HYDRAULIC CHARACTERISTICS OF THE NEW RIVER IN THE NEW RIVER GORGE NATIONAL RIVER, WEST VIRGINIA

By J. B. Wiley and D. H. Appel

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MANUEL LUJAN, JR., Secretary

U.S. GEOLOGICAL SURVEY

Dallas L. Peck, Director

For additional information write to:

District Chief
U.S. Geological Survey, WRD
603 Morris Street
Charleston, West Virginia 25301

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CONVERSION FACTORS AND ABBREVIATIONS

Readers who prefer to use metric (International System) units rather than inch-pound units in this report can make conversions using the following factors:

multiply inch-pound unit	By	To obtain metric unit
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
pound (lb)	453.6	gram (g)
gallon (gal)	3.785	liter (L)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

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."

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ABSTRACT

Traveltime, dispersion, water-surface and streambed profiles, and cross-section data were collected for use in application of flow and solute-transport models to the New River in the New River Gorge National River, West Virginia. Dye clouds subjected to increasing and decreasing flow rates (unsteady flow) showed that increasing flows shorten the cloud and decreasing flows lengthen the cloud. After the flow rate was changed and the flow was again steady, traveltime and dispersion characteristics were determined by the new rate of flow. Seven stage/streamflow relations identified the general changes of stream geometry throughout the study reach. Channel cross sections were estimated for model input. Low-water and streambed profiles were developed from surveyed water-surface elevations and water depths.

INTRODUCTION

The New River flows northward from its headwaters in North Carolina, through western Virginia, and into south-central West Virginia, where it joins the Gauley River at Gauley Bridge to form the Kanawha River (fig. 1). The New River Gorge National River was established by Public Law 95-625 on November 10, 1978, and falls within the jurisdiction of the U.S. Department of Interior, National Park Service (NPS) (fig. 2). The NPS is responsible for (1) conserving the outstanding natural, scenic, and historical values and objects, and (2) preserving a 53-mile segment of the lower New River (approximately from Hinton to Fayette) in West Virginia as a free-flowing stream for the enjoyment and benefit of present and future generations. The main attraction of the National River is a combination of scenic wilderness, fishing, and excellent white-water rafting. The recreational quality and safety depends in part on the regulated flow from Bluestone Dam and unregulated flow from the Greenbrier River.

The U.S. Geological Survey (USGS), in cooperation with the NPS, is studying the effects of changes in streamflow on an accidental spill of a soluble contaminant on the lower New River. The potential for such a spill exists because of the presence of a major east-west railroad that traverses the River gorge. In addition, several major highway bridges cross the River. River managers can use computer models to assist them in mitigating the affects of an accidental spill.

Purpose and Scope

The purpose of this report is to identify existing studies and present additional data that will be utilized in applying flow and solute-transport models to the lower New River. Data presented include traveltime and dispersion of dye under unsteady-flow conditions, stage-streamflow rating curves at selected river locations, a streambed profile, and a profile of the water surface at low flow. The area of study is limited by the National River boundaries and identifies hydraulic characteristics of the mainstem of the New River.

Acknowledgments

The U.S. Army Corps of Engineers, Huntington District, regulated outflow from Bluestone Dam to provide steady and unsteady flow conditions for dye measurements. Personnel from the National Park Service assisted with data collection activities during traveltime measurements and pool depth measurements.

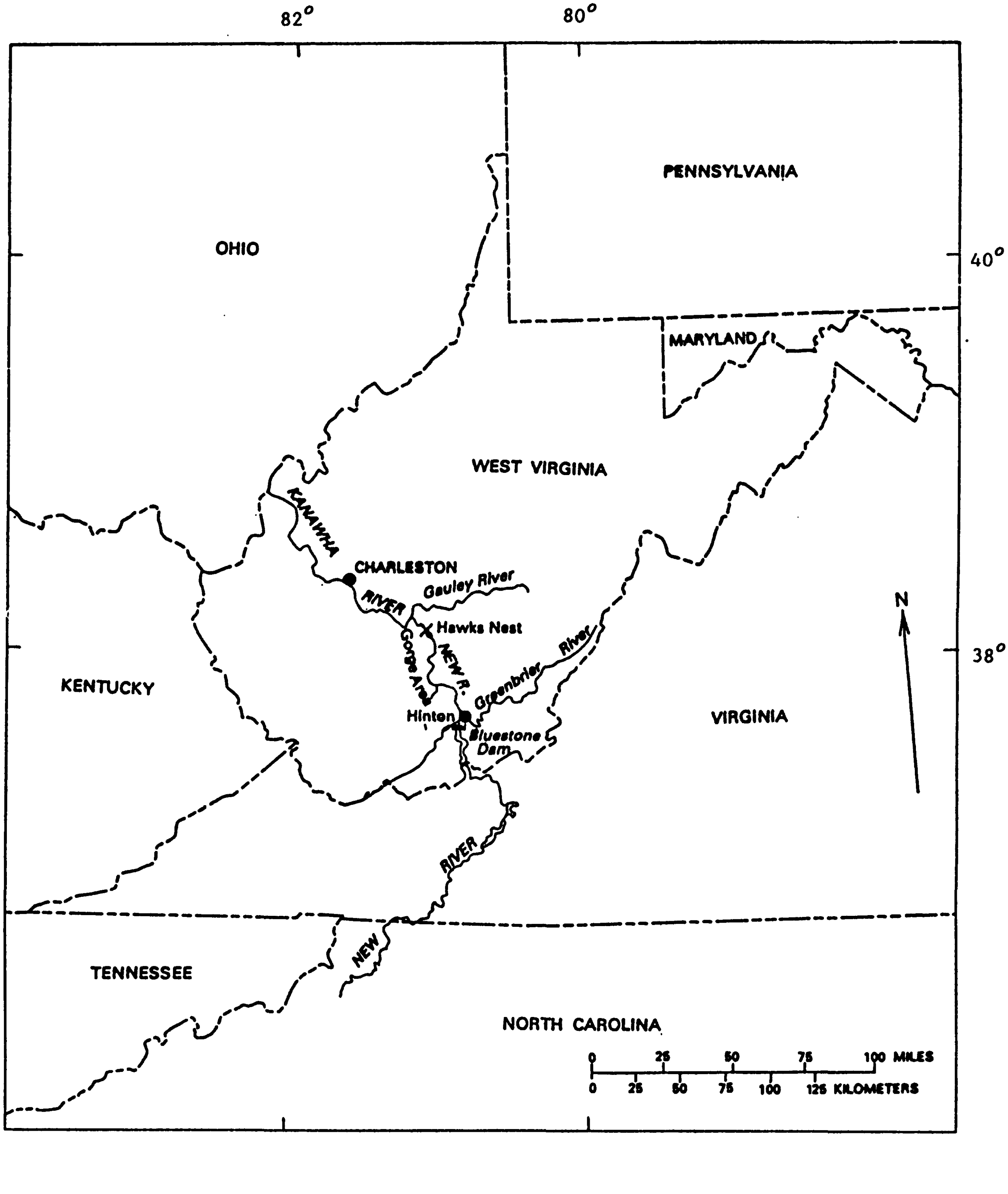

Figure 1.--General location of the New River.
[From Appel and Moles, 1987, p. 3.]

