Prepared in cooperation with the
Alaska Department of Fish and Game and
City and Borough of Juneau

Hydrology, Geomorphology, and Flood Profiles of the Mendenhall River, Juneau, Alaska

Water-Resources Investigations Report 99-4150

U.S. Department of the Interior
U.S. Geological Survey

Cover: Surveying flood marks on the Mendenhall River near cross section 74

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U.S. GEOLOGICAL SURVEY

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Anchorage, Alaska
1999

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Charles G. Groat, Director

For additional information:

District Chief
U.S. Geological Survey
4230 University Drive, Suite 201
Anchorage, AK 99508-4664

http://ak.water.usgs.gov

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	by	To obtain
inch (in.)	25.4	millimeter
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer
foot per year (ft/yr)	0.3048	meter per year
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot per mile (ft/mi)	0.1894	meter per kilometer

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. Elevations used in this report are referenced to Mean Lower Low Water (MLLW) which is a local datum. This datum is 8.2 feet below the National Geodetic Vertical Datum of 1929.

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ABSTRACT

Water-surface-profile elevations for the 2-, 20-, 25-, 50-, and 100-year floods were computed for the Mendenhall River near Juneau, Alaska, using the U.S. Army Corps of Engineers Hydrologic Engineering Center River Analysis System model. The peak discharges for the selected recurrence intervals were determined using the standard log-Pearson type III method. Channel cross sections were surveyed at 60 locations to define hydraulic characteristics over a 5.5-mile reach of river beginning at Mendenhall Lake outlet and extending to the river mouth. A peak flow of 12,400 cubic feet per second occurred on the Mendenhall River on October 20, 1998. This discharge is equivalent to about a 10-year flood on the Mendenhall River and floodmarks produced by this flood were surveyed and used to calibrate the model. The study area is currently experiencing land-surface uplift rates of about 0.05 foot per year. This high rate of uplift has the potential to cause incision or downcutting of the river channel through lowering of the base level. Vertical datum used in the study area was established about 37 years before the most recent surveys of river-channel geometry. The resulting difference between land-surface elevations and sea level continues to increase. Continuing incision of the river channel combined with increased land-surface elevations with respect to sea level may result in computed flood profiles that are higher than actual existing conditions in the tidally influenced reach of the river.

INTRODUCTION

In 1997, the U.S. Geological Survey (USGS), in cooperation with the Alaska Department of Fish and Game and the City and Borough of Juneau, conducted an investigation to estimate water-surface profiles for flood flows of selected recurrence intervals on the Mendenhall River in Juneau, Alaska. Increasing development in the Mendenhall Valley coupled with the current rates of tectonic uplift have resulted in a need for refined flood profiles of the Mendenhall River. These profiles will aid managers and planners in evaluating and prescribing bank protection and stabilization methods.

The Alaska Department of Fish and Game and the City and Borough of Juneau are concerned with impacts of bank-hardening projects on river geomorphology, the riparian zone, and instream fish habitat on the Mendenhall River. Currently, flood-plain managers use water-surface profiles and flood maps from the Federal Emergency Management Agency (FEMA) (1990) flood insurance study. This study was based on surveys completed in the late 1960’s. Established benchmark elevations used in the FEMA report and for development activities around the Mendenhall Valley were last surveyed in the 1960’s. Hicks and Shofnos (1965) first documented ongoing tectonic uplift in southeast Alaska. Their results, later confirmed by Hudson and others (1982), indicated that rates of uplift in the Juneau area could be as much as 0.05 ft/yr. The National Oceanic and Atmospheric Administration (1999) has determined that sea-level trends at the Juneau tide gage have declined 0.04 ft/yr since 1936. These findings indicate that land surface may have uplifted as much as 1.8 ft in the study area (with respect to sea level) since the initial flood profiles were generated.

Purpose and Scope

The purpose of the study was to determine water-surface profiles for selected flood flows of the Mendenhall River. The City and Borough of Juneau and the Alaska Department of Fish and Game requested profiles for the 2-, 10-, 25-, 50-, and 100-year floods. The discharges for floods of the selected recurrence intervals were computed using standard log-Pearson type III frequency analysis. The water-surface profiles that would result from these floods were determined for a 5.5-mile reach of the river using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center River Analysis System (HEC-RAS) model (U.S. Army Corps of Engineers, 1997a, b, c). This report also includes discussion of the Mendenhall River geomorphology and relates river morphology and flooding potential to regional land-surface uplift, which is ongoing in the study area.

Description of Study Area

The City and Borough of Juneau, located on the northeast side of Gastineau Channel, is the largest population center in southeastern Alaska (fig. 1). Located within the Inside Passage of southeast Alaska, approximately 900 mi northwest of Seattle, Washington, and 75 mi from the open water of the Pacific Ocean, the community is accessible only by plane or boat. The Mendenhall River flows through the Mendenhall Valley, which is located about 10 mi northwest of the City of Juneau. The population in the valley has grown from 2,940 in 1966 (Barnwell and Boning, 1968) to more than 12,000 in 1998 (K.J. Bailey, City and Borough of Juneau, written commun., 1999). The east banks of the Mendenhall River have had substantial development since 1966, whereas much of the west bank remains undeveloped.

Elevations in Mendenhall River Basin, an area of about 103 mi^2, range from sea level to nearly 7,000 ft. A large part of the upper basin is covered by glaciers, whereas the valley floor is relatively flat and covered with streets and housing developments. Muskeg and spruce forest cover most of the undeveloped regions of the valley. The Mendenhall River flows out of the terminus of Mendenhall Glacier at the northern edge of the valley and into Mendenhall Lake. Mendenhall Lake receives additional inflow from Nugget Creek, Steep Creek, and a few small tributaries. After exiting the lake, the river flows through the Mendenhall Valley in a generally southward direction until it enters salt water in Fritz Cove.

The Mendenhall River provides aquatic habitat for chum, pink, sockeye, and coho salmon; cutthroat and steelhead/rainbow trout; and Dolly Varden. The river is also used as a migration route for fish bound for Montana and Steep Creeks and several small unnamed creeks flowing into the west side of Mendenhall Lake. The Alaska Department of Fish and Game has estimated as many as 15,000 salmon and 30,000 Dolly Varden migrate up the river annually (Bethers and others, 1995). The Montana Creek tributary hosts one of the most popular fisheries on the Juneau road system.

The maritime climate of Juneau is characterized by frequent storms and abundant precipitation as is true for most of southeast Alaska. The mountainous terrain in the Juneau area results in highly variable differences in temperature and precipitation within the area. Mean annual precipitation at the Juneau Airport is 53 in. (water equivalent) and includes 98 in. of snow. Mean annual precipitation in downtown Juneau (8 mi from the airport) is 94

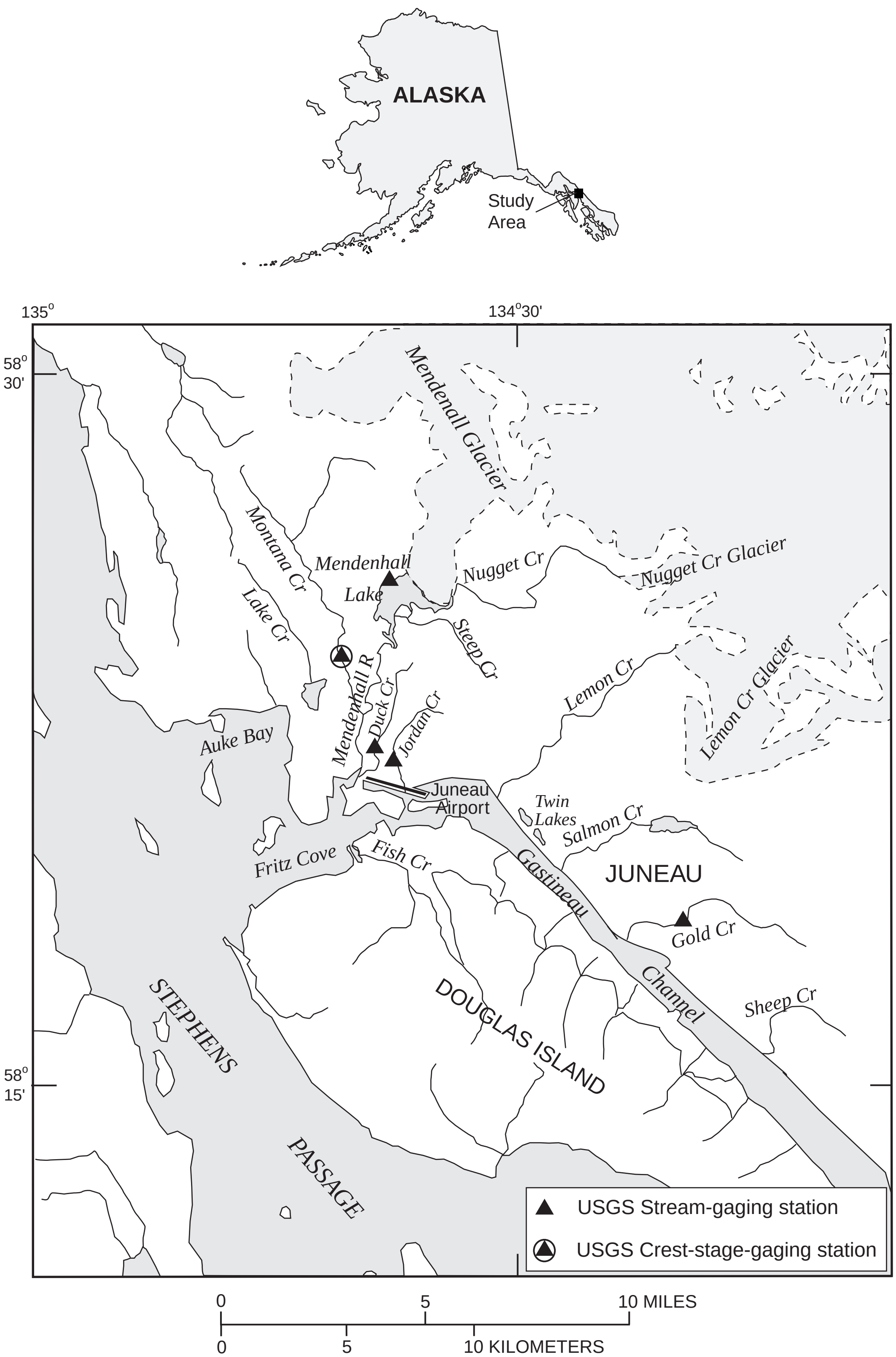


Figure 1. Location of Mendenhall River in Juneau, Alaska.

in. Mean annual precipitation near the source of Mendenhall Glacier is estimated to be greater than 220 in. (Jones and Fahl, 1994, plate 2). The highest average monthly precipitation occurs in the fall when regional storms dominate the weather patterns; the lowest precipitation occurs in late spring (National Oceanic and Atmospheric Administration, 1999).

HYDROLOGY OF THE MENDENHALL RIVER BASIN

The principal source of the Mendenhall River is meltwater from Mendenhall Glacier. Other sources include runoff from Nugget, Steep, and Montana Creeks (fig. 1). During the summer, a large part of the streamflow in Nugget Creek consists of glacial melt water from Nugget Creek Glacier. Although flows in Steep and Montana Creeks are influenced primarily by rainfall, flow in the Mendenhall River is largely influenced by temperature. Peak flows in the Mendenhall River commonly occur during late summer as a result of heavy rains coupled with high temperatures that cause glacial melting.

Streamflow on the Mendenhall River has been measured since 1965 at the USGS gaging station Mendenhall River near Auke Bay (station No. 15052500) (fig. 1) (U.S. Geological Survey, 1971-99). The gaging station is at the north end of Mendenhall Lake, 1.2 mi north of the lake outlet. The average annual mean flow is 1,250 ft^3/s and ranges from a minimum monthly mean of 93 ft^3/s in February to a maximum monthly mean of 3,330 ft^3/s in August. The lowest daily mean discharge measured was 19 ft^3/s on March 1, 1969. The instantaneous peak flow during the period of record on the Mendenhall River was 16,000 ft^3/s on September 11, 1995 (U.S. Geological Survey, 1999). The maximum known high water outside of the period of streamflow record occurred in late summer 1961, when the flow was approximately 27,000 ft^3/s at the river mouth (Barnwell and Boning, 1968).

The Montana Creek near Auke Bay gaging station (No. 15052800) (fig. 1) was operated as a continuous-record station from 1966 to 1975 and from 1984 to 1987, and operated as a crest-stage partial record station from 1997 to present (U.S. Geological Survey, 1971-99). The average annual mean flow is 104 ft^3/s and ranges from a minimum monthly mean of 42.4 ft^3/s in January to a maximum monthly mean of 167 ft^3/s in June. The lowest daily mean discharge for Montana Creek during the period of record was 3.4 ft^3/s on February 8, 1972. The instantaneous peak flow on Montana Creek during the period of record was 3,800 ft^3/s on October 20, 1998.

Peak-flow data on the Mendenhall River indicate that floods are most likely to occur from July through September and sometimes in October. An intense storm on October 20, 1998, resulted in a peak discharge on the Mendenhall River of about 12,400 ft^3/s, which was determined to have a recurrence interval of about 10 years. The same storm resulted in a peak discharge on Montana Creek of about 3,800 ft^3/s, which has a recurrence interval greater than 100 years.

GEOMORPHOLOGY OF THE MENDENHALL RIVER

Mendenhall River Channel Formation

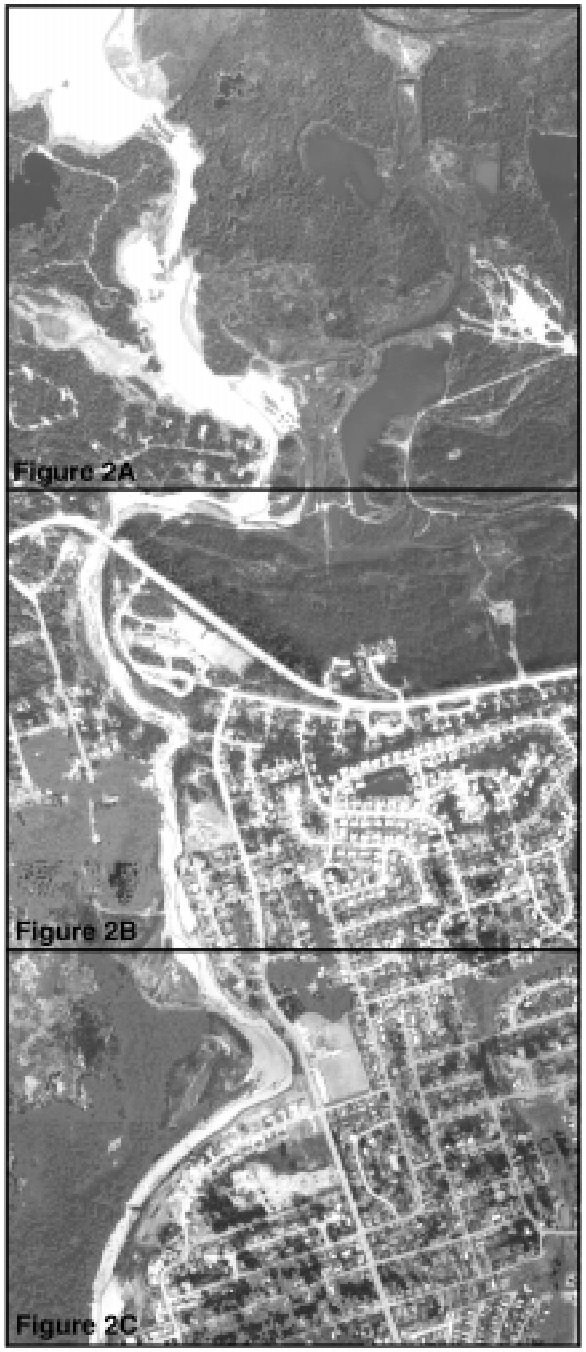
The Mendenhall Glacier probably began its most recent recession in about 1750, and the recession has continued at a rate of about 40 ft/yr (Barnwell and Boning, 1968). As the glacier retreated, the remaining moraine material formed a dam impounding Mendenhall Lake. Meltwater from the glacier and Nugget Creek flowed over the morainal material into a broad braided channel on the eastern side of the valley (Barnwell and Boning, 1968). Between 1750 and 1900, the moraine dam was breached at the current outlet of the lake and the Mendenhall River incised a channel through the floodplain deposits at its present location. Ancestral flows along the east side of the valley were probably responsible for the channel formation of modern day Jordan and Duck Creeks (fig. 1). After the glacier's most recent recession, the lake became (and remains) a sink for coarse debris and sediment from the Mendenhall Glacier and from Nugget and Steep Creeks. Current sources of coarse sediment for the Mendenhall River are derived from bank erosion and downcutting of the channel. Montana Creek also contributes coarse material to the lower reaches of the river.

