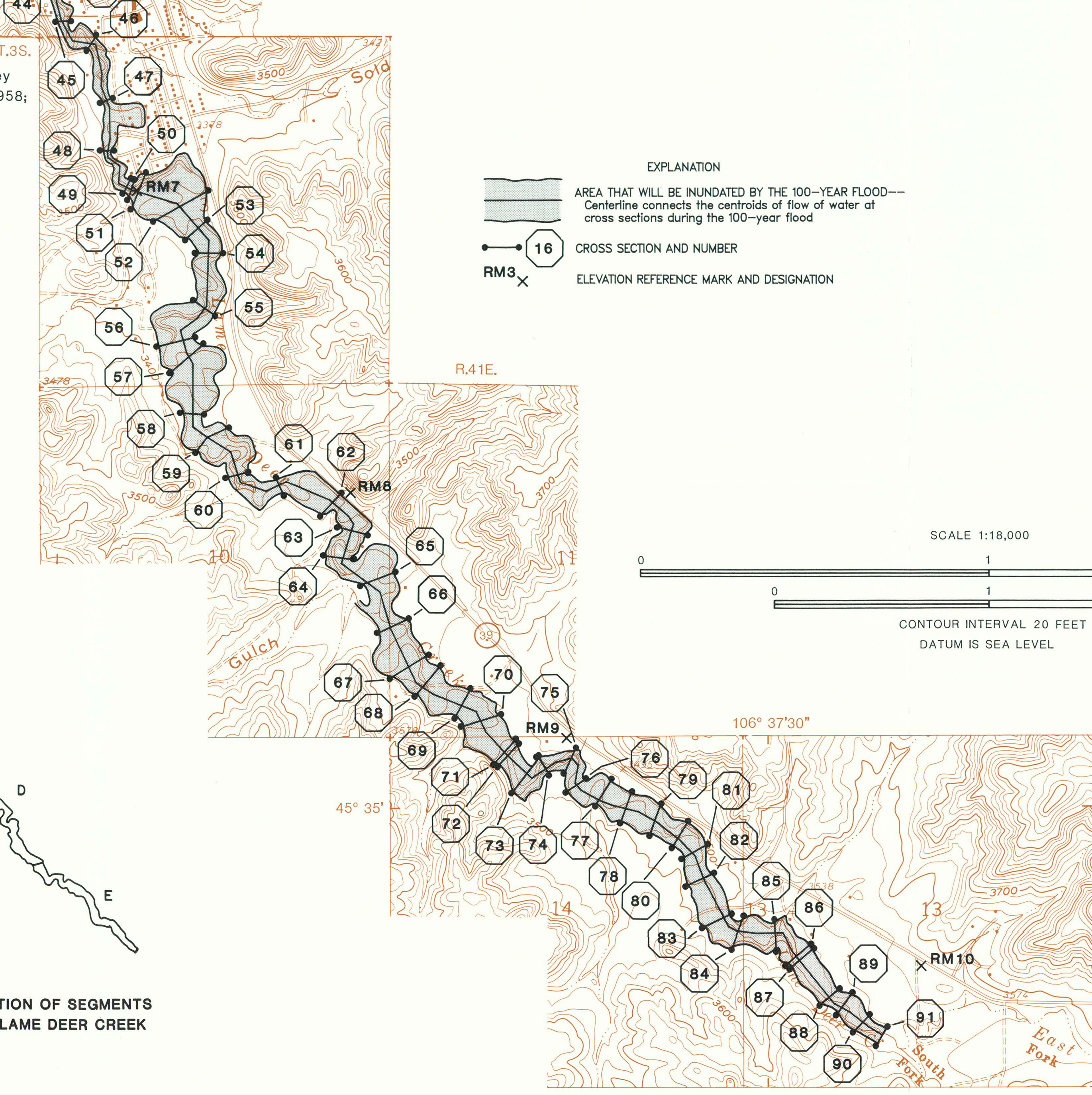


Figure 4.--Cross section 40, which shows the channel condition at the private bridge crossing at Lame Deer.