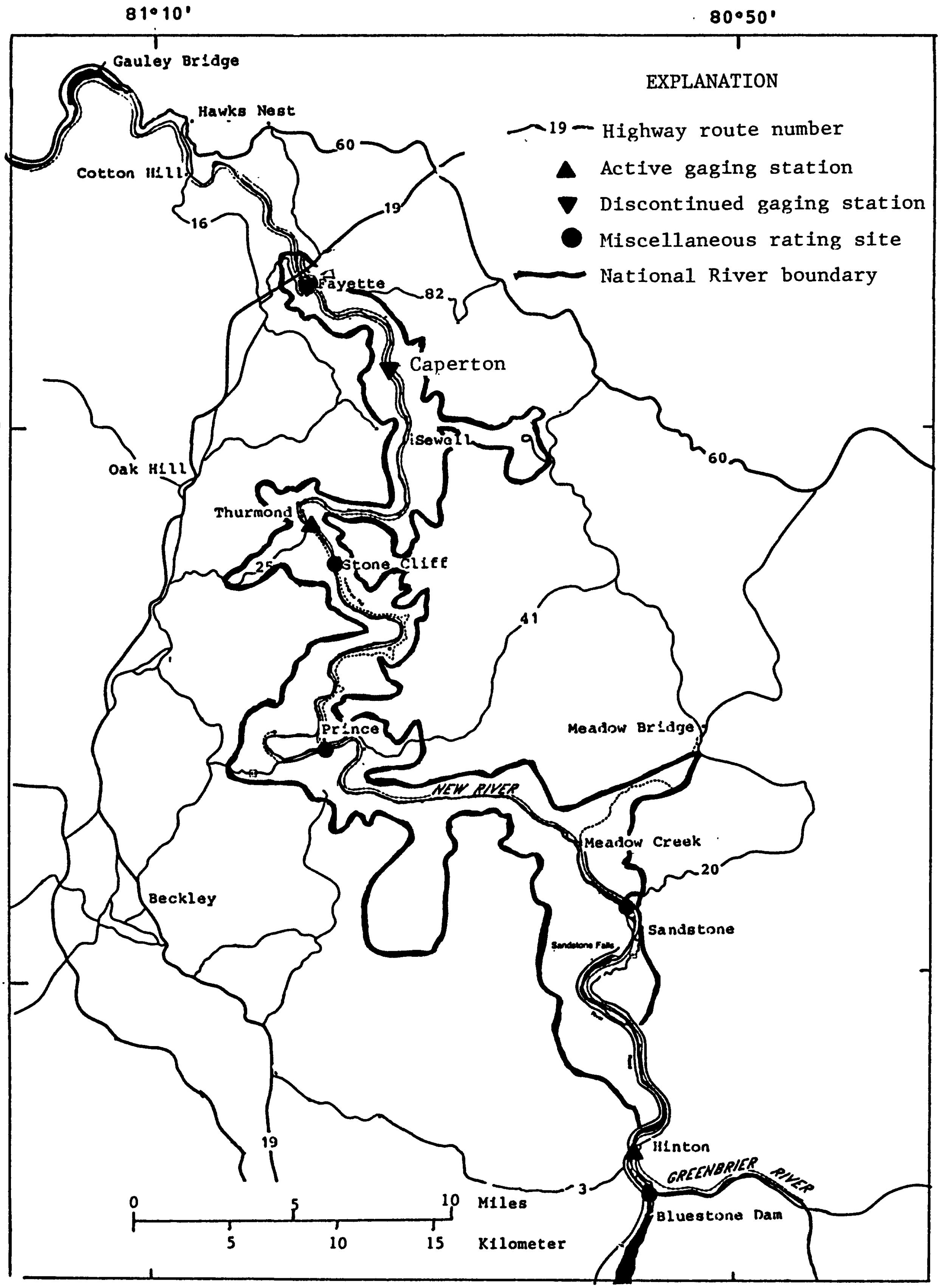

Figure 2.--Study area and New River Gorge National River. [Modified from Appel and Moles, 1987, p. 4.]

PREVIOUS STUDIES

Results from two previous publications by the U.S. Geological Survey are being used to apply the flow and solute-transport models. These reports are "Traveltimes of flood waves on the New River Between Hinton and Hawks Nest, West Virginia," (Appel, 1983) and "Traveltime and dispersion in the New River, Hinton to Gauley Bridge, West Virginia," (Appel and Moles, 1987). Three graphs from these reports are important to model application. The graphs are presented as figures 3-5, and a brief explanation of each follows. The reader is referred to the original reports for additional information.

Traveltimes of floodwaves through the study reach are shown in figure 3. Traveltime of a wave between any two points within the National River jurisdiction can be estimated from this set of curves. For example, when the streamflow is 4,000 ft^3/s (cubic feet per second), the time required for a floodwave to travel from Prince to Thurmond is approximately 3.5 hours. Estimated traveltimes between locations not shown can be interpolated with respect to their stream distance between the community curves.

Traveltimes of peak concentrations of soluble materials under steady streamflow conditions are shown in figure 4 and dispersion of the peak concentration is presented in figure 5. Using these two sets of curves, the traveltimes and dispersion of the peak concentration of soluble materials between any two points along the study reach can be estimated. For example, when the streamflow is 3,000 ft^3/s and 500 lbs (pounds) of soluble contaminate are spilled near Sandstone, the time for the peak concentration to reach Stone Cliff (fig. 4) is approximately 28.5 hours and the peak concentration at Stone Cliff (fig. 5) is approximately 100 micrograms per liter (500 lbs X 0.20 micrograms per liter per lb).

DATA COLLECTION

Recently collected data that will be used to apply flow and solute-transport models for this river reach include:

1. Two measurements of unsteady-flow traveltime and dispersion of soluble dye;
2. Stage/streamflow rating curves at selected locations;
3. Profiles of water surface and streambed;
4. River cross sections.

Each of these data sets will be discussed separately in the following sections of this report.