Present Channel Conditions

Computed water-surface profiles of the river between Mendenhall Lake and Fritz Cove (fig. 2) have slopes ranging from less than 0.001 in the tidally influenced reaches to about 0.012 in the steepest reach. Just above the Mendenhall Loop Road Bridge (cross section 93, fig. 2B), the water-surface slope decreases to the approximate slope observed in the lower reaches of the river. The steepest reach of river extending upstream from cross section 86 to cross section 94 (fig. 2B) has cut through a large terminal moraine of the Mendenhall Glacier. Bed materials in this reach consist predominantly of large angular boulder material with diameters exceeding 8 ft. The size of the bed material controls the slope of the river throughout most of this reach. The finer grained moraine sediments have been winnowed away leaving the larger material in the channel. The stream lacks the competence to transport the larger bed material, consequently limiting further downcutting of the streambed and controlling the slope through this reach of the river. Large glacially transported boulders are also scattered throughout the upper reach of the river.

The reach extending from cross section 64 (fig. 2D) to cross section 85 (fig. 2B) has bed material composed of relatively erosion-resistant peat deposits—formed by forest growth—which have been buried by subsequent alluvium. The remnant root structures and trunks of trees remain upright and intact in several parts of the channel (fig. 3). These deposits appear persistently throughout the reach, although they are covered by gravel and cobbles in some areas. Downstream from cross section 64, the channel bed has incised below the peat layer. Upstream from cross section 64, the channel bed has scoured through the peat layer intermittently indicating that this layer may eventually erode.

Examination of aerial photos of the Mendenhall River from 1948, 1962, 1972, 1982, and 1998 indicates a relatively stable lateral channel configuration during the past 50 years. During this time interval, the number and size of gravel bar deposits seem to have been reduced along the river; however, substantial mining of gravel deposits along the river may have temporarily influenced bar formation and degradation. Slight increases in channel sinuosity can be noticed in reaches extending from cross sections 49 to 52 (fig. 2E) and from 59 to 66 (fig. 2D). Although the channel has remained relatively stable, this is not necessarily predictive of continued channel stability. River channels typically adjust slope and channel patterns episodically. Long periods of stability can be interrupted by intermittent periods of rapid channel adjustment. These rapid adjustments can be initiated by large flood flows or a rapid channel slope adjustment such as the cutoff of a meander neck (Petts and Foster, 1985, p. 152; Simon, 1992).



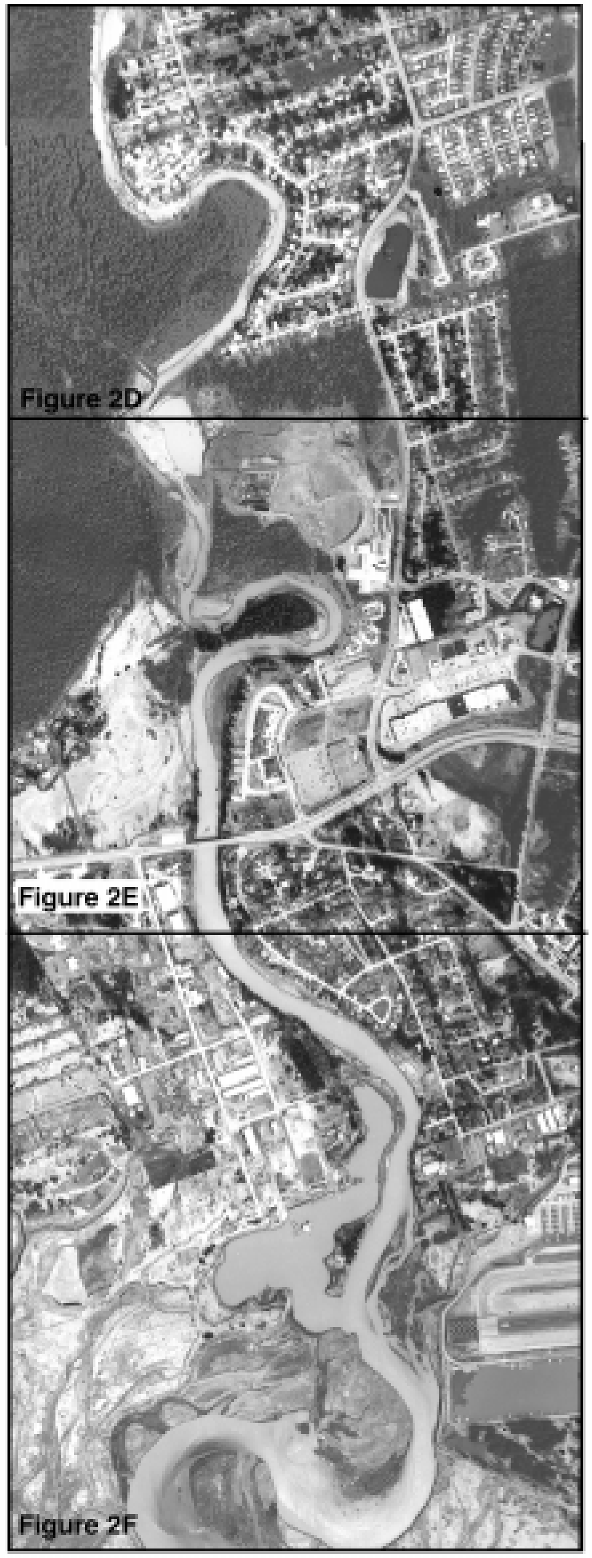


Figure 2. Aerial view of Mendenhall River from Mendenhall Lake outlet to mouth of Fritz Cove. Locations of selected cross sections and reference marks (RM) shown on figures 2A-2F. (Aerial photos of April 22, 1998 provided by R&M Engineering.)

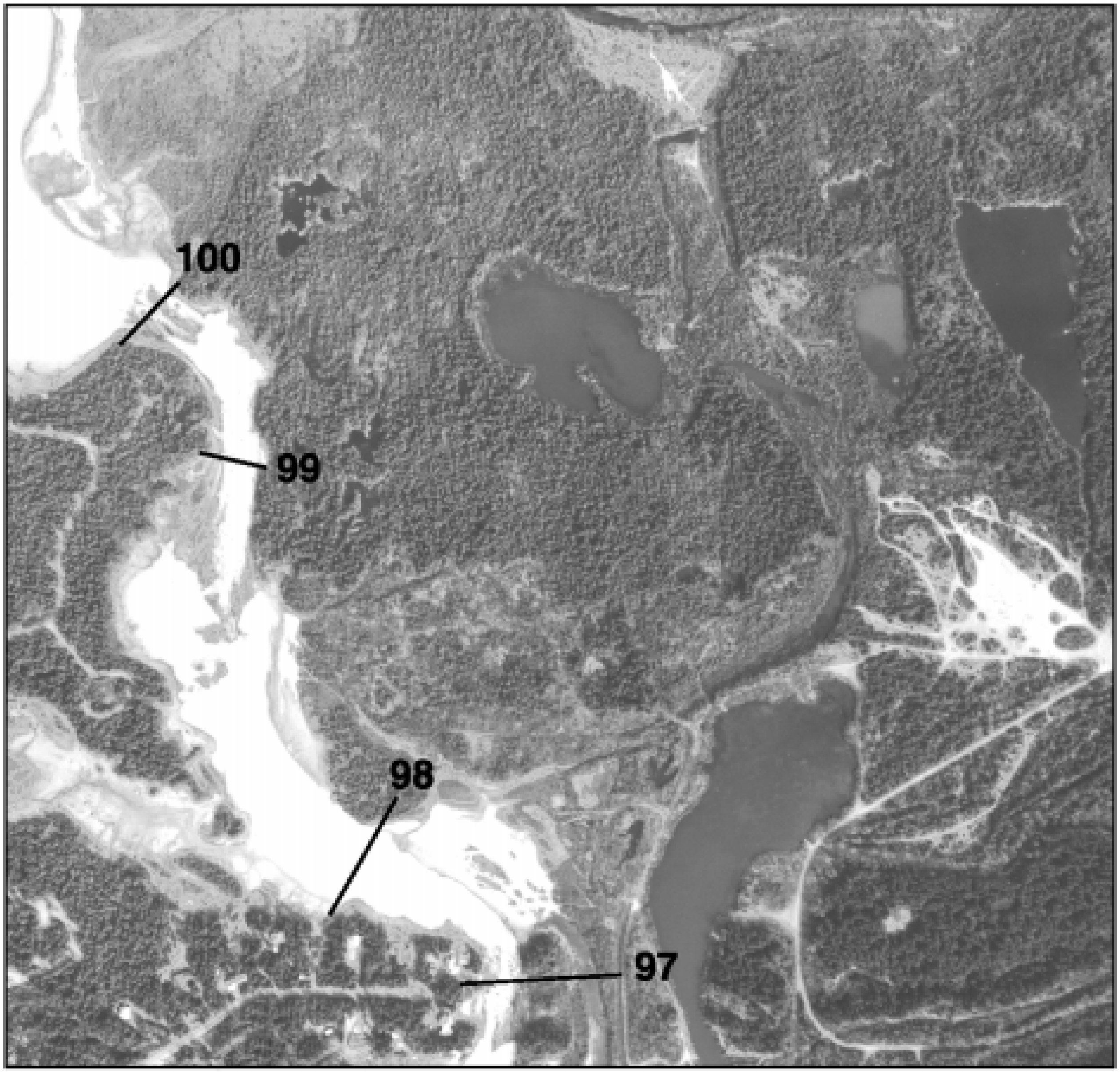


Figure 2A. Cross sections 100 to 97.

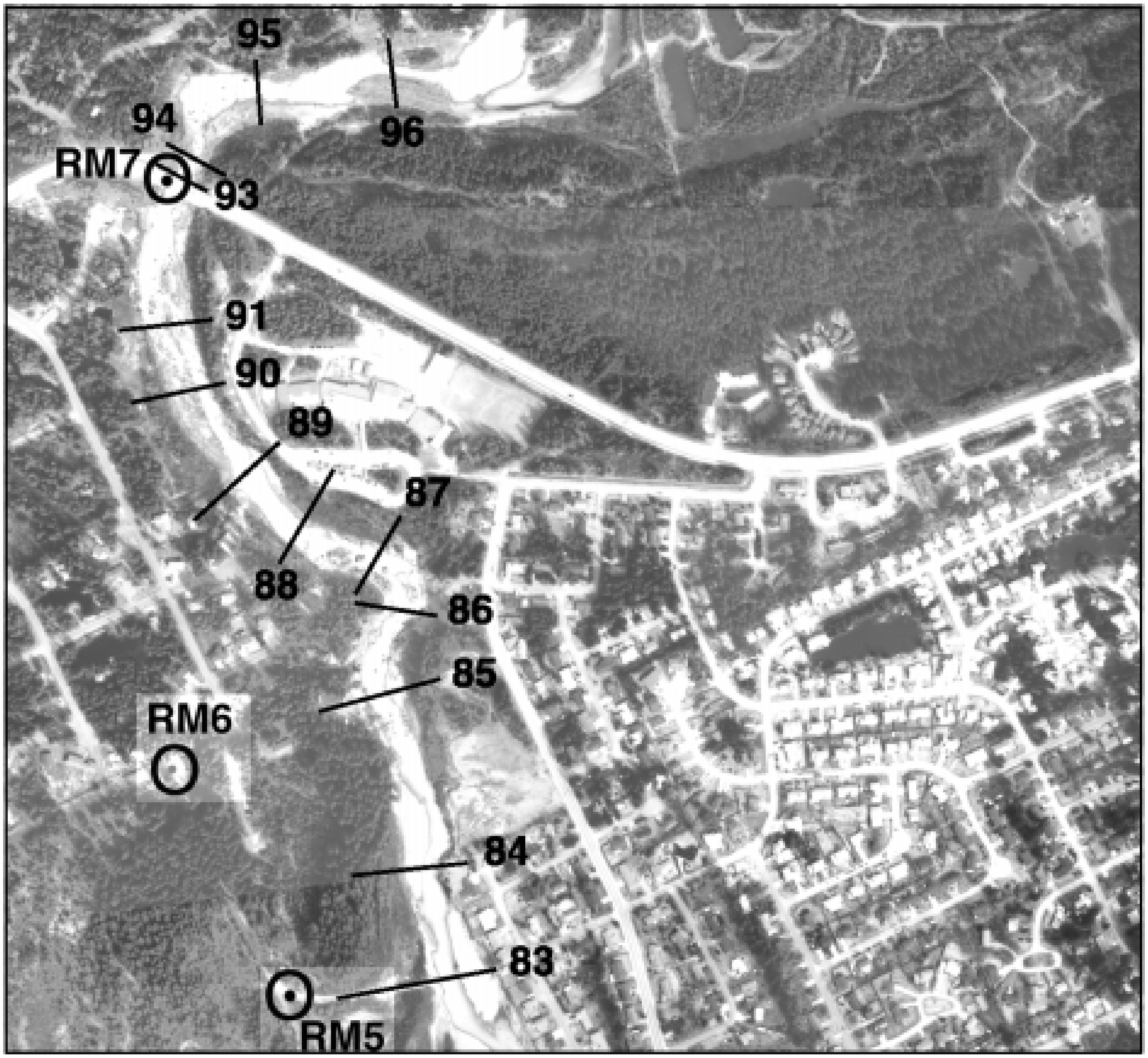


Figure 2B. Cross sections 96 to 83.