Base from U.S. Geological Survey
Fischer Butte, 1958; Jimtown, 1958;
Lame Deer, 1958; 1:24,000

EXPLANATION

AREA THAT WILL BE INUNDATED BY THE 100-YEAR FLOOD--Centerline connects the centroids of flow of water at cross sections during the 100-year flood

16 CROSS SECTION AND NUMBER

RM3 × ELEVATION REFERENCE MARK AND DESIGNATION

SCALE 1:18,000

0 1 2 MILES

0 1 2 KILOMETERS

CONTOUR INTERVAL 20 FEET
DATUM IS SEA LEVEL

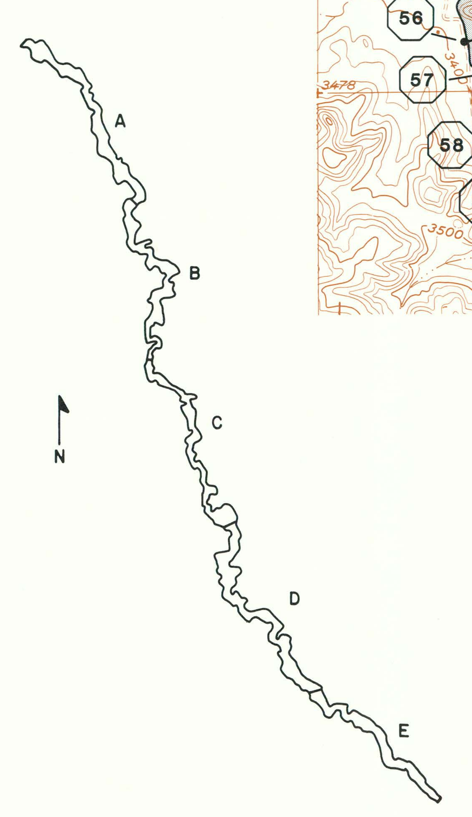


DIAGRAM SHOWING POSITION OF SEGMENTS OF THE PROFILE ALONG LAME DEER CREEK

EXPLANATION

- - - - - WATER-SURFACE ELEVATION OF 100-YEAR FLOOD

——— STREAMBED

(7) LOCATION OF CROSS SECTION AND NUMBER

MAP SHOWING AREA INUNDATED BY THE 100-YEAR FLOOD, LOCATION OF CROSS SECTIONS, AND LOCATION OF ELEVATION REFERENCE MARKS

Table 1.--Elevation reference marks along Lame Deer Creek

Reference mark	Elevation (feet above sea level)	Description of location
RM1	3,210.90	A disk, stamped "S 362 (5)" and set in top of concrete post projecting 2.0 feet above ground, is located 0.2 mi southwest of Jimtown, along State Highway 39, 20 ft west of highway, at northern boundary of the Northern Cheyenne Indian Reservation.
RM2	3,181.26	Downstream crown of 8-ft corrugated metal culvert is located at crossing along Lame Deer Creek, 3.4 mi northwest of Lame Deer, at culvert on State Highway 39.
RM3	3,294.15	A standard U.S. Coast and Geodetic Survey bench mark disk, stamped "P 220 1934" and set in top of concrete post projecting 0.5 ft above ground, is located 1.8 mi northwest of Lame Deer along State Highway 39, 143 ft southwest of the centerline of the highway and about 1 ft higher than the road.
RM4	3,284.70	Upstream crown of left 5-ft by 7-ft corrugated metal pipe arch culvert, is located at crossing along Lame Deer Creek, 1.0 mi northwest of Lame Deer, at culvert on State Highway 39.
RM5	3,319.16	Upstream crown of left 7.5-ft by 12-ft corrugated metal pipe arch culvert, is located at crossing along Lame Deer Creek, at Lame Deer, at culvert on U.S. Highway 212.
RM6	3,339.11	Top of steel bolt, painted red and located in the east end of bridge crossing Lame Deer Creek, is located at Lame Deer, in the top of the north side of the bridge abutment.
RM7	3,360.59	Upstream crown of 5-ft by 3-ft corrugated metal pipe arch culvert, is located at crossing along Lame Deer Creek, 0.5 mi south of Lame Deer, at culvert on local access road.
RM8	3,423.81	Top of spike, 1.5 ft above ground in post for buried telephone lines, stamped "422A," is located 1.4 mi southeast of Lame Deer, along Lame Deer Creek, on right bank by secondary road.
RM9	3,493.56	Top of spike, 1.5 ft above ground in power pole stamped "3885," is located 2.3 mi southeast of Lame Deer, along Lame Deer Creek, on right bank by secondary road.
RM10	3,573.58	Top of spike, 1.3 ft above ground in power pole, is located 3.7 mi southeast of Lame Deer, along Lame Deer Creek, on right bank by secondary road.

CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
cubic foot per second (ft^3/s)	0.028317	cubic meter per second
foot (ft)	0.3048	meter
inch (in.)	25.4	millimeter
mile (mi)	1.609	kilometer

Temperature in degrees Fahrenheit (°F) can be converted to degrees Celsius (°C) by the equation:

$$°C = 5/9\ (°F - 32)$$

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

For additional information write to:

District Chief
U.S. Geological Survey
428 Federal Building
Drawer 10076
301 South Park
Helena, MT 59626-0076

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