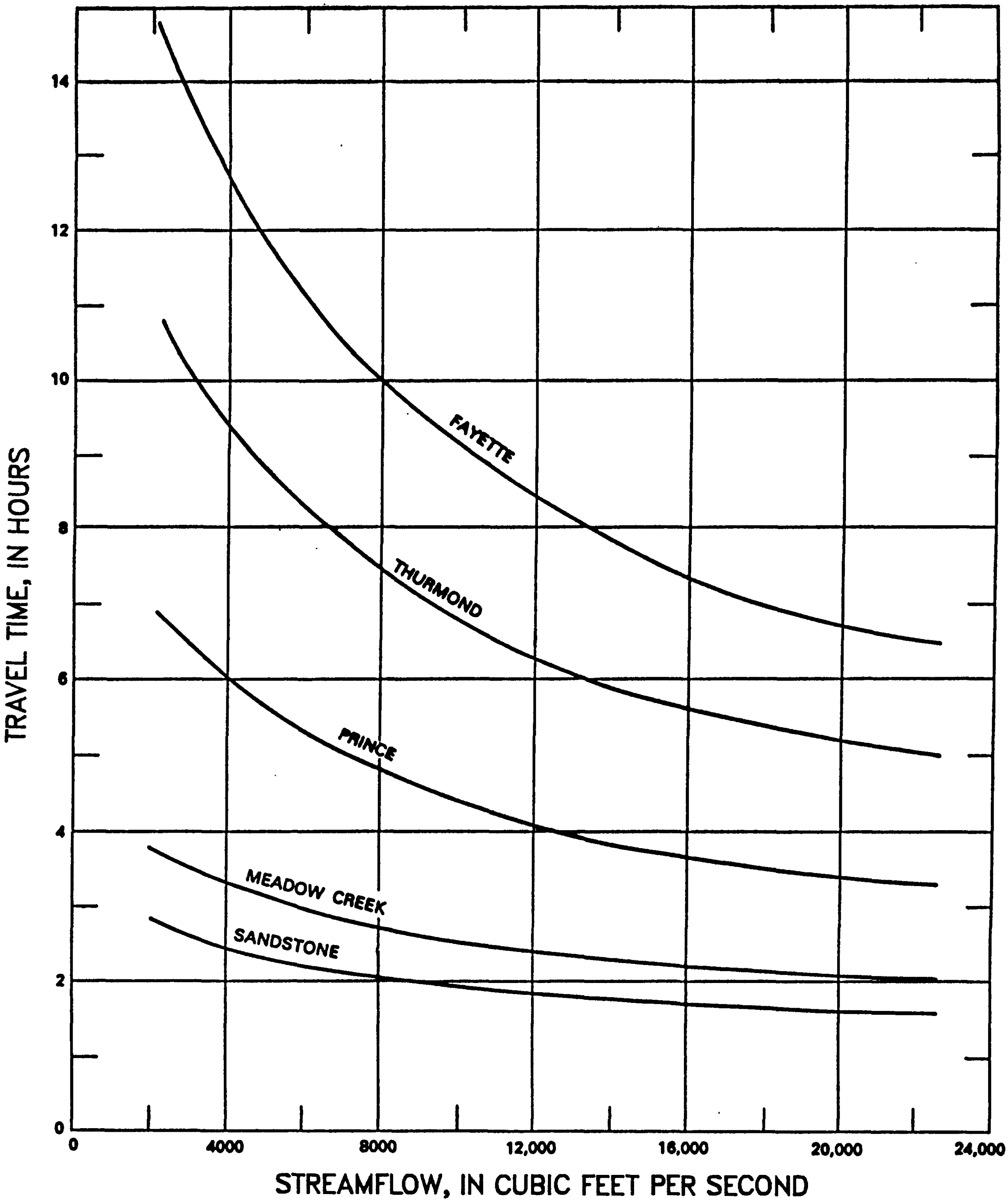

Figure 3.--Traveltimes of flood waves from Hinton to selected communities in the New River Gorge.
[Modified from Appel, 1983, p. 10.]

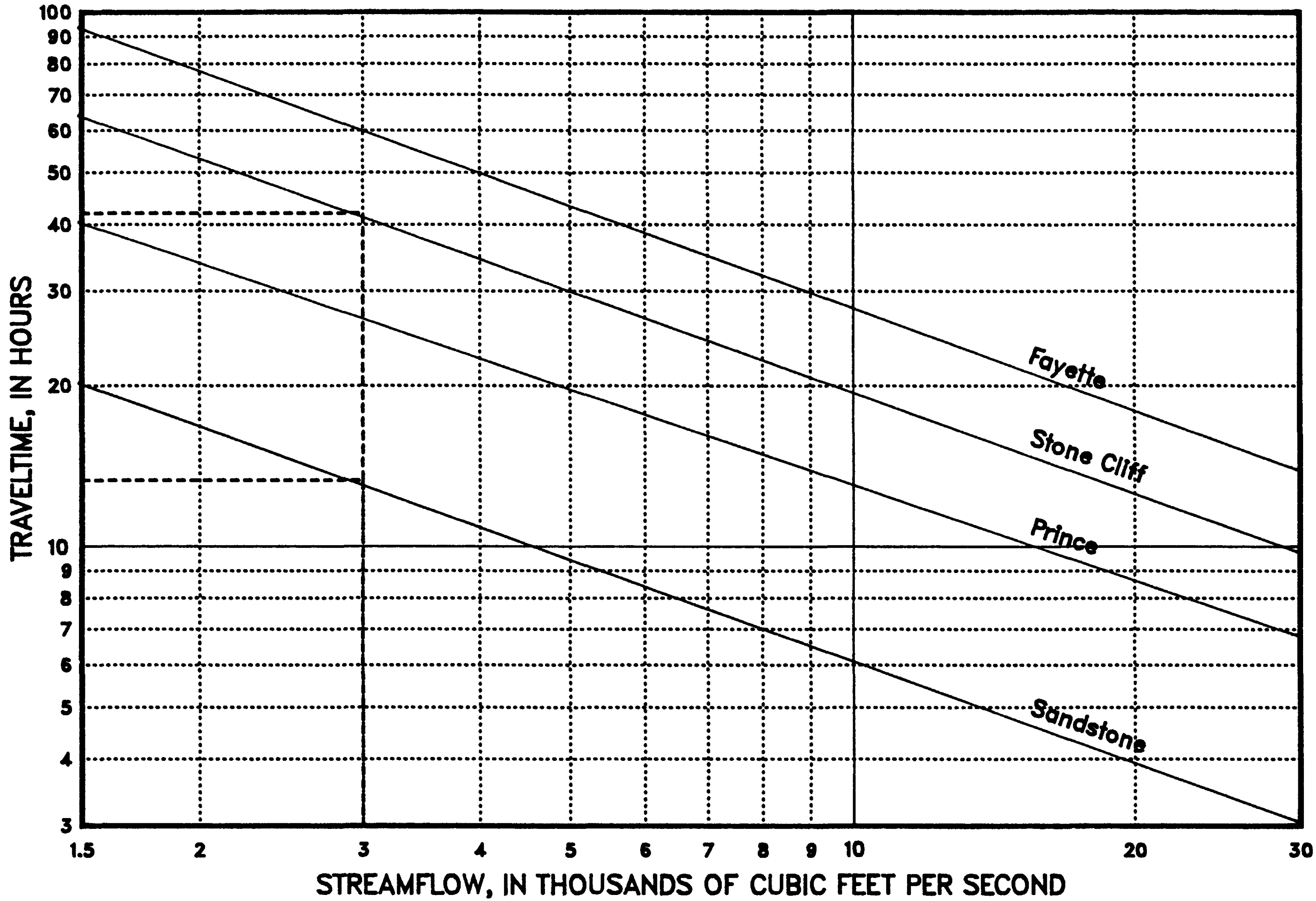

Figure 4.--Traveltime-streamflow relations of peak concentration of dye from Hinton to selected sites. [Modified from Appel and Moles, 1987, p. 14.]