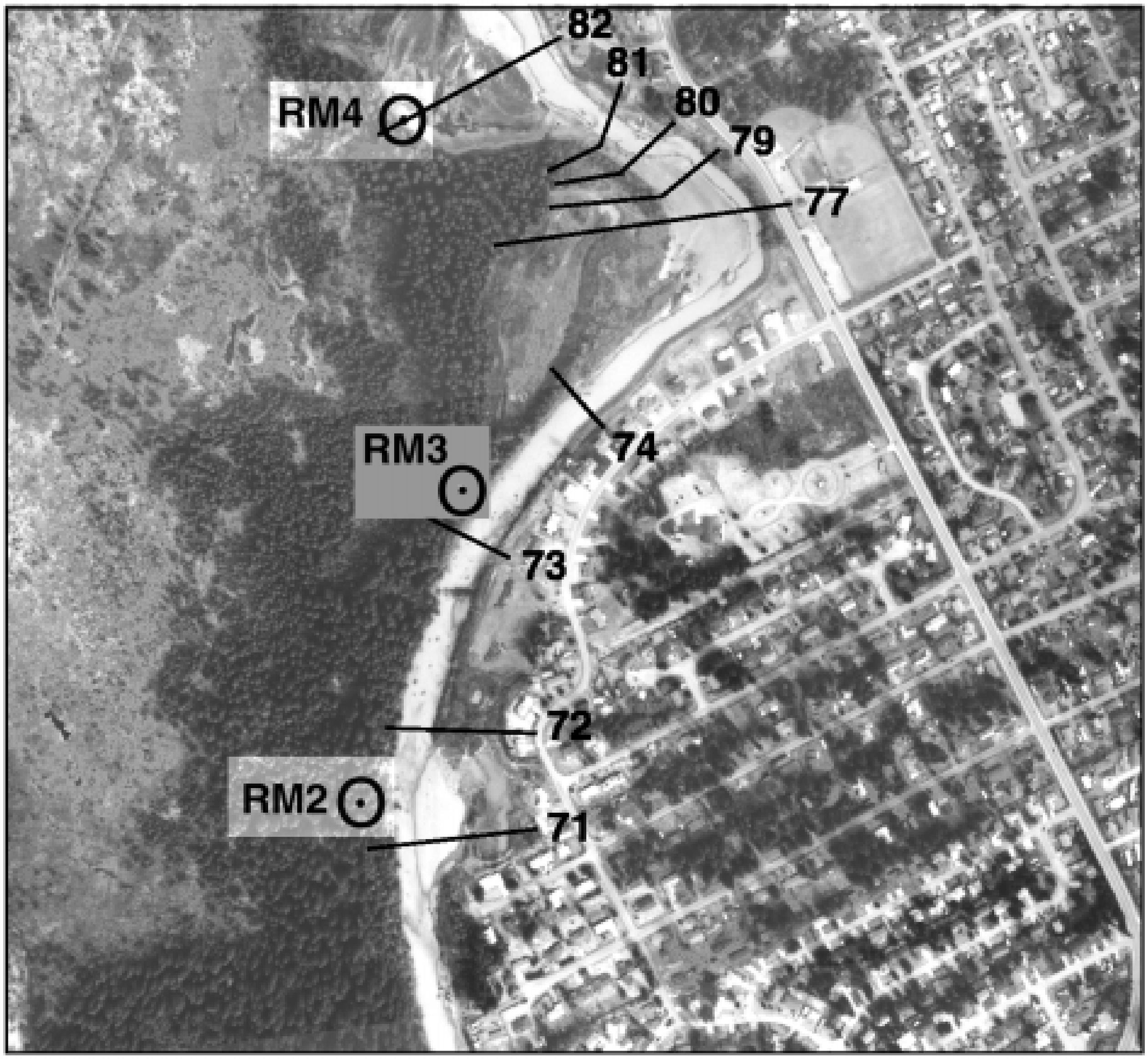


Figure 2C. Cross sections 82 to 71.

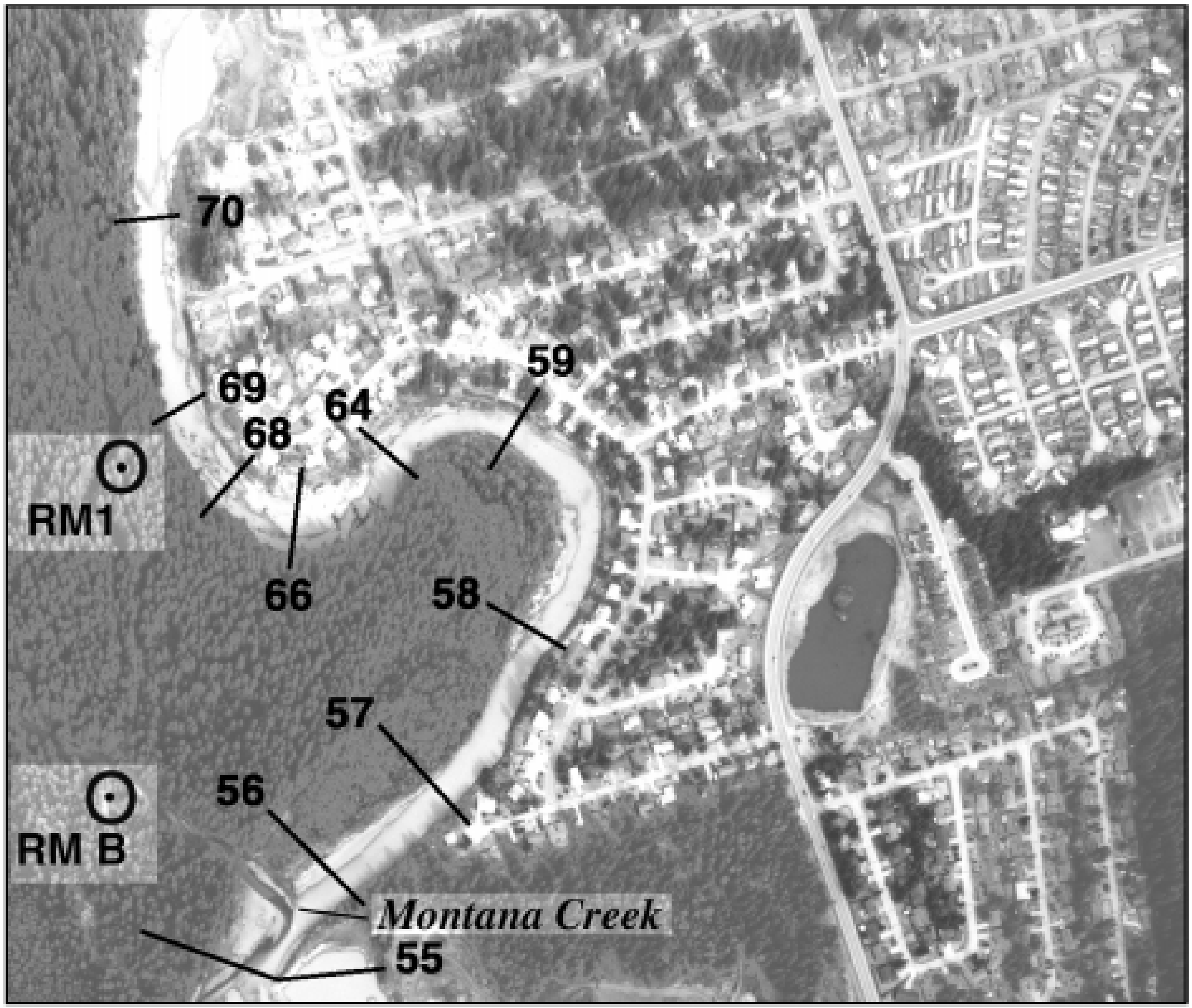


Figure 2D. Cross sections 70 to 55.

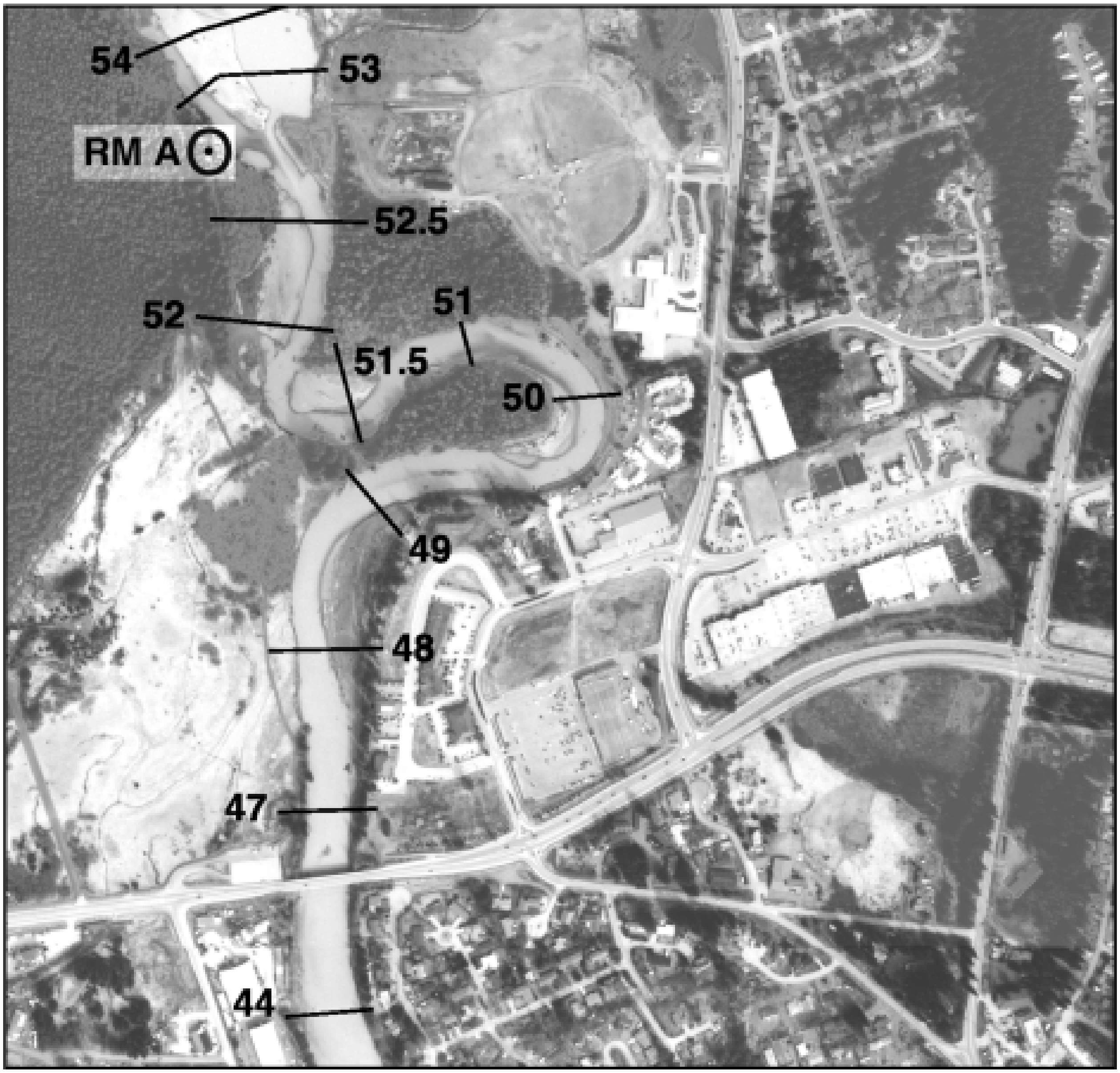


Figure 2E. Cross sections 54 to 44.

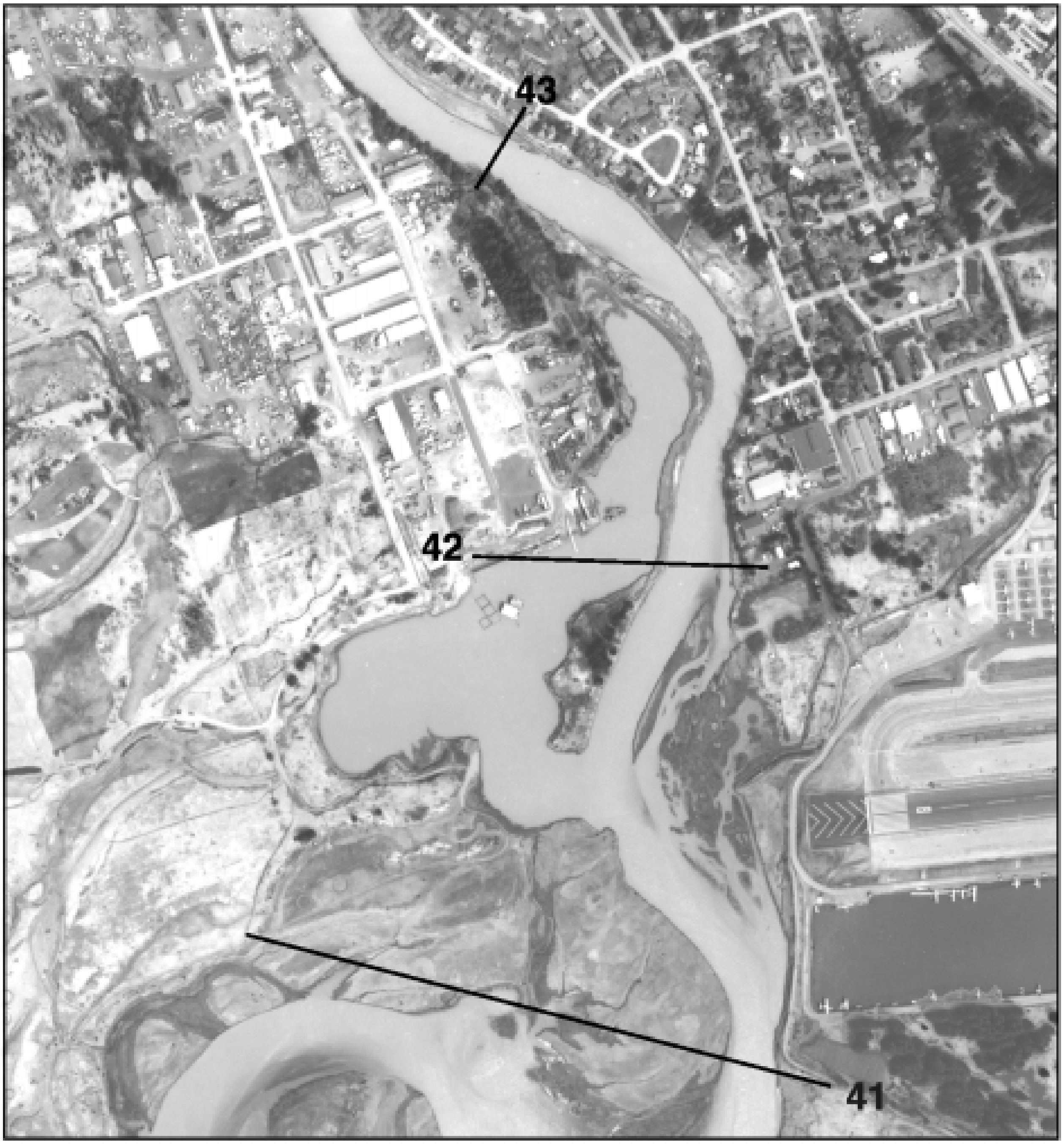


Figure 2F. Cross sections 43 to 41.

Figure 3. Upright stumps and root structures in channel bed, Mendenhall River, Alaska. (View is looking upstream from cross section 73).

Regional Uplift

Sea level observations in southeast Alaska indicate land-surface uplift relative to the level of the sea. Work first documented by Hicks and Shofnos (1965) indicated maximum uplift rates of about 0.13 ft/yr in Bartlett Cove, an area just east of Glacier Bay. Values given for uplift in the Juneau area were about 0.05 ft/yr from the period 1936 to 1962. Hicks and Shofnos believed the most probable cause of the observed uplift is rebound from present localized deglaciation in combination with general post-Wisconsin deglaciation. During 1979 and 1980, USGS personnel from the Alaska Geologic Earthquake Hazards Project measured the elevations of selected tidal benchmarks relative to sea level to determine whether emergence in the region was continuous (Hudson and others, 1982). Comparing the data sets of Hicks and Shofnos with those of the Alaska Geologic Earthquake Hazards Project indicated that regional uplift has continued at rates comparable to those determined by Hicks and Shofnos with some localized differences. Hudson and others (1982) measured 0.92 ft of uplift for the Juneau area for the period from 1959 to 1979-80. Their work included tentative interpretations suggesting that uplift is tectonic in origin. They indicated that the regional tectonic uplift may be related to strain buildup along the transform boundary that is defined by the Queen Charlotte-Fairweather transform fault system, which lies roughly at the western margin of the uplifted region. Continued observation of tidal-gage data will be required to better understand the magnitude and extent of uplift in the region.

Mendenhall River Channel Adjustments

A river will attempt, over time, to incise its channel to "base level," the level below which deposition will dominate over erosion. For the Mendenhall River and other coastal rivers, base level is sea level. The presently occurring uplift of the land surface in the Mendenhall Valley is equivalent to a lowering of base level. That is, sea level appears to be declining relative to the land surface, although it is actually the land rising relative to sea level. As base level declines, the gradient of the channel will be increased in the downstream reach. The increased gradient of the channel can be expected to result in increased velocities and increased ability of the stream to scour the bed, resulting in downcutting of the stream channel. These downcutting or incision processes will continue upstream until the gradient is adjusted so as to supply just the ability to transport the sediment supplied by the stream. These processes have been described by Mackin (1948) and Leopold and others (1964). As the gradient of the channel adjusts over time, it should eventually develop a longitudinal profile that is parallel to the original profile, but at a lower elevation about equal to base level lowering (Mackin, 1948).

Channel incision is slowed if there is an abundant sediment supply from upstream or if the river channel is heavily armored by materials that resist erosion. The large sediment supply from Mendenhall Glacier, however, is trapped by Mendenhall Lake and does not reach the river. The relatively small contribution of sediment from Montana Creek is not sufficient to prevent further incision of the Mendenhall River. The rate of incision, however, is slowed in the upper reaches by armoring of the banks and bed of the river. Above cross section 86, the river is armored by large boulders. Between cross sections 64 and 85, the river is armored by a mat of peat tied together by roots and trunks of dead trees. As this vegetative armor decomposes in coming decades, the rate of incision may increase in the reach between cross sections 64 and 85. Continuation of the channel incision process can be expected in the Mendenhall River channel system downstream from cross section 85; however, a variety of other hydraulic adjustments could influence the channel geomorphology so as to satisfy requirements imposed by base level lowering. If channel-incision processes continue, elevations of flood peaks, particularly in the unarmored lower reaches, can be expected to decrease.

Benchmarks of the vertical (elevation) datum used to determine both water-surface profiles and river channel geometry have risen with respect to sea level since their establishment. This same datum is used in the Mendenhall Valley for construction of roads, buildings, and other structures that may be subjected to flooding. Computed and actual flood profiles of the lower reaches of the Mendenhall River are significantly influenced by high tides. The lower reach of the river is noticeably influenced by large high tides as far upstream as cross section 69 (fig. 2D). As a result of land-surface uplift, the water level during high tide does not reach the same bank elevation as it once did.

The computations of water-surface profiles begin at the mouth of the river and are calculated in an upstream direction. The starting elevation is a predicted high tide elevation. If a regional land-surface-uplift rate of 0.05 ft/yr is assumed to be accurate and applied to the 1962 establishment of the base benchmark at the Juneau airport, total uplift for the time period from 1962-98 would be about 1.8 ft. Assuming that the land has risen 1.8 ft since 1962, a 20-foot tide in 1998 would reach only as far up the channel bank as an 18.2-foot tide in 1962.

METHODS OF ANALYSIS

The magnitude of a flood that is expected to be equaled or exceeded once on average during any 2-, 10-, 25-, 50-, and 100-year period (recurrence interval) was selected by the Alaska Department of Fish and Game and the City and Borough of Juneau for analysis. Although the recurrence interval represents the long-term average period between floods of a specific magnitude, rare floods could occur at short intervals or even within the same year. The risk of experiencing a rare flood increases when periods greater than 1 year are considered. The probability of a flood of a given recurrence interval occurring in a defined time period can be determined using the equation given by Zembrzuski and Dunn (1979, p. 22):

$$P = 1 - \left(1 - \frac{1}{t}\right)^n$$

where P is the probability of at least one exceedence within the specified time period, n is the time period, and t is the recurrence interval. P can be multiplied by 100 to obtain chance of exceedence. For example, the risk of having a flood that equals or exceeds the 100-year flood (1 percent chance of annual occurrence) in any 50-year period is about 40 percent, and for any 90-year period, the risk increases to about 60 percent. The analyses reported reflect flooding potentials that were based on conditions existing in the basin in 1998.

Hydrologic Analysis

Hydrologic analyses were carried out to establish the peak discharge-frequency relation for floods on the Mendenhall River and Montana Creek. Flood-discharge values are based on a statistical analysis of discharge records at the streamflow-gaging stations. The Mendenhall River near Auke Bay gaging station has 34 years of peak-flow records (1966-99) available for analysis. The peak flow of 1995 (16,000 ft^3/s) was considered to be the largest flow since 1965. The peak discharge on the Mendenhall River for the summer of 1961 (about 27,000 ft^3/s) was not used for this analysis, because stage and discharge could not be verified. The Montana Creek near Auke Bay gaging station has 17 non-consecutive years of peak-flow records available for analysis: 1966-75, 1984-87, and 1997-99.

The peak discharges were analyzed for selected recurrence intervals (table 1) by the

Table 1. Summary of 2-, 10-, 25-, 50-, and 100-year discharges at the Mendenhall River and Montana Creek gaging stations, Juneau, Alaska

[mi^2, square miles; see figure 1 for gaging-station locations]

USGS stream-gaging station and number	Drainage area (mi^2)	Flood discharge (in cubic feet per second)				
		2 year	10 year	25 year	50 year	100 year
Mendenhall River near Auke Bay (15052500)	85.1	8,340	12,300	14,200	15,700	17,100
95 percent confidence limits for Bulletin 17B[a] estimates		7,650–9,090	11,100–14,100	12,700–16,800	13,800–18,900	14,800–21,000
Montana Creek near Auke Bay (15052800)	15.5	1,240	2,070	2,560	2,960	3,380
95 percent confidence limits for Bulletin 17B[a] estimates		1,060–1,440	1,740–2,700	2,080–3,590	2,340–4,360	2,610–5,230

[a]U.S. Interagency Advisory Committee on Water Data (1982)

standard log-Pearson type III method (U.S Interagency Advisory Committee on Water Data, 1982). Values for floods of these recurrence intervals have been published by Jones and Fahl (1994). The values in this report differ slightly from those of Jones and Fahl for two reasons: (1) an additional 10 years of streamflow data were used in the analysis and (2) only the log-Pearson type III method was used in this study. The 100-year peak discharge for the gaging station Mendenhall River near Auke Bay is 17,100 ft^3/s; the 100-year peak discharge for the gaging station Montana Creek near Auke Bay is 3,380 ft^3/s (table 1)

Hydraulic Analysis

Water-surface elevations for the 2-, 10-, 25-, 50-, and 100-year flood were computed using the U.S. Army Corps of Engineers Hydrologic Engineering Center River Analysis System (HEC-RAS) model (U.S. Army Corps of Engineers, 1997a). The computational procedure of this model is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head). The following assumptions are implicit in the analytical expressions used in HEC-RAS: flow is steady, flow is gradually varied (except at hydraulic structures), flow is one dimensional so that velocity components in directions other than the direction of flow are not accounted for, and river channels have slopes less than 10 percent (U.S. Army Corps of Engineers, 1997b).

The HEC-RAS model uses surveyed channel cross sections to define the hydraulic characteristics of the channel. The locations of the cross sections were selected to represent the hydraulic characteristics of a reach, and each cross section was surveyed to define its shape. Sixty cross sections were surveyed during September 1997 and during the spring of 1998. Structural geometry and elevations were also obtained for two bridges. Cross sections were surveyed both upstream and downstream from the bridges to permit computation of any backwater that may occur as a result of the structures. A cross section typical of channel conditions is shown in figure 4. A cross section of the channel at the Mendenhall Loop Road Bridge is shown in figure 5.

Roughness of the channel influences flood-profile elevations by creating resistance to flow. Roughness coefficients (Manning's *n*) represent a summation of factors providing resistance to flow. The major factors are the size and shape of materials that make up the bank and bed of the channel. Other factors include channel surface irregularities, variations in channel geometry, depth, density and type of vegetation, obstructions, and the degree of channel meandering (Coon, 1998, p. 2). Values used for the roughness coefficients along the Mendenhall River range from 0.025 to 0.06 for the main channel and from 0.025 to 0.075 for overbank channel.

Peak Flow of October 20, 1998

On October 20, 1998, a peak flow of 12,400 ft^3/s was recorded at the Mendenhall River gaging station. The discharge was calculated from the stage-discharge relation shortly after a measurement of 11,000 ft^3/s. This peak was associated with an intense rainstorm accompanied by unseasonably warm temperatures and high winds. The heaviest rainfall occurred on October 19 and 20. The Juneau airport recorded 6.28 in. of rainfall in a 48-hour period (the highest recorded for a 2-day period). Rainfall totals demonstrate the variability within the Juneau area; during the same storm, Auke Bay recorded 5.75 in. and Twin Lakes (fig. 1) received 10.0 in. Rainy weather persisted for several days prior to the peak flow, which resulted in saturated soils at the onset of the storm. The freezing level had dropped to

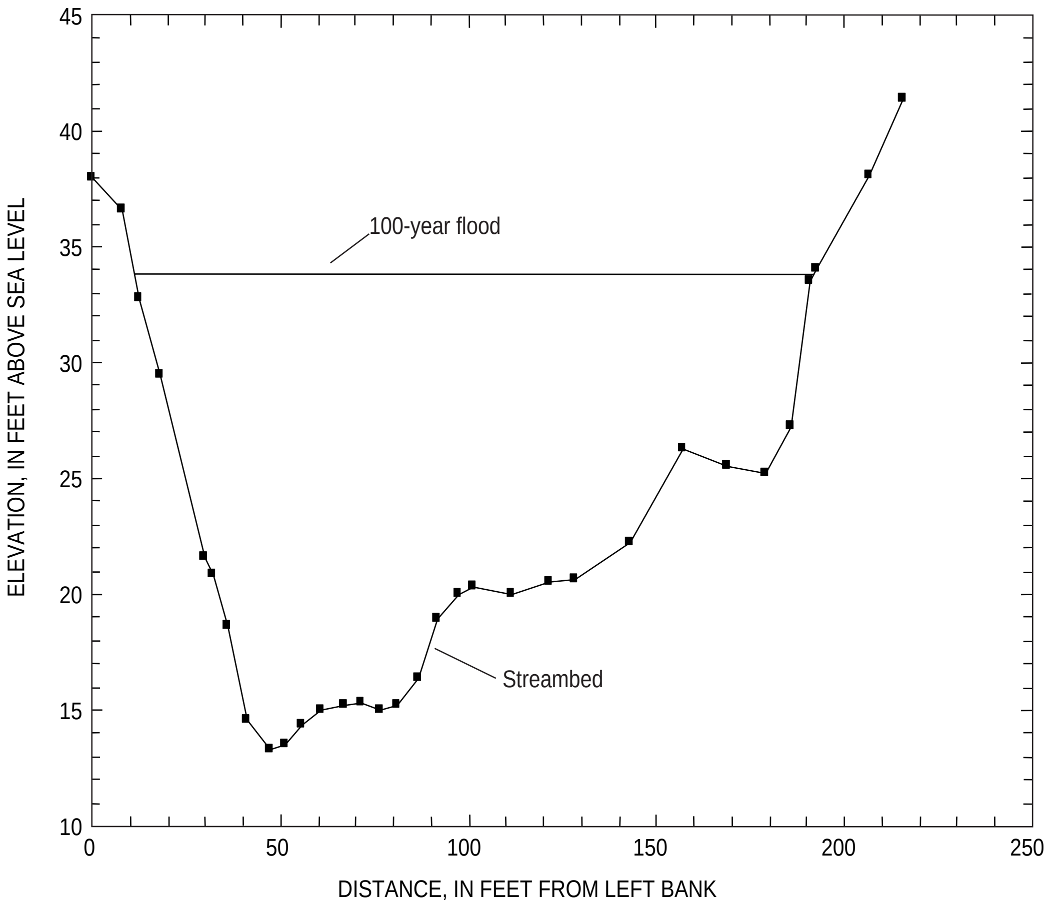


Figure 4. Cross section 74, showing typical channel conditions in the lower reach of the Mendenhall River, Alaska.

2,000 ft before the storm, but rose to 6,000 ft on October 19. The rapid rise in temperature accompanied by high winds probably contributed substantially to the peak flow by melting snow at higher elevations (National Oceanic and Atmospheric Administration, written commun., 1998).

The October 20 peak provided an opportunity to calibrate flood profiles on the Mendenhall River. Floodmarks left by the peak were surveyed at several cross sections along the length of the river. After the floodmarks were plotted at their respective cross section, channel-roughness coefficients and hydraulic properties were adjusted to provide profiles closely matching the measured floodmarks. The surveyed flood-mark elevations and computed water-surface profiles for the October 20 peak are shown on figure 6. The computation of profiles for calibration used a discharge of 12,400 ft^3/s from the outlet of Mendenhall Lake continuing downstream to cross section 56 (fig. 2D); at cross section 55, the discharge was increased to 13,600 ft^3/s to account for tributary inflow from Montana Creek.