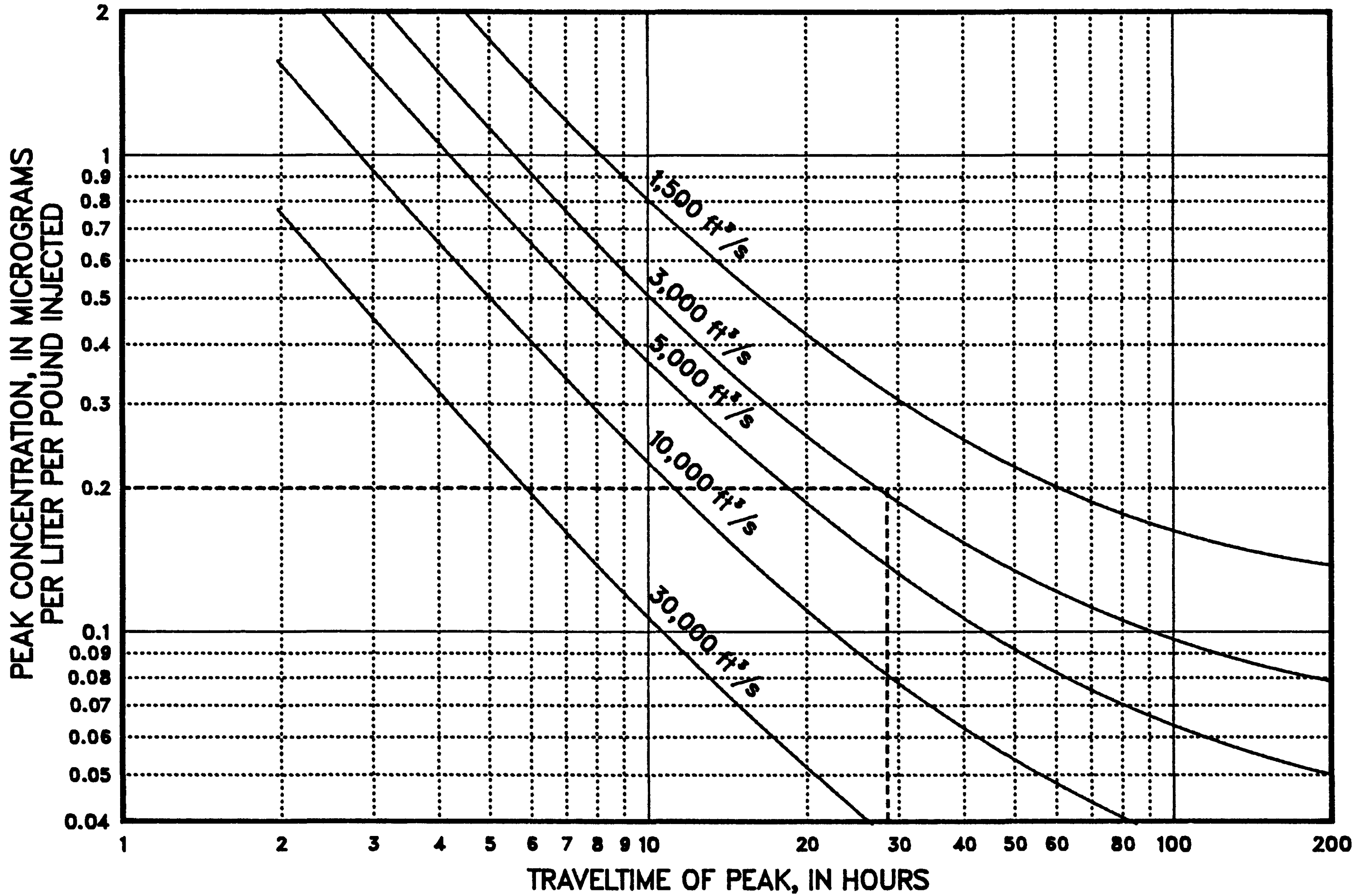

Figure 5.--Peak concentrations resulting from the injection of 1 pound of a conservative soluble material at selected streamflows. [Modified from Appel and Moles, 1987, p. 19.]

Traveltime and Dispersion of Dye in Unsteady Flow

Dye was injected as a slug into the river at Hinton while the river was at a constant flow rate (steady flow). The dye was allowed to travel downstream before the flow rate was changed by regulating Bluestone Dam. The change in flow rate (unsteady flow) was designed to move through the dye cloud between Prince and Stone Cliff. After the unsteady flow passed the dye cloud, a new steady flow was continued until the dye cloud moved past Fayette (fig. 2).

Two measurements investigating the effects of changes in streamflow on the traveltime and dispersion characteristics of dye were conducted. The first measurement increased the flow rate 160 percent and the second measurement decreased the flow rate 50 percent. Results from the first measurement are shown in figure 6. The flow rate at the time of dye injection was 4,500 ft^3/s and was increased to approximately 11,800 ft^3/s as the dye cloud moved between Prince and Stone Cliff. The leading edge of the increasing flow rate arrived at Prince two hours after the peak concentration and at Stone Cliff at approximately the same time as the leading edge of the dye. The dye cloud took about 10 hours to pass Prince and was about 12 miles long at that point. If the flow had remained steady at 4,500 ft^3/s instead of being increased to 11,800 ft^3/s, the respective estimated times of passage at Stone Cliff and Fayette would have been 20 and 24 hours (Apple and Moles, 1987, p. 16) instead of the observed 8.5 hours for both sites, and the respective estimated arrival times of the peak concentration at Stone Cliff and Fayette would have been 33 and 48 hours (fig. 4) instead of the observed 30 and 38 hours. The difference in these observed times (38 hours - 30 hours = 8 hours) is equivalent to the differences for a steady flow of 11,800 ft^3/s between Stone Cliff and Fayette (Appel and Moles, 1987, p. 14).

The flow rate was decreased from 8,100 ft^3/s to 4,400 ft^3/s for the second measurement (fig. 7). The leading edge of the decreasing flow rate arrived at Prince one hour after the peak concentration and at Stone Cliff approximately at the same time as the leading edge of the dye. The dye cloud was estimated to take about 7 hours to pass Prince at a streamflow of approximately 8,100 ft^3/s (Apple and Moles, 1987, p. 16), but the reduction of flow increased time of passage of the dye cloud to about 13 hours. If the flow had remained steady at 8,100 ft^3/s instead of being reduced to 4,400 ft^3/s the respective estimated times of passage at Stone Cliff and Fayette would have been 8 and 11 hours (Appel and Moles, 1987, p. 16) instead of the observed 18 and 21 hours, and the respective estimated arrival times of the peak concentration at Stone Cliff and Fayette would have been 22 and 32 (fig. 4) hours instead of the observed 24 and 38 hours. The difference in these observed times (38 hours - 24 hours = 14 hours) is equivalent to the difference for a steady streamflow of 4,400 ft^3/s between Stone Cliff and Fayette (Appel and Moles, 1987, p. 14).