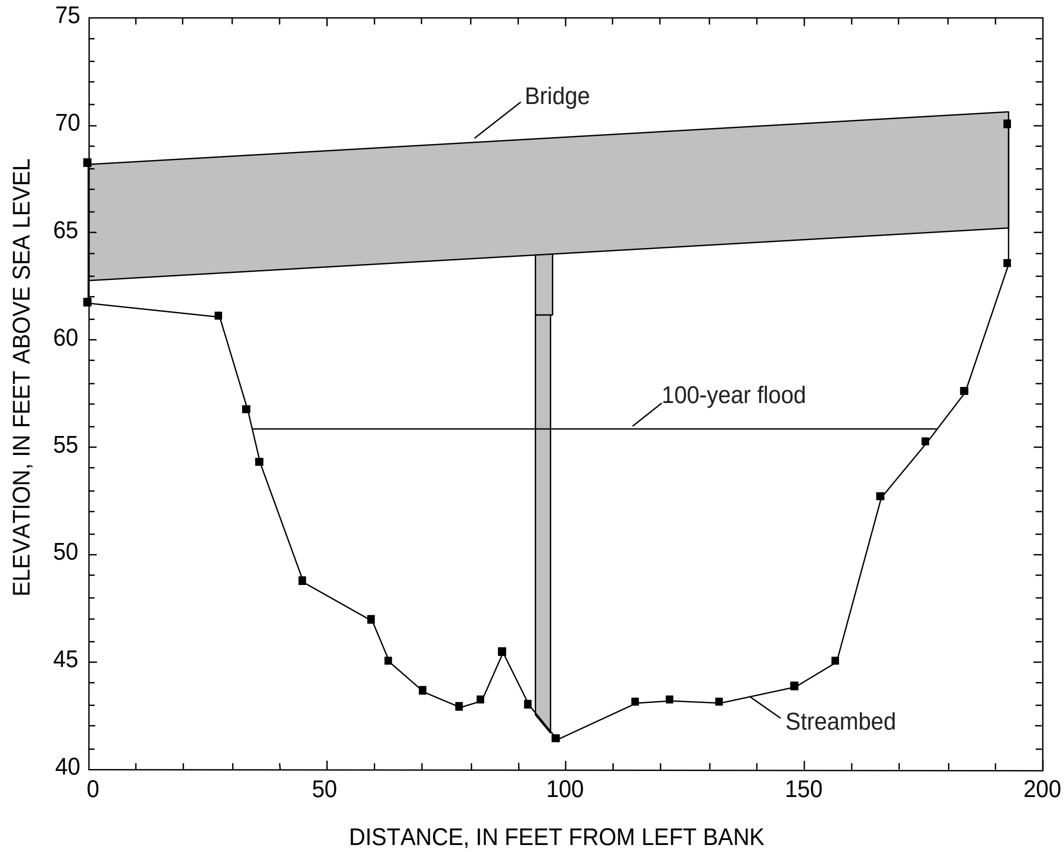


Figure 5. Cross section 93, showing upstream side of the Mendenhall River Road Bridge, Alaska.

Channel-roughness coefficients used in the initial hydraulic computations and at cross sections where no floodmarks were surveyed were based on judgment of onsite observations of the channel and flood-plain area with reference to Barnes (1967) and Hicks and Mason (1991). The value for roughness coefficients can be expected to change slightly with increase or decrease in discharge for a given reach of stream. Because it was not practical to survey water-surface profiles over the range of flows needed, the *n* values determined from calibration at 12,400 ft^3/s were used for water-surface profile computations of all discharges analyzed. Work done by Coon (1998, p. 131) found that "on low-gradient, wide channels with large relative smoothness, the computed *n* values remained relatively constant with increasing flow depth. On high-gradient channels with low relative smoothness, the computed roughness coefficient decreased with increasing depth."

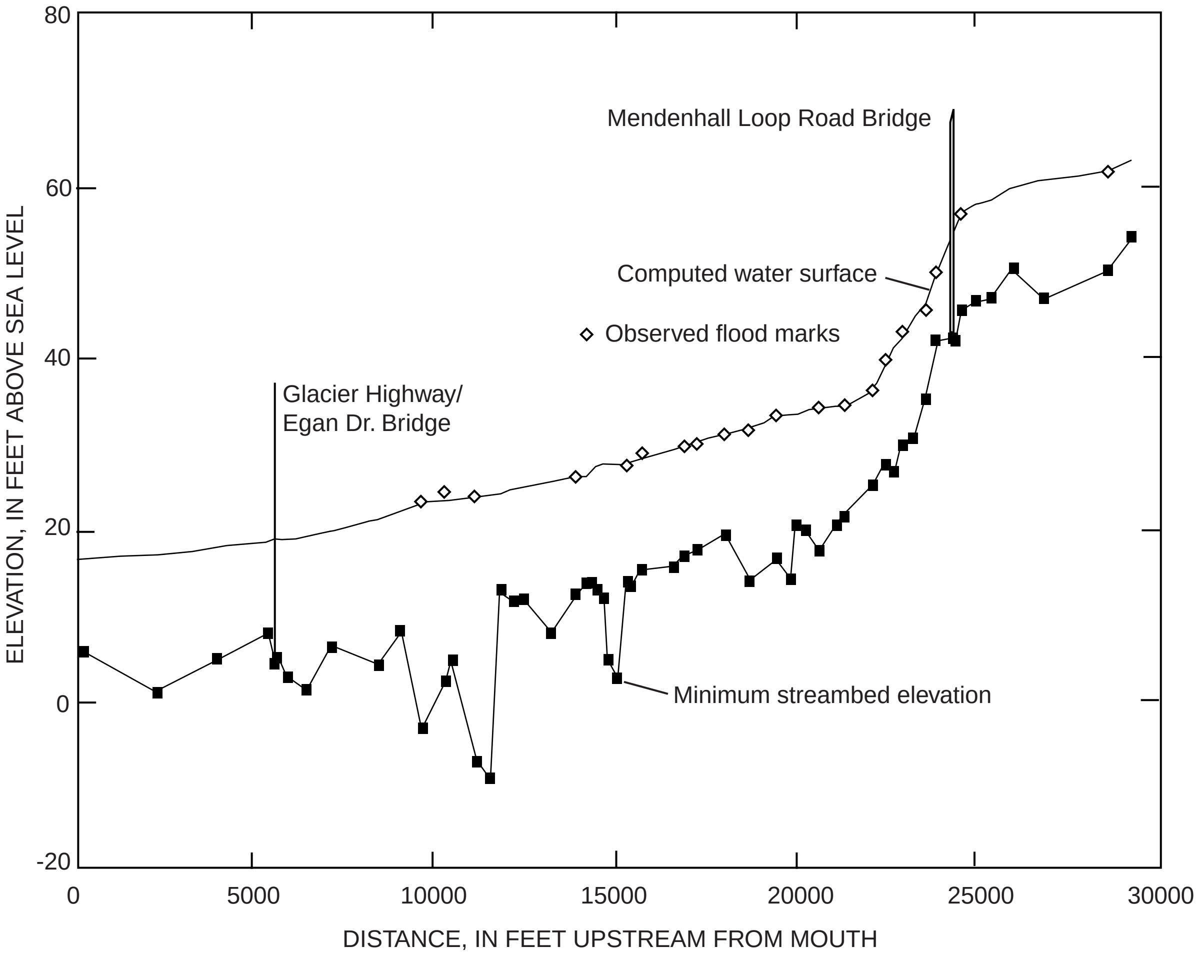


Figure 6. Profile of computed water-surface elevations for the peak flow of October 20, 1998, streambed elevations, location of cross sections, and observed flood marks.

Coon's work indicates that the selected roughness coefficients will remain valid for the lower reaches of the study area over the range of discharges analyzed. The high-gradient reach of the river (cross sections 85 to 41, figs. 2B-F) has larger roughness coefficients that may decrease slightly with the increasing depths associated with 50-and 100-year flood discharges. This factor would result in actual water-surface elevations that may be slightly lower than the computed water-surface profiles for the high-gradient reach of the river.

Flood Profile Computations

For the computation of the 100-year flood profile, the discharge value of 17,100 ft^3/s was used from the outlet of Mendenhall Lake continuing downstream to cross section 56 (fig. 2D); at cross section 55, the discharge was increased to 20,500 ft^3/s to account for tributary inflow from Montana Creek. Identical methods were used for the computations of the 2-, 10-, 25-, and 50-year flood profiles using the respective flood discharges from Mendenhall River and Montana Creek (table 1).

Examination of 11 peak flows from Montana Creek and Mendenhall River (1970-75, and 1984-87, including the peak of October 20, 1998) indicates that peak flow from the Montana Creek drainage area has a shorter time of concentration and is therefore not likely to coincide with the peak flows of the Mendenhall River. The peak flows on the Mendenhall River usually occurred 9 to 48 hours after the peak of Montana Creek with the exception of peaks on August 24, 1974 and October 16, 1986. On those dates, the Mendenhall River peak flows (5,900 and 5,960 ft^3/s, respectively), occurred one-half hour after those of Montana Creek. Adding the discharges of the Mendenhall River and Montana Creek for the 2-, 10-, 25-, 50-, and 100-year floods results in a conservative estimate of peak flows below cross section 56 because the peaks are not likely to coincide. The storm on October 20, 1998 resulted in a peak flow of 3,800 ft^3/s on Montana Creek at about 11:00 a.m. The peak flow on the Mendenhall River occurred at 9:00 p.m. During this 10-hour period, the discharge for Montana Creek had already decreased to 1,200 ft^3/s.

Computations of flood-profile elevations begin at the downstream end of the study area at a location where the water-surface elevation will be controlled by the elevation of the tide. The starting water-surface elevation (20 ft) used to compute the 2-, 10-, 25-, 50-, and 100-year flood profiles was determined from a high tide that would occur during a month in which peak flows of the 100-year recurrence interval were likely to occur (Federal Emergency Management Agency, 1990). The calculated profiles for the 2-, 10-, 25-, 50-, and 100-year flood assume that peak flows coincide with the peak of the tide cycle at a high tide of 20 ft. Should these peak flows coincide with tides of smaller magnitude, or across the low end of the tide cycle, water-surface elevations will be lower in the downstream reach of the river than those predicted in this report. The model indicates that water-surface profile elevations upstream from cross section 62 will not be significantly affected by tides during a 100-year flood.

Water-surface elevations of the upstream boundary of the study area (Mendenhall Lake outlet) can be converted to gage datum at the Mendenhall River near Auke Bay gaging station by subtracting 54.42 ft from the computed profile. Water-surface elevations at cross section 100 (Mendenhall Lake outlet) will not match the stage-discharge rating curve at the gaging station. The channel configuration of the lake outlet will not satisfy the required model assumption of steady gradually varied flow due to the rapid decrease in depth and width and subsequent increase in velocity as the river exits the lake.

FLOOD PROFILES

The water-surface profiles for the 2-, 10-, 25-, 50-, and 100-year floods (table 2; p. 22-23) were drawn for the Mendenhall River from the outlet of Mendenhall Lake to its mouth at Fritz Cove (figs. 7-11; p. 24-33). The profiles show the computed water-surface elevations, the minimum streambed elevations, and the location of bridges and cross sections used in the hydraulic analysis. The hydraulic analyses were based on unobstructed flow. The flood elevations shown can only be considered valid if hydraulic structures do not fail. Profiles will not account for debris jams or catastrophic bank failures that may occur during flooding.

All field surveys and elevations are referenced to Mean Lower Low Water, which is a local datum that is 8.2 ft below the National Geodetic Vertical Datum of 1929. The survey data were tied to a network of vertical reference marks that were established during the field surveys. Approximate locations of reference marks are shown on figure 2A-F as “RM” and reference-mark descriptions are given in the appendix.

SUMMARY

The Mendenhall River is heavily influenced by glacial meltwater, and large floods are most likely to occur when heavy rain falls during a period of high glacial melt (July to September). The Mendenhall River channel was probably formed about 100 to 250 years ago, when the Mendenhall Glacier began its most recent retreat. After the river breached the terminal moraine at the present lake outlet, it rapidly incised a channel through moraine deposits and across the floor of the Mendenhall Valley. The river channel has maintained lateral stability since this time. Although the Mendenhall River originates as a glacial stream, it does not carry a large load of coarse sediment. Mendenhall Lake acts as a sink for most coarse sediments supplied to the system from its glacial sources. Other sources of coarse sediment may include sediment derived from channel incision, bank-erosion processes, and Montana Creek.

Rates of land-surface uplift in the study area are probably near 0.05 ft/yr. Continued uplift will likely result in a continuation of channel downcutting in the lower reaches, making it less likely that large floods will overtop the banks of the river and extend into the flood plain. Continuation of the channel incision process can be expected in the Mendenhall River channel system downstream from cross section 85 (fig. 2B); however, a variety of other hydraulic adjustments could influence the channel geomorphology so as to satisfy requirements imposed by base level lowering. If channel incision processes continue, elevations of flood peaks in the lower reaches can be expected to decrease.

Standard hydrologic and hydraulic methods were used to analyze flood flow data for the Mendenhall River. The magnitudes of the 2-, 10-, 25-, 50-, and 100-year floods were determined for the reach of the Mendenhall River extending downstream from the Mendenhall Lake outlet to the mouth at Fritz Cove. Flood discharges for the 100-year flood ranged from 17,100 ft^3/s at the lake outlet to 20,500 ft^3/s downstream from the confluence with Montana Creek. It is assumed that Montana Creek and Mendenhall River will peak simultaneously and that the peak will coincide with a 20-foot high tide. These assumptions result in conservative calculations of discharge below cross section 56, and conservative computation of water-surface profiles downstream from cross section 69.

Data used for 60 channel cross sections were obtained from field surveys of a 5.5-mile reach of the river. Manning's roughness coefficients were estimated using engineering judgment and further refined and calibrated using floodmarks from a known discharge. These data were used to compute water-surface elevations for the 2-, 10-, 25-, 50-, and 100-year floods at each cross section. Computations were made using USACE HEC-RAS streamflow model.

Table 2. Computed water-surface elevations for the 2-, 10-, 25-, 50-, and 100-year flood discharges, Mendenhall River, Alaska

[Selected cross-section locations are shown on figures 2A-2F]

Cross section number	Distance upstream from mouth (feet)	Water-surface elevation (feet above sea level)				
		2 year	10 year	25 year	50 year	100 year
Mendenhall Lake	29,250	62.6[a]	64.1[a]	64.7[a]	65.1[a]	65.5[a]
99	28,439	59.3	60.9	61.6	62.1	62.5
98	26,659	58.8	60.2	60.8	61.3	61.8
97	25,849	57.9	59.4	60.1	60.6	61.1
96	25,209	56.0	57.7	58.6	59.2	59.8
95	24,809	55.2	57.1	58.0	58.7	59.3
94	24,384	54.0	56.2	57.1	57.8	58.4
93.5	24,216	52.6	54.4	55.2	55.8	56.4
93	Bridge	Bridge	Bridge	Bridge	Bridge	Bridge
92	24,156	51.9	53.5	54.2	54.7	55.2
91	23,686	47.7	48.8	49.4	49.9	50.3
90	23,386	43.3	45.7	46.4	47.0	47.5
89	23,001	41.2	43.7	44.7	45.4	45.9
88	22,701	39.6	41.8	42.8	43.6	44.2
87	22,494	38.8	40.7	41.6	42.3	42.9
86	22,224	36.8	38.6	39.4	40.0	40.5
85	21,919	33.6	35.7	36.8	37.6	38.2
84	21,139	32.0	33.9	34.8	35.5	36.1
83	20,876	31.9	33.9	34.8	35.5	36.1
82	20,389	31.3	33.5	34.4	35.2	35.8
81	20,019	31.1	33.2	34.2	34.9	35.6
80	19,769	30.9	33.1	34.1	34.8	35.4
79	19,609	30.7	32.9	33.9	34.7	35.3
77	19,219	30.3	32.7	33.7	34.5	35.1
74	18,439	29.1	31.5	32.5	33.2	33.8
73	17,839	28.2	30.6	31.6	32.4	33.1
72	17,049	27.4	29.7	30.7	31.4	32.1
71	16,709	27.1	29.5	30.5	31.3	32.0
70	16,399	26.6	28.9	29.9	30.7	31.4
69	15,529	25.7	28.0	28.9	29.7	30.3
68	15,206	25.4	27.7	28.6	29.4	30.0
67	15,062	25.4	27.7	28.7	29.5	30.1
66	14,775	25.3	27.6	28.6	29.3	29.9

Table 2. Computed water-surface elevations for the 2-, 10-, 25-, 50-, and 100-year flood discharges, Mendenhall River, Alaska--Continued

[Selected cross-section locations are shown on figures 2A-2F]

Cross section number	Distance upstream from mouth (feet)	Water-surface elevation (feet above sea level)				
		2 year	10 year	25 year	50 year	100 year
65	14,579	25.2	27.5	28.4	29.1	29.7
64	14,419	25.2	27.4	28.4	29.1	29.7
63	14,265	25.1	27.3	28.3	29.0	29.6
62	14,117	24.7	26.9	27.8	28.5	29.1
61	13,935	24.3	26.3	27.2	27.8	28.4
59	13,656	24.3	26.3	27.2	27.8	28.4
58	12,976	23.8	25.7	26.5	27.1	27.6
57	12,266	23.3	25.1	25.9	26.5	27.0
56	11,936	23.2	24.9	25.8	26.4	26.9
55	11,586	22.8	24.5	25.3	25.9	26.5
54	11,226	22.8	24.5	25.3	25.9	26.5
53	10,903	22.8	24.5	25.3	25.9	26.5
52.5	10,266	22.5	24.2	25.0	25.6	26.2
52	10,039	22.4	24.0	24.8	25.5	26.0
51.5	9,437	22.0	23.6	24.3	24.9	25.5
51	8,811	21.5	22.7	23.3	23.8	24.3
50	8,251	21.2	22.3	22.9	23.4	23.8
49	6,951	20.7	21.4	21.8	22.2	22.6
48	6,194	20.5	21.1	21.5	21.8	22.1
47	5,653	20.4	20.8	21.1	21.3	21.5
46	5,383	20.3	20.8	21.0	21.2	21.4
45.5	Bridge	Bridge	Bridge	Bridge	Bridge	Bridge
45	5,333	20.3	20.7	21.0	21.2	21.4
44	5,123	20.3	20.7	20.9	21.1	21.3
43	3,700	20.2	20.4	20.5	20.7	20.8
42	2,100	20.0	20.0	20.0	20.0	20.0
41		20.0	20.0	20.0	20.0	20.0

[a]Water-surface elevation from stage-discharge relation extended above 11,000 ft^3/s

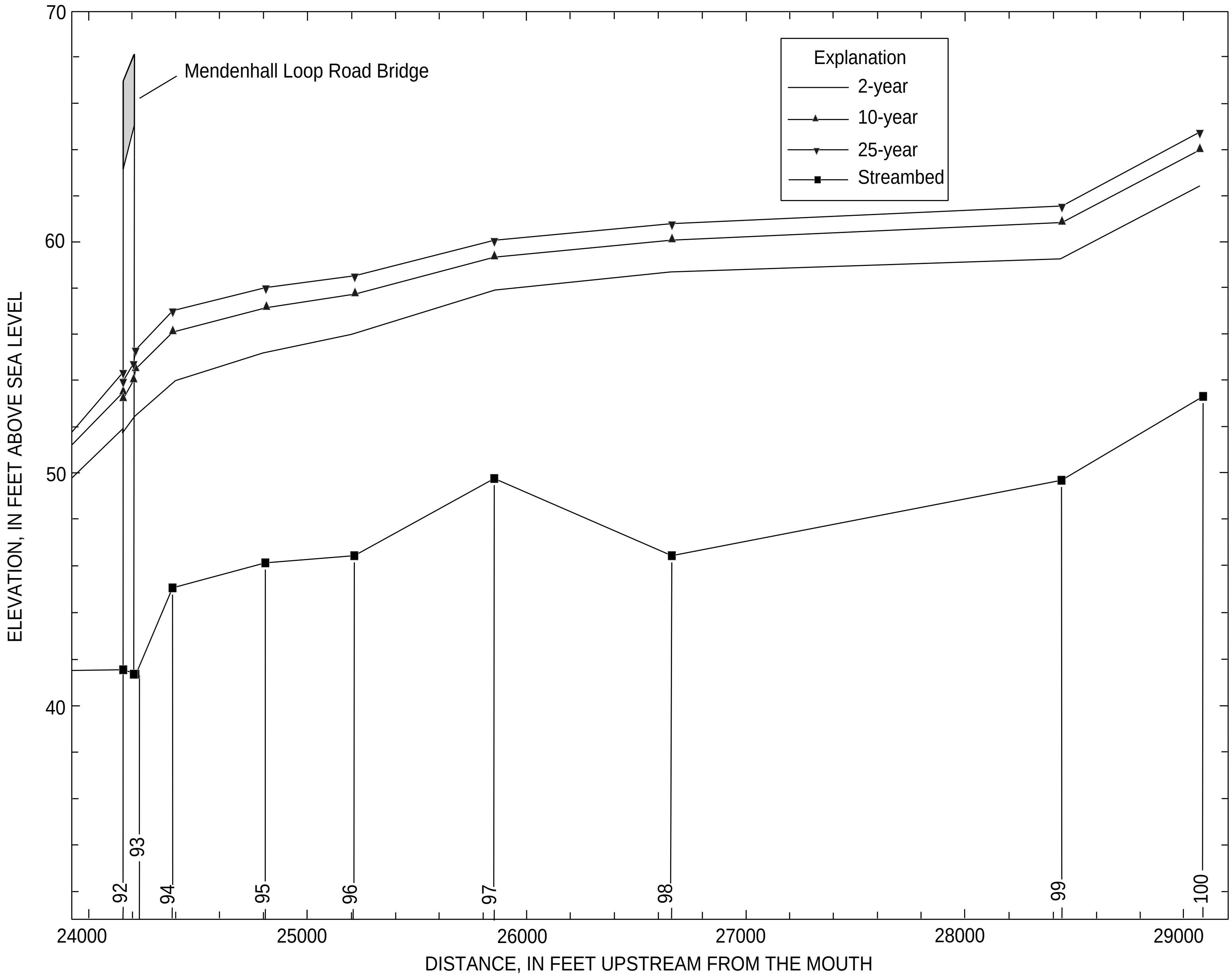


Figure 7A. Profiles of computed water-surface elevations, elevations of streambed, and locations of cross sections for the Mendenhall River, Alaska, cross sections 100 to 92, for 2-, 10-, and 25-year floods.

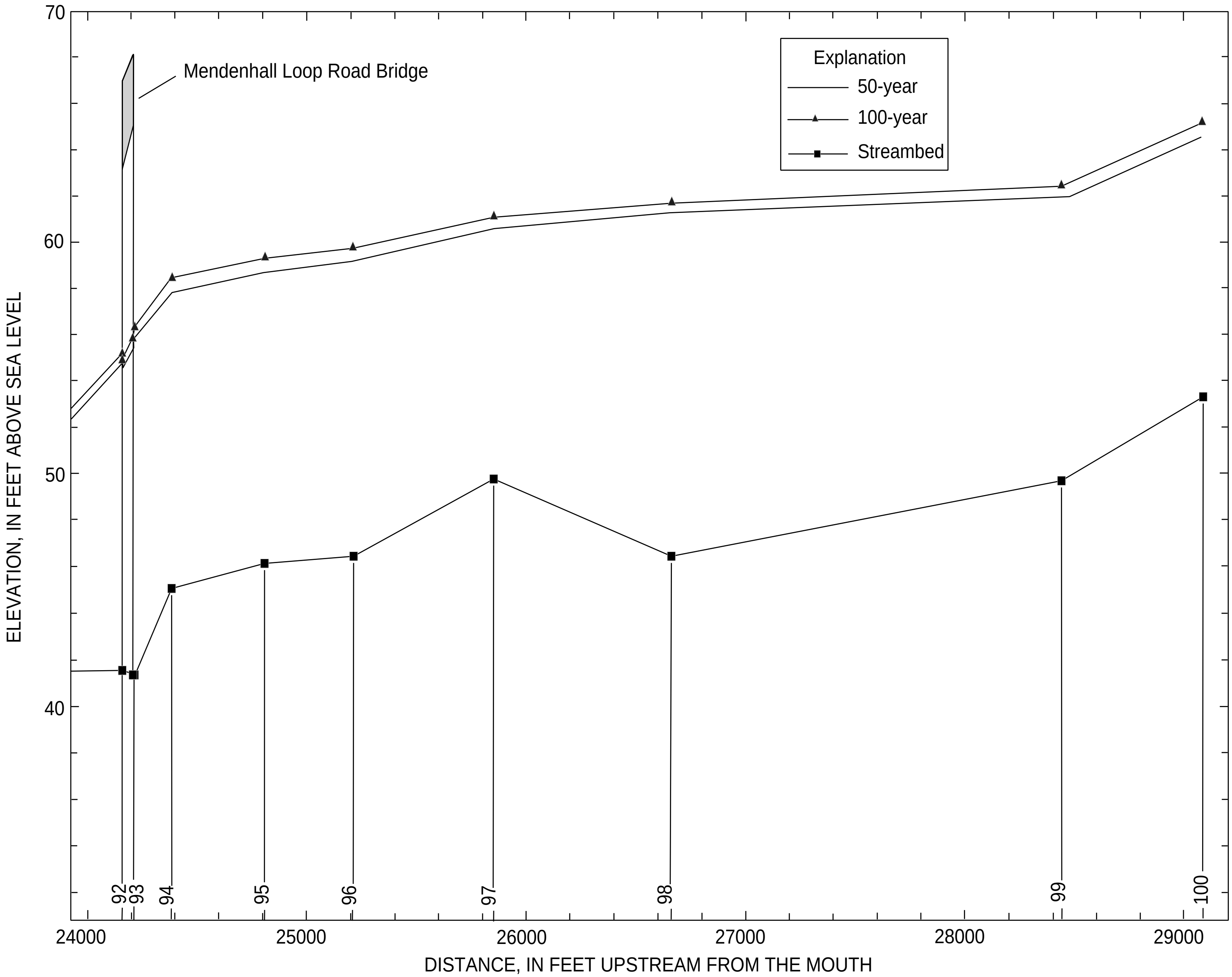


Figure 7B. Profiles of computed water-surface elevations, elevations of streambed, and locations of cross sections for the Mendenhall River, Alaska, cross sections 100 to 92, for 50-, and 100-year floods.

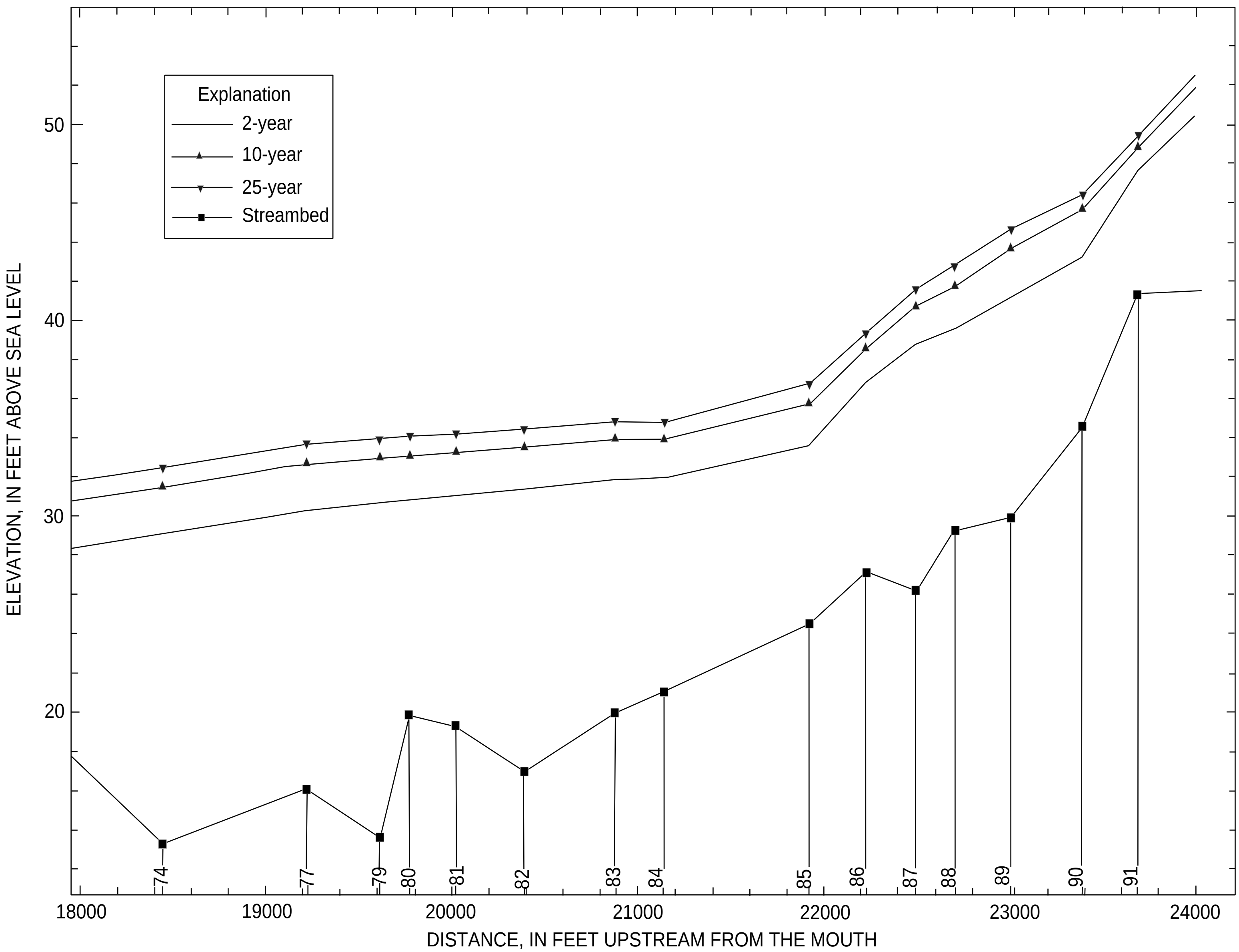


Figure 8A. Profiles of computed water-surface elevations, elevations of streambed, and locations of cross sections for the Mendenhall River, Alaska, cross sections 91 to 74, for 2-, 10-, and 25-year floods.