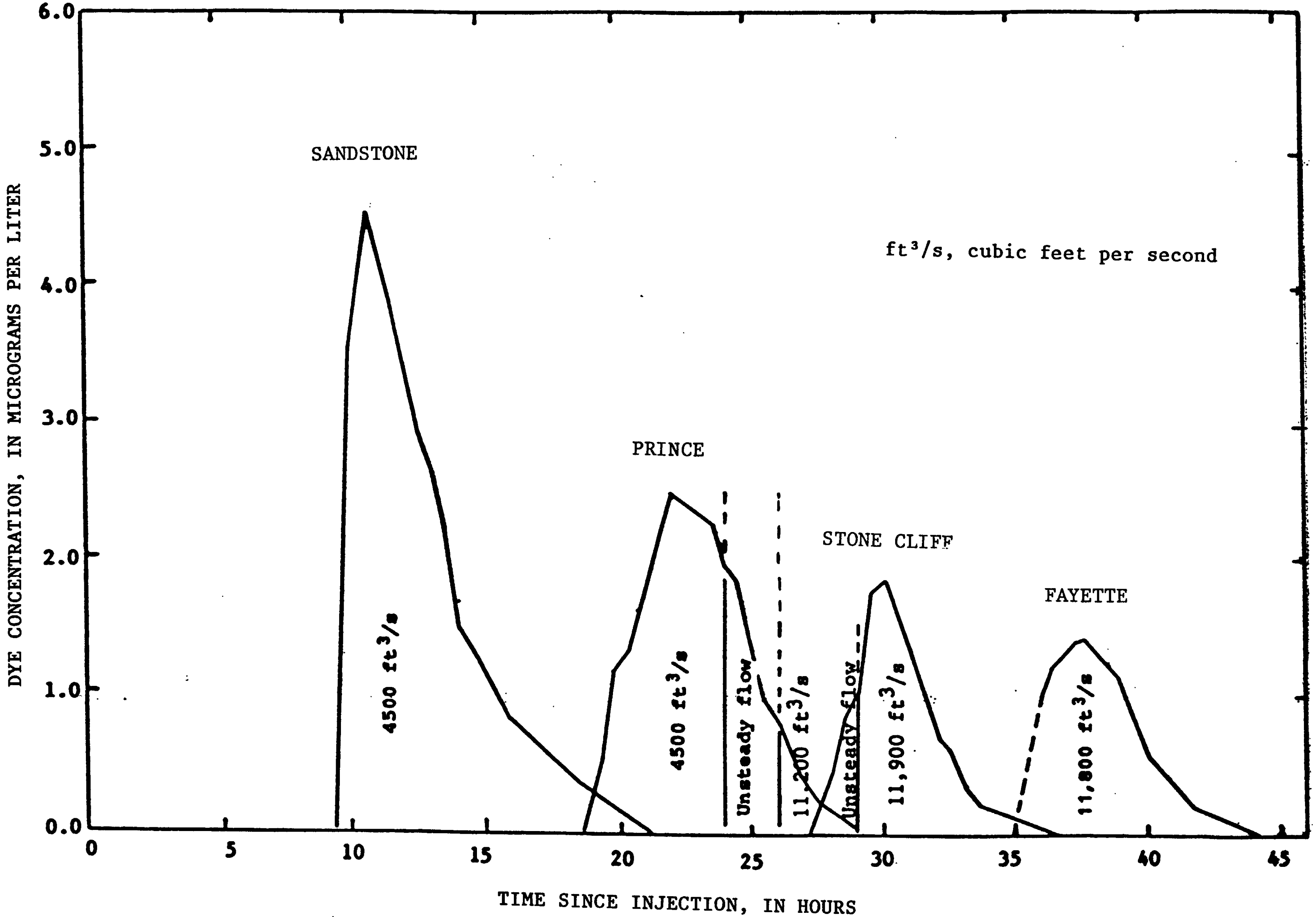

Figure 6.--Time-concentration curves for increasing unsteady flow.
[Modified from Appel, 1987, p. 68.]

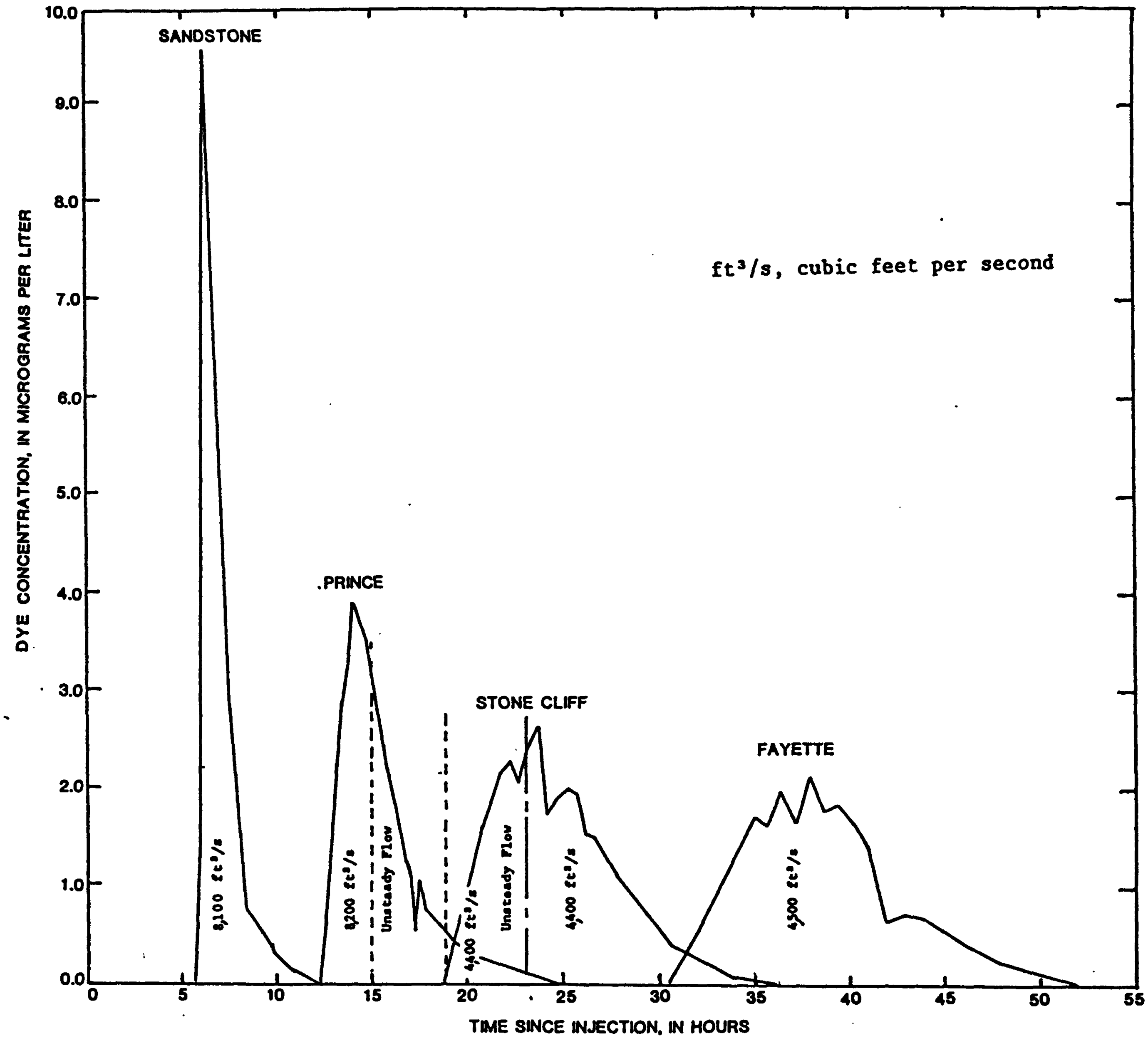

Figure 7.--Time-concentration curves for decreasing unsteady flow.

Changing flow rates altered the characteristics of the dye cloud. When an increase in flow rate began moving through the dye cloud, stream velocities at the trailing edge of the dye cloud started to increase. As the changes in flow rate continued to move through the dye cloud, the rate of travel of the trailing edge increased relative to the leading edge and caused the dye cloud to compress. When a decreasing flow rate began moving through a dye cloud, the stream velocity at the trailing edge of the dye cloud started to decrease. As the change in flow rate continued to move through the dye cloud, the rate of travel of the trailing edge decreased relative to the leading edge and caused the cloud to lengthen. Traveltimes for peak concentration and time of passage of the dye cloud were decreased when flow rates were raised and increased when flow rates were lowered. The new traveltime and dispersion characteristics of the dye cloud after a change in flow has occurred are determined by the new flow rate as the dye cloud moves downstream.

Rating Curves

A rating curve is a stage/streamflow relation at a particular location in a stream that represents the physical properties of the controlling section in the river channel. Rating curves were determined at seven locations in the study reach. Two sites are at existing streamflow gaging stations, one site is at a discontinued streamflow gaging station, and four sites are located at highway bridges. The relations for gaged sites are shown in figure 8. An expanded-scale plot, figure 9, is provided for easier reading of lower stages and streamflows. The relations for the miscellaneous sites are shown in figure 10. An expanded-scale plot is not provided for the miscellaneous curves because they lack accuracy at low stages and streamflows.

The description, location, and datum of each site are listed in table 1. A stage that is obtained from a rating curve can be converted to elevation above sea level by adding it to the datum at that site. For example, a stage of 1.51 ft at Hinton will convert to 1,356.69 ft above sea level (1.51 ft + 1,355.18 ft).

Table 1.--Description, location, and datum of rating sites
[USGS, United States Geological Survey]

Site Name	Description and location	Datum, in feet above sea level.
Hinton	03184500 - USGS gaging station / Water-stage recorder on right bank at Hinton, 0.2 miles upstream from Madam Creek, and 1.5 miles downstream from the Greenbrier River.	1,355.18
Sandstone	Miscellaneous site / Fluorescent yellow mark on upstream face at fifth drain from left bank on east lane of Interstate 64 bridge at Sandstone. Elevation of the reference point is 1336.78 feet above sea level.	1,256.00
Prince	Miscellaneous site / Top of the fourth grate from the left abutment on downstream side of highway 41 bridge at Prince. Elevation of reference point is 1192.78 feet above sea level.	1,149.00
Stone Cliff	Miscellaneous site / At station 400 (USGS measuring site for Thurmond gage) marked on top of downstream guard rail of highway 25 bridge at Stone Cliff. Elevation of reference point is 1113.30 feet above sea level.	1,038.00
Thurmond	03185400 - USGS gaging station / Water-stage recorder on right bank at Thurmond, at C&O Railroad pump house, 0.1 mile upstream from Dunloup Creek.	1,030.71
Caperton	0318500 - USGS discontinued gaging station / On left bank 50 feet downstream from suspension foot bridge (bridge does not exist at this time) at Caperton, two miles southeast of Nuttall Station.	938.44
Fayette	Miscellaneous site / Staff gage painted on upstream side of left bank pier of highway 82 bridge (bridge is condemned at this time) at Fayette, 0.1 mile upstream from Wolf Creek.	839.73

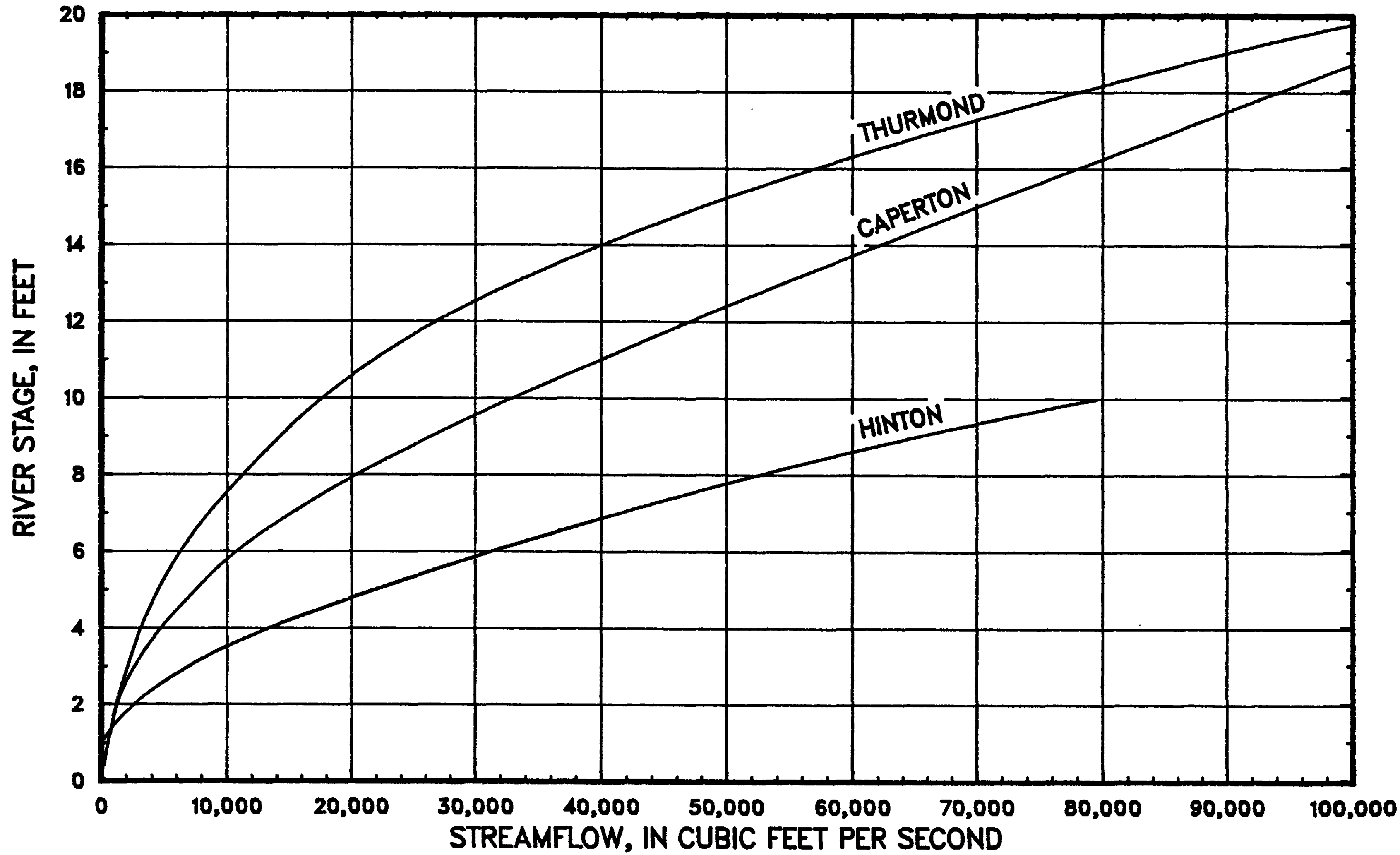

Figure 8.--Stage/streamflow relations at gaged sites.