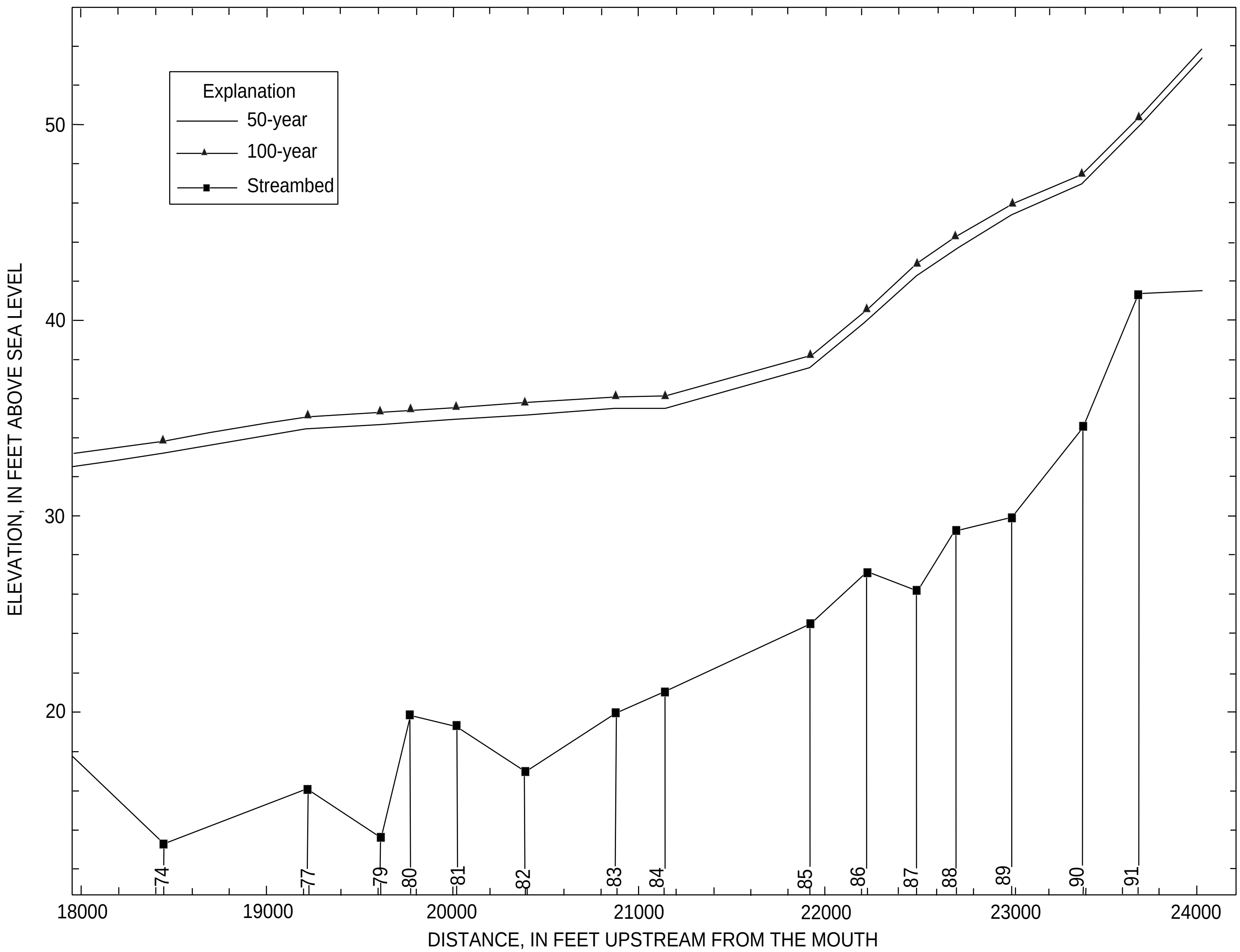


Figure 8B. Profiles of computed water-surface elevations, elevations of streambed, and locations of cross sections for the Mendenhall River, Alaska, cross sections 91 to 74, for 50-, and 100-year floods.

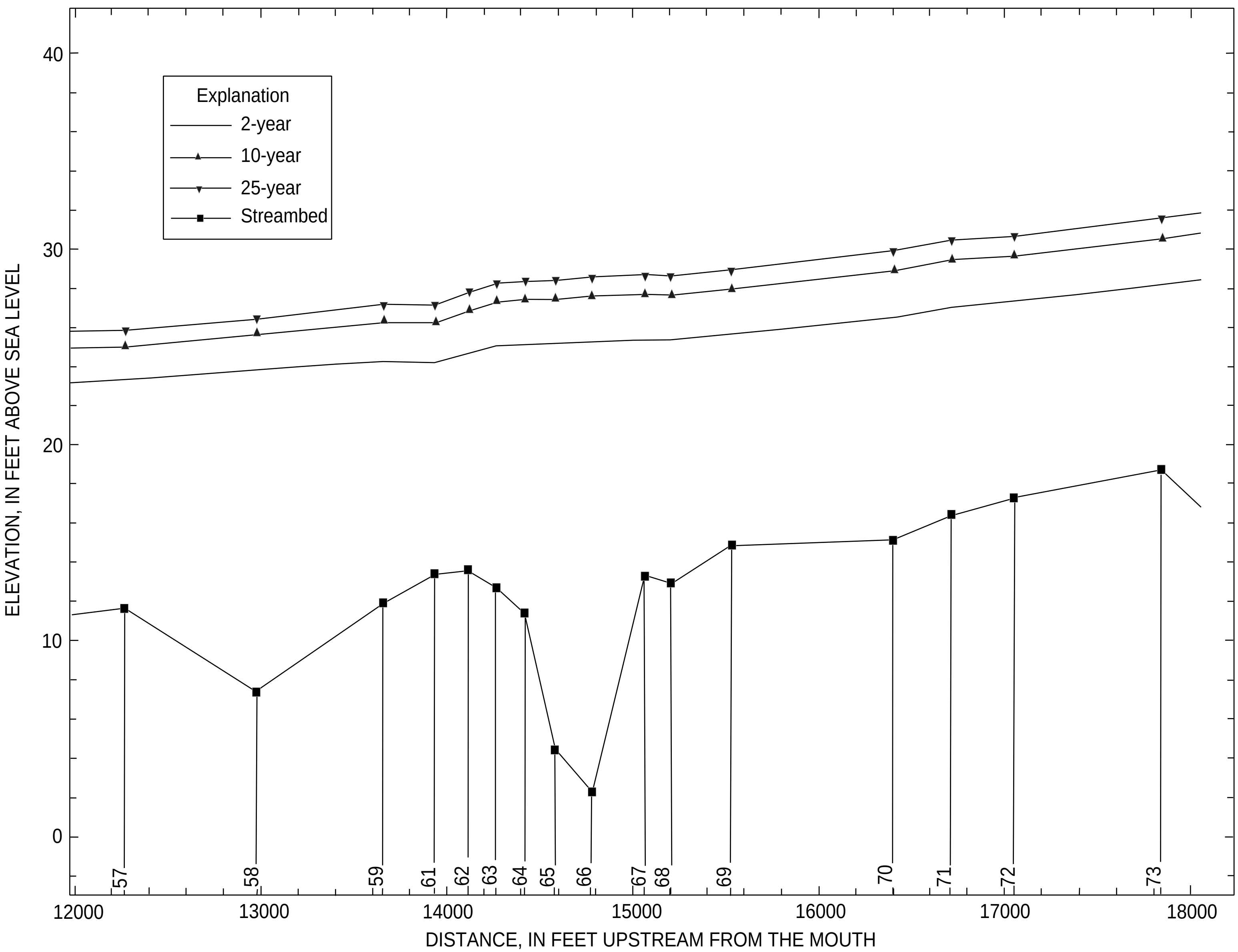


Figure 9A. Profiles of computed water-surface elevations, elevations of streambed, and locations of cross sections for the Mendenhall River, Alaska, cross sections 73 to 57, for 2-, 10-, and 25-year floods.

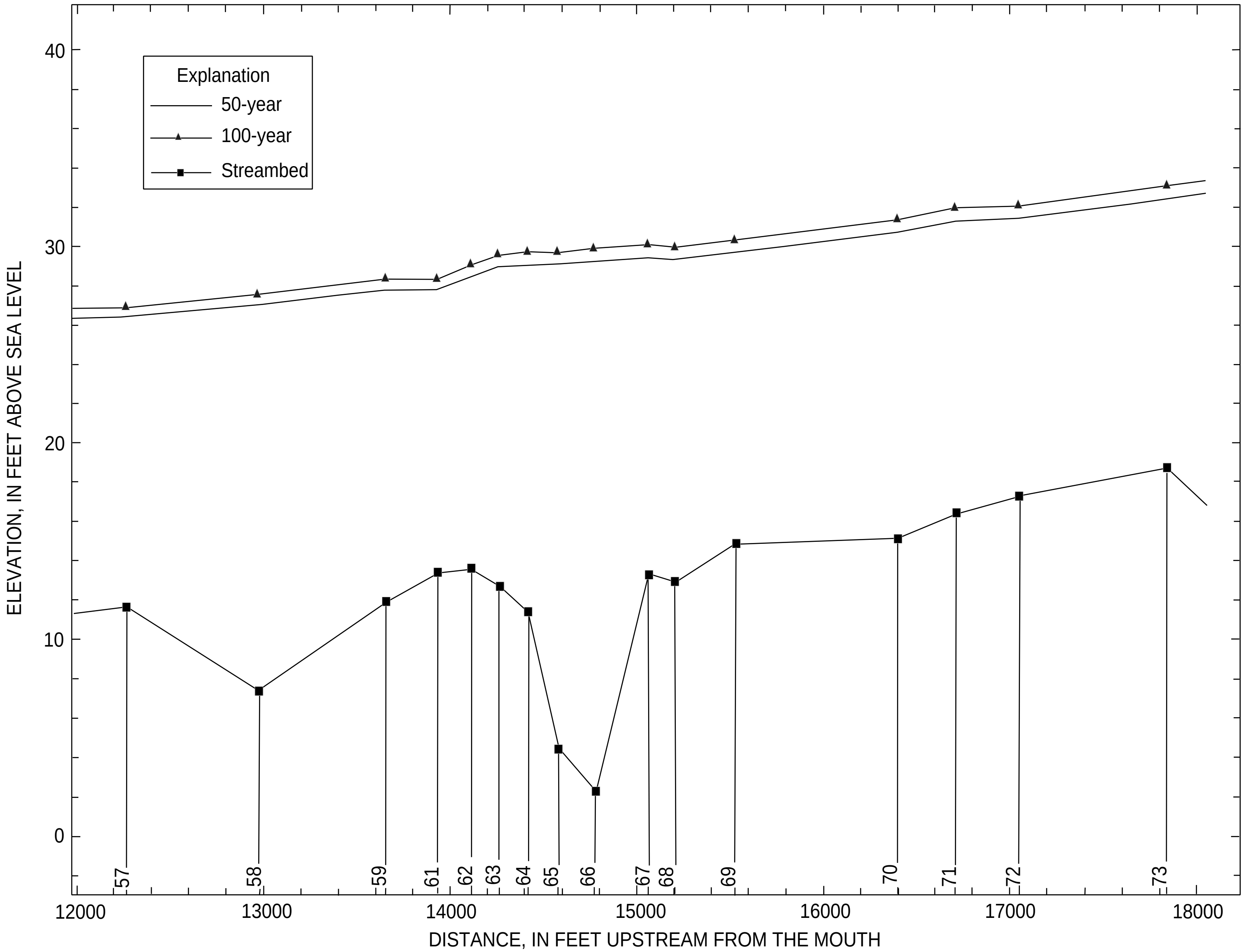


Figure 9B. Profiles of computed water-surface elevations, elevations of streambed, and locations of cross sections for the Mendenhall River, Alaska, cross sections 73 to 57, for 50-, and 100-year floods.

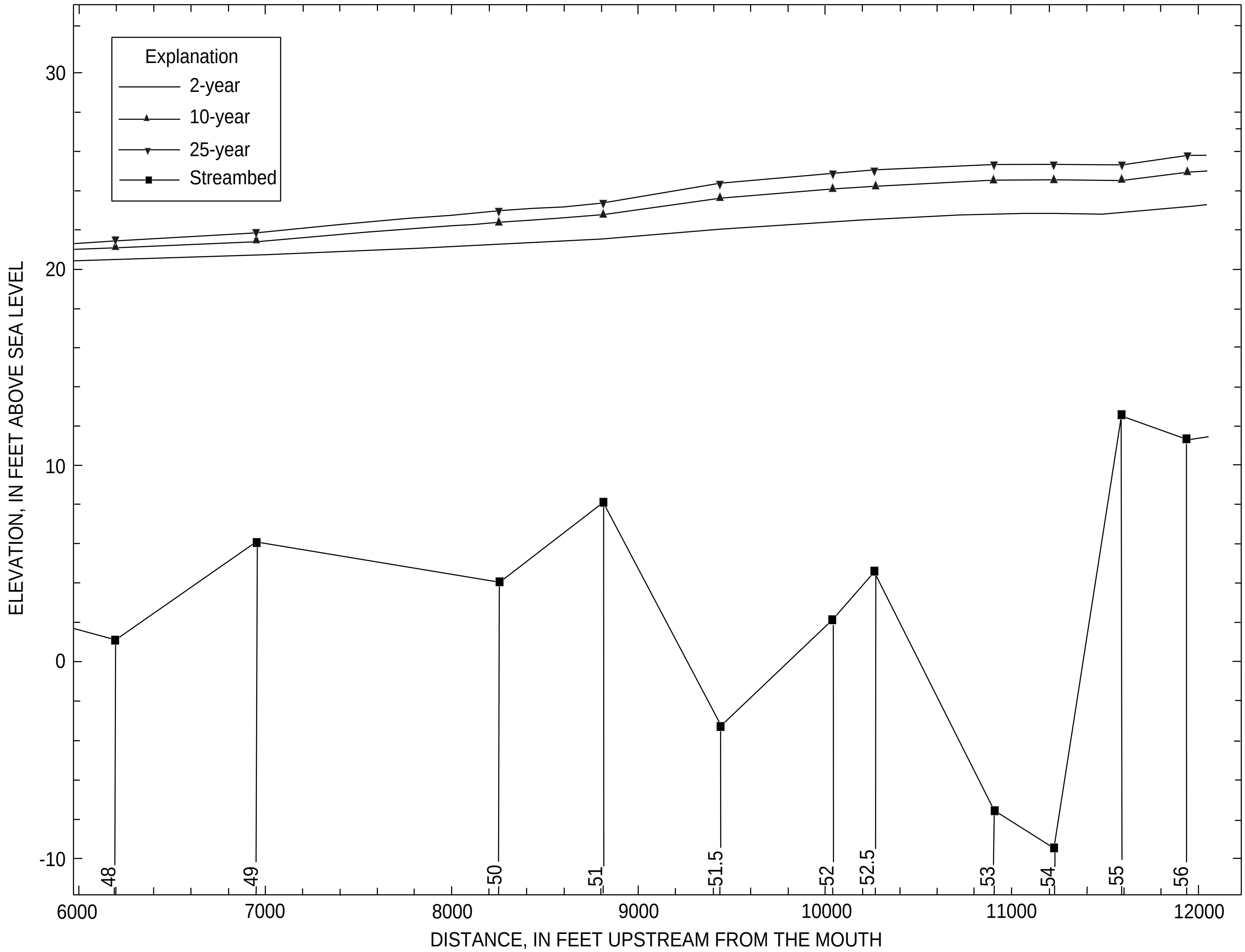


Figure 10A. Profiles of computed water-surface elevations, elevations of streambed, and locations of cross sections for the Mendenhall River, Alaska, cross sections 56 to 48, for 2-, 10-, and 25-year floods.