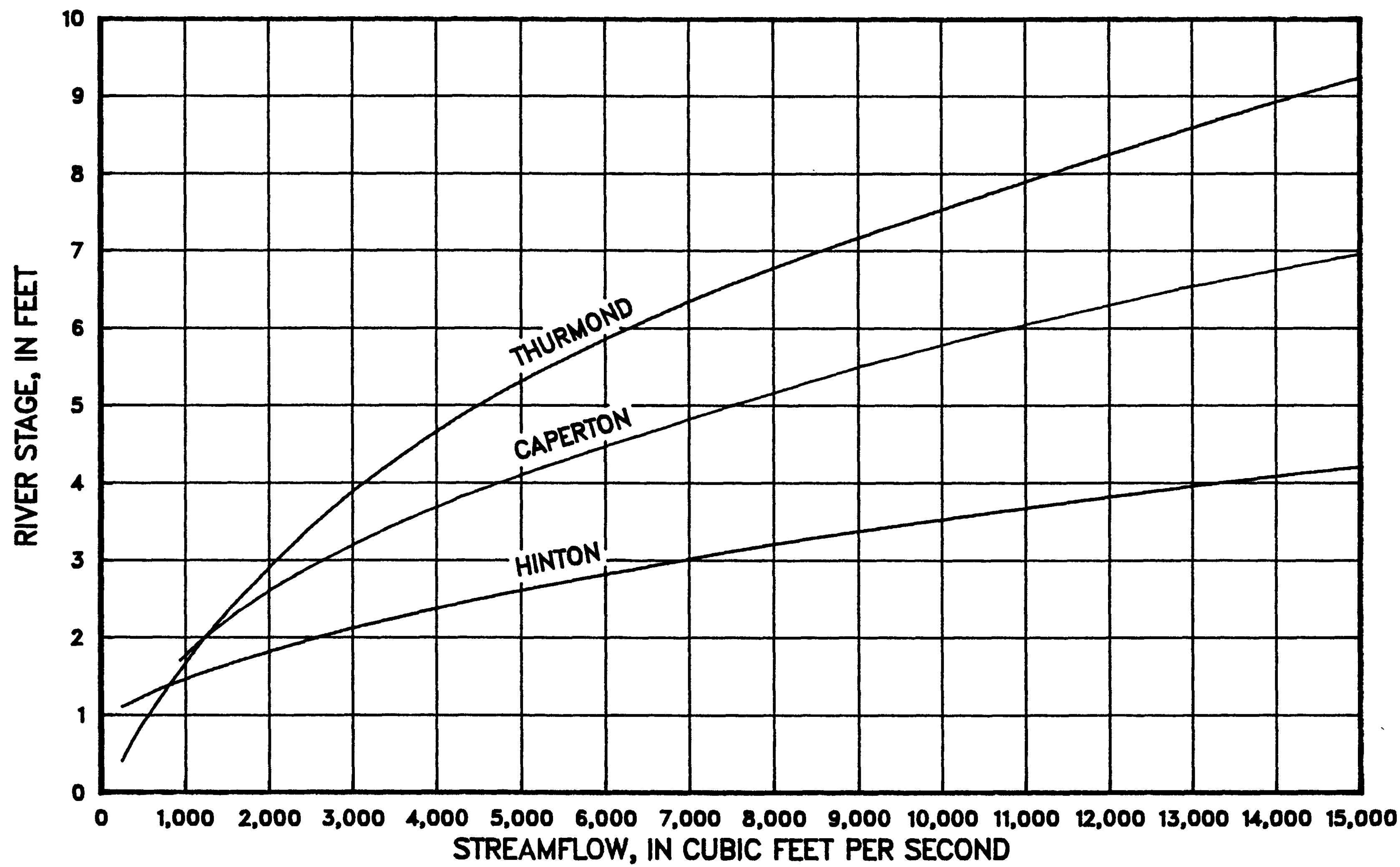

Figure 9.--Expanded-scale plot of stage/streamflow relations at gaged sites.

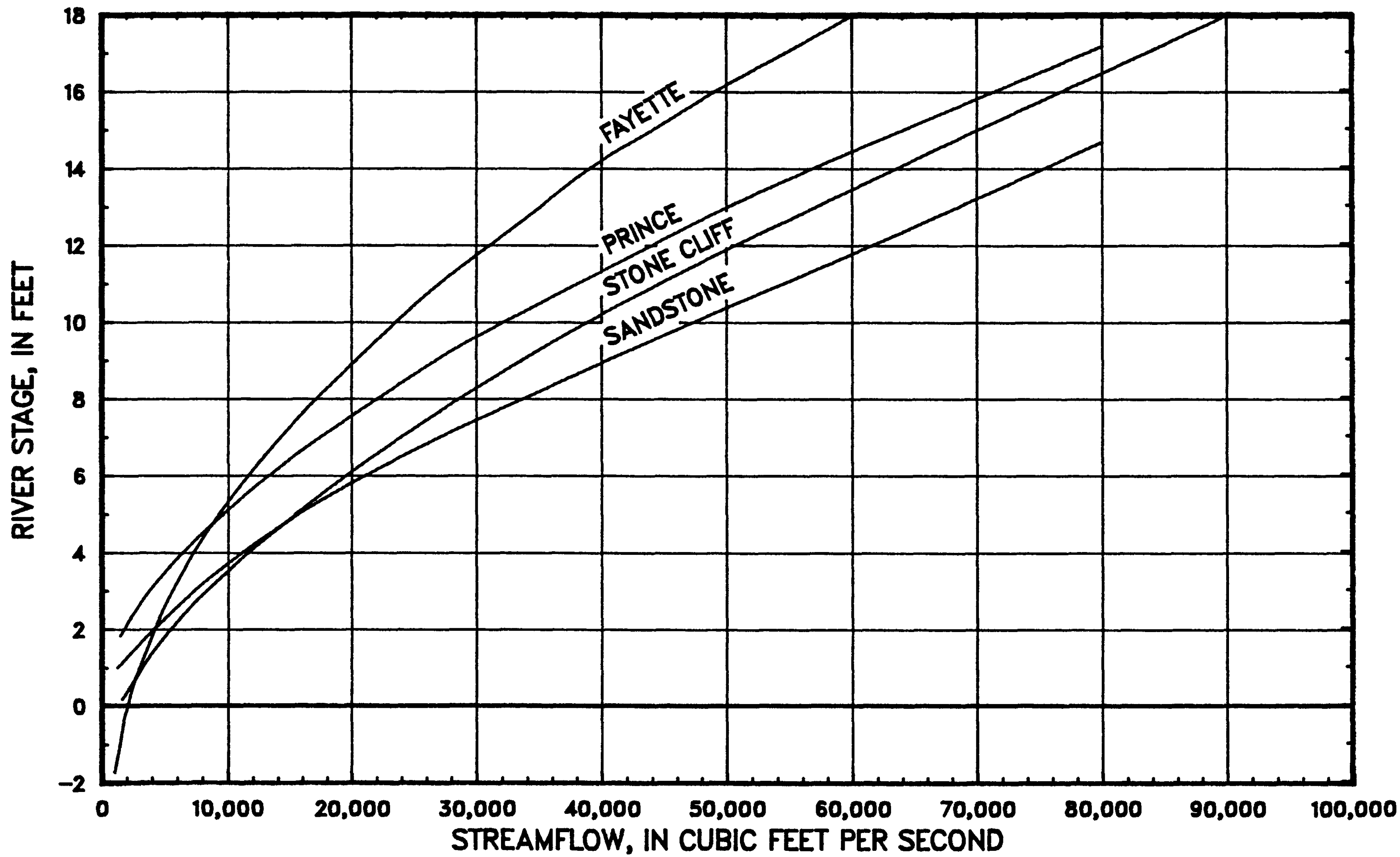

Figure 10.---Stage/streamflow relations at miscellaneous sites.

Water-Surface and Streambed Profiles

The New River consists of a series of pools and riffles, including one significant waterfall within the National River boundary (figs. 11-25). The water surface during low flow may drop 5 ft flowing over a typical riffle and about 25 ft over Sandstone Falls (fig. 23). Elevations for the 53-mile reach are referenced to sea level.

Water surfaces were surveyed to sea level at various flow rates below a streamflow of 3,000 ft^3/s. Survey points were selected upstream and downstream from each rapid. River depths were measured by electronic soundings at various streamflows less than 8,000 ft^3/s. Measuring points were selected at approximately one third of the distance from each bank where the continuous reading equipment showed a change in bed slope occurring. River depth curves were developed for measurements taken from each bank and these curves were averaged to develop a final depth curve. A water-surface profile at approximately a streamflow of 2,000 ft^3/s and a channel bottom profile were computed using the data described above and rating curves located throughout the study reach (figs. 11-25). Distances shown in figures 11-25 are measured upstream from the mouth of the Kanawha River.

River Cross Sections

Cross sections of the 53-mile study reach are necessary for input into the flow model. Estimates of ground elevations for these cross sections were evaluated using aerial photography, topographic maps, rating curves, and the water-surface and streambed profiles.

The NPS provided a 1 in. = 800 ft topographic map with 20-ft contours compiled from photos taken when streamflow was at approximately 28,000 ft^3/s. The NPS also provided photographs of the study area when streamflow was approximately 2,000 ft^3/s. The low-water photos were overlayed onto the topographic map, and the edges of the low-water were delineated onto the contour map.

Water-surface (at approximately a streamflow of 2,000 ft^3/s) and streambed profiles (figs. 11-25) are used to select distances between cross sections so that changes in cross-section areas represent area changes along the study reach. Cross sections were located close together where the area of the stream changes quickly.

Cross-sections were selected and marked on the contour map. Distances along each cross section were measured from an arbitrary point on the left bank. Elevations were determined (1) at contour-line crossings by reading directly from the map, (2) at the edges of water at a streamflow of 28,000 ft^3/s by extrapolating the water-surface profile and the stage/streamflow rating curves, (3) at the edges of water at a streamflow of 2,000 ft^3/s by reading directly from the low-water profile, and (4) at two "under-water" points approximately one-third of the distance from each bank by reading directly from the streambed profile.