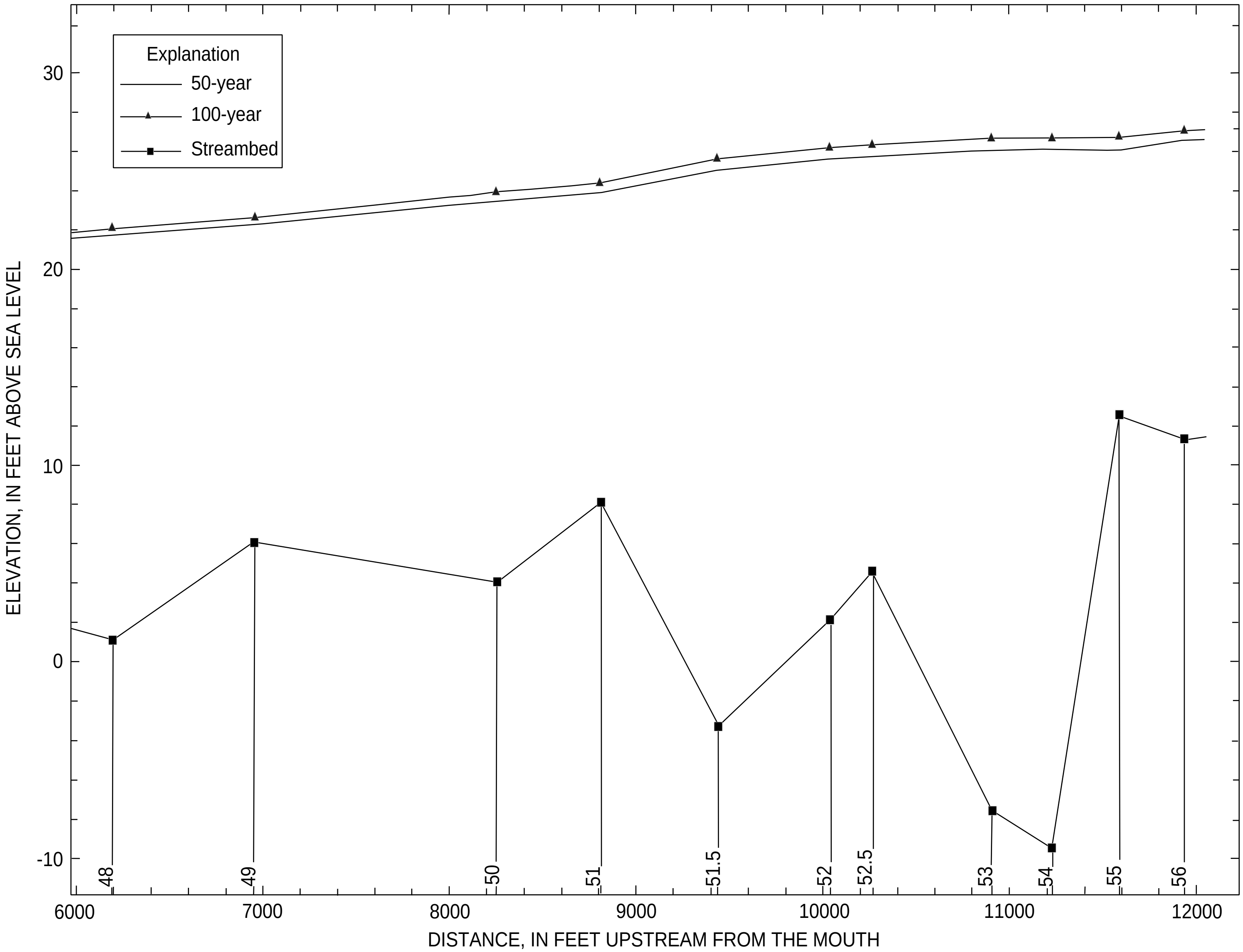


Figure 10B. Profiles of computed water-surface elevations, elevations of streambed, and locations of cross sections for the Mendenhall River, Alaska, cross sections 56 to 48, for 50-, and 100-year floods.

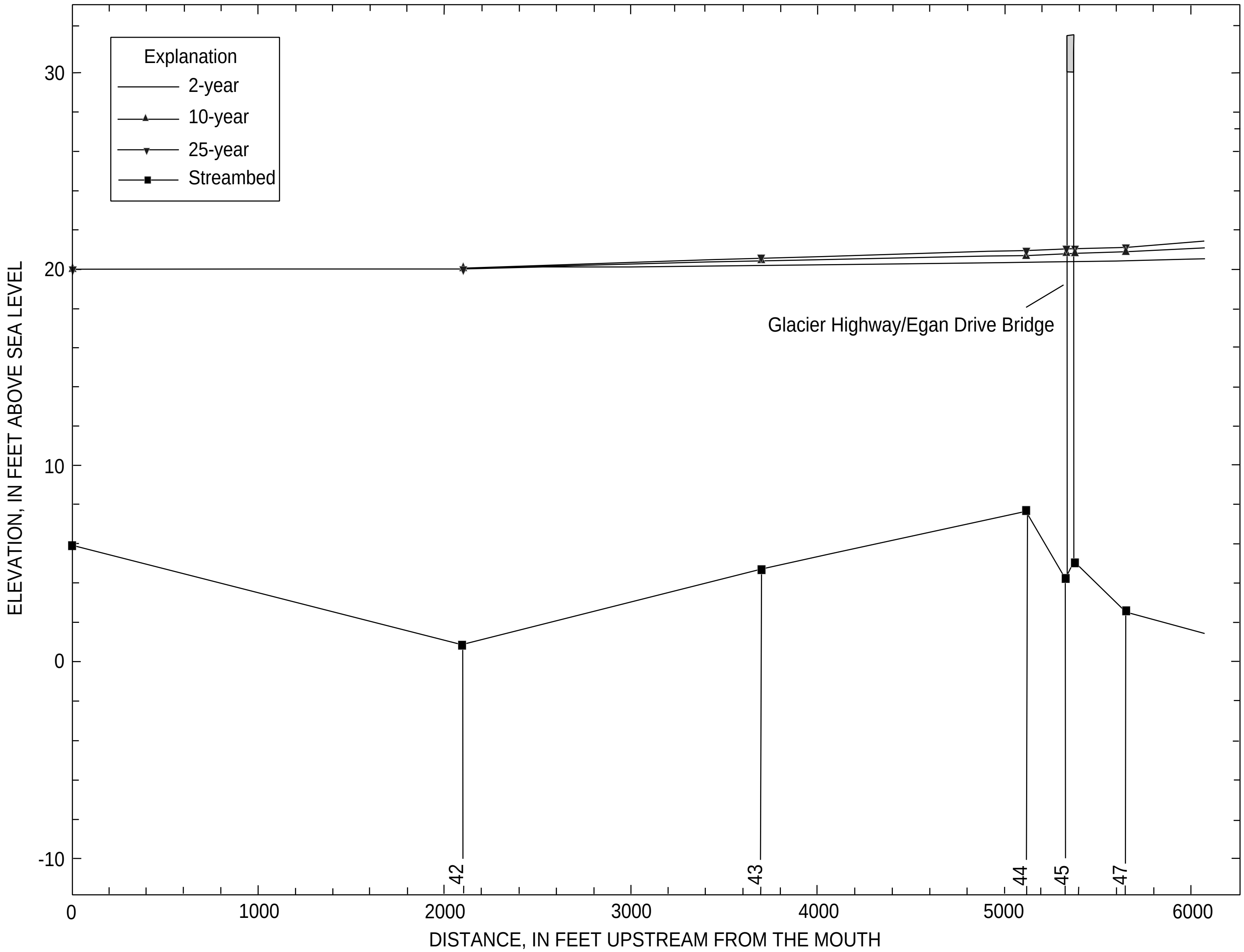


Figure 11A. Profiles of computed water-surface elevations, elevations of streambed, and locations of cross sections for the Mendenhall River, Alaska, cross sections 47 to 42, for 2-, 10-, and 25-year floods.

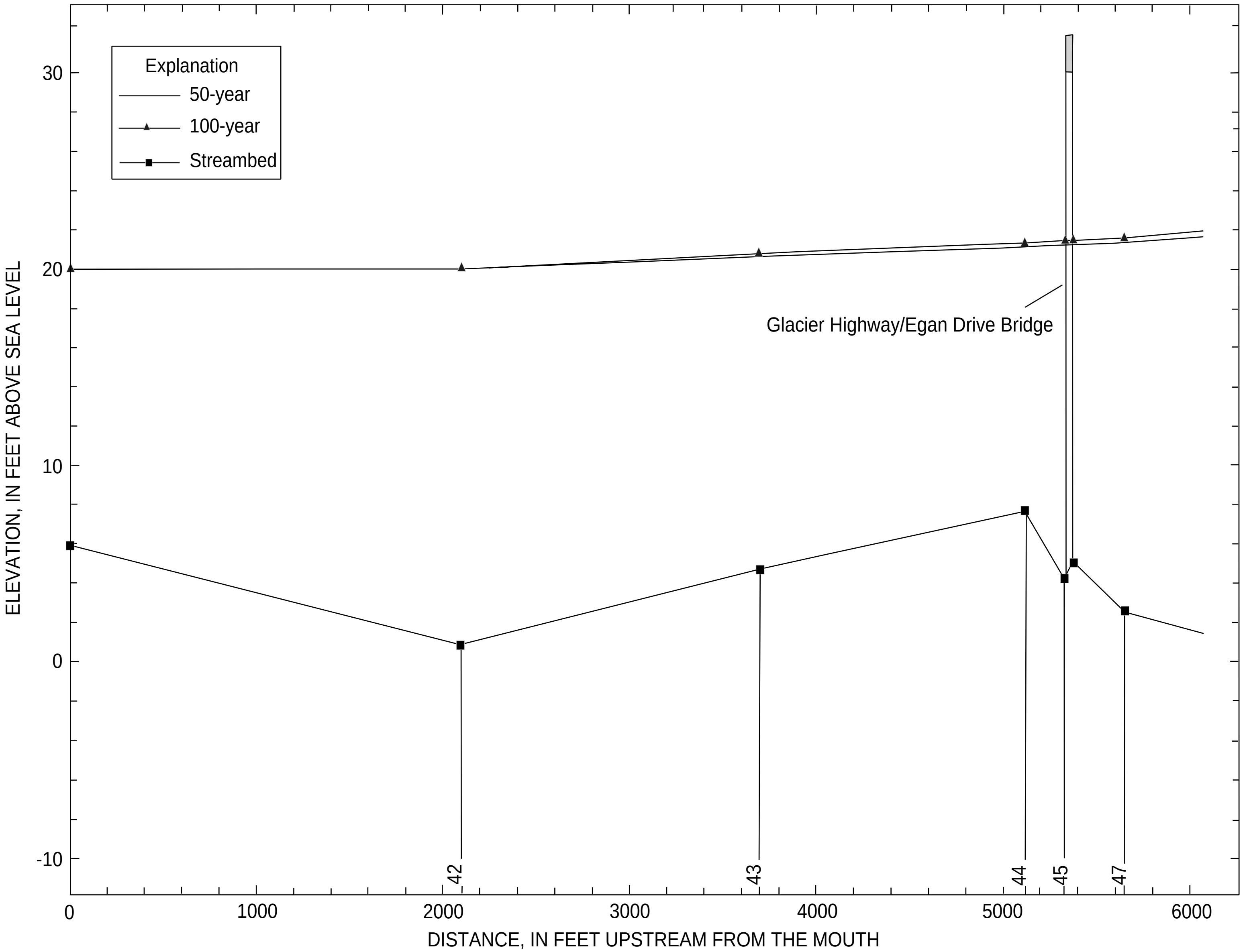


Figure 11B. Profiles of computed water-surface elevations, elevations of streambed, and locations of cross sections for the Mendenhall River, Alaska, cross sections 47 to 42, for 50-, and 100-year floods.

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APPENDIX

Elevation Reference Marks

The project basis of vertical control is based on the U.S. Coast and Geodetic Survey monument “STA. A AP 1962” at the Juneau Airport. Elevation of the monument is 26.46 feet Mean Lower Low Water. The monument has been subsequently destroyed. Elevations of the following reference marks should be accurate to within 0.05 feet. Locations of reference marks (RM) are shown on figure 2A-F. Reference marks were established by levels.

RM A	Steel bar with aluminum cap marked “ADOT.”
RM B	On the west side of the Kazdigoowu Heen Dei Trail about 40 feet south of the Montana Creek footbridge. RM B is a spike in a 24-inch spruce tree. Elevation is 33.35 feet.
RM 1	On the east side of the Kazdigoowu Heen Dei Trail across the Mendenhall River from the northwest end of meander way, RM 1 is a spike in the north side of a 24-inch spruce tree, marked with a 3-inch aluminum square stamped with the number 1. Elevation is 37.37 feet.
RM 2	On the east side of the Kazdigoowu Heen Dei Trail on the right bank of the Mendenhall River across from the intersection of Sharon Street and Richards Drive. RM 2 is a spike in the north side of a 28-inch spruce tree marked with a 3-inch aluminum square stamped with the number 2. Elevation is 37.37 feet.
RM 3	On the east side of the Kazdigoowu Heen Dei Trail across the Mendenhall River from Killewich Drive Spike. RM 3 is a spike in the north side of a 30-inch spruce tree about 20 feet from the right bank of the Mendenhall River. It is marked with a 3-inch aluminum square stamped with the number 3. Elevation is 42.47 feet.
RM 4	On the east side of the Kazdigoowu Heen Dei Trail across the Mendenhall River from the south end of Marion Drive. RM 4 is a spike in the north side of a 48-inch spruce tree about 12 feet from the right bank of the Mendenhall River. Elevation is 44.37 feet.
RM 5	On the east side of the Kazdigoowu Heen Dei Trail on a hummock of high ground immediately past the first spur trail south of the north end of the trail. RM 5 is a 4-foot steel rod driven into the ground across the Mendenhall River from the intersection of Taku Boulevard and Marion Drive. Elevation is 44.66 feet.
RM 6	At the end of River Road, walk around the gate to the west and follow dirt road to parking lot. The RM is a steel pin is at the base of a spruce tree. The spruce tree is marked with a stake and reads RM Bob. Elevation is 50.98 feet.
RM 7	Brass cap in sidewalk on the northwest corner of the Mendenhall Loop Road Bridge. Elevation is 70.65 feet.