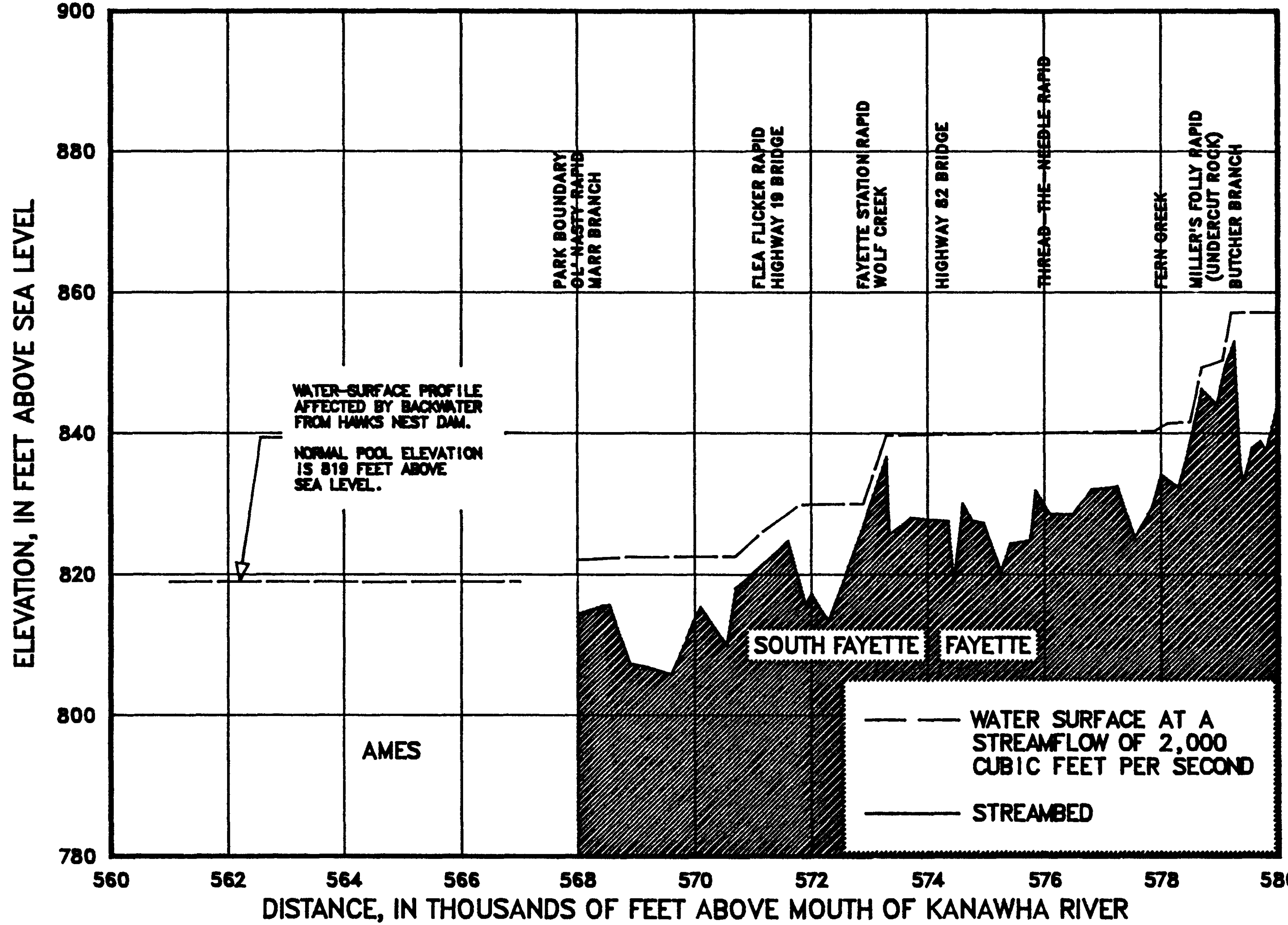

Figure 11.--Water-surface and streambed profiles in the New River Gorge National River.

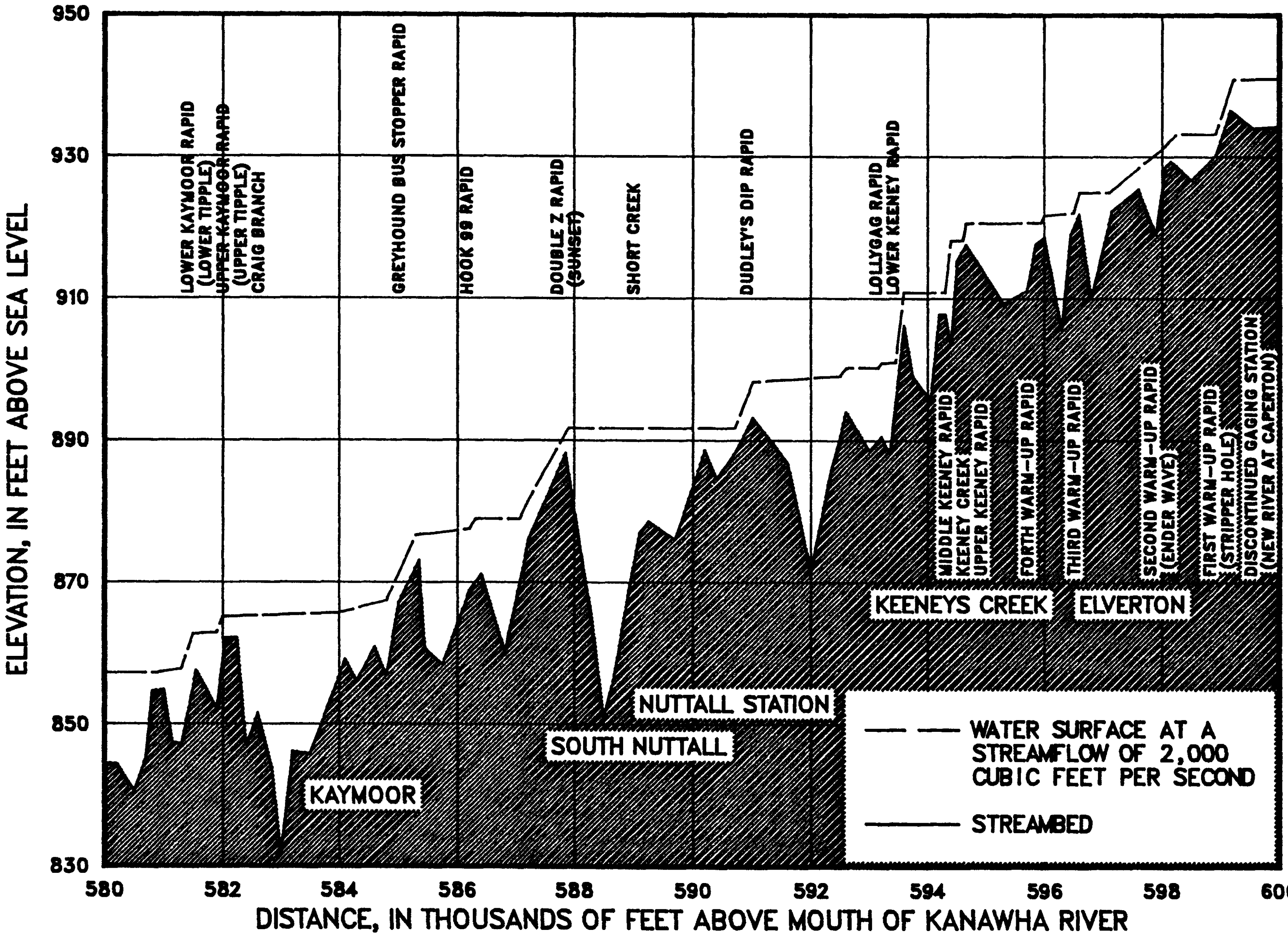

Figure 12.---Water-surface and streambed profiles in the New River Gorge National River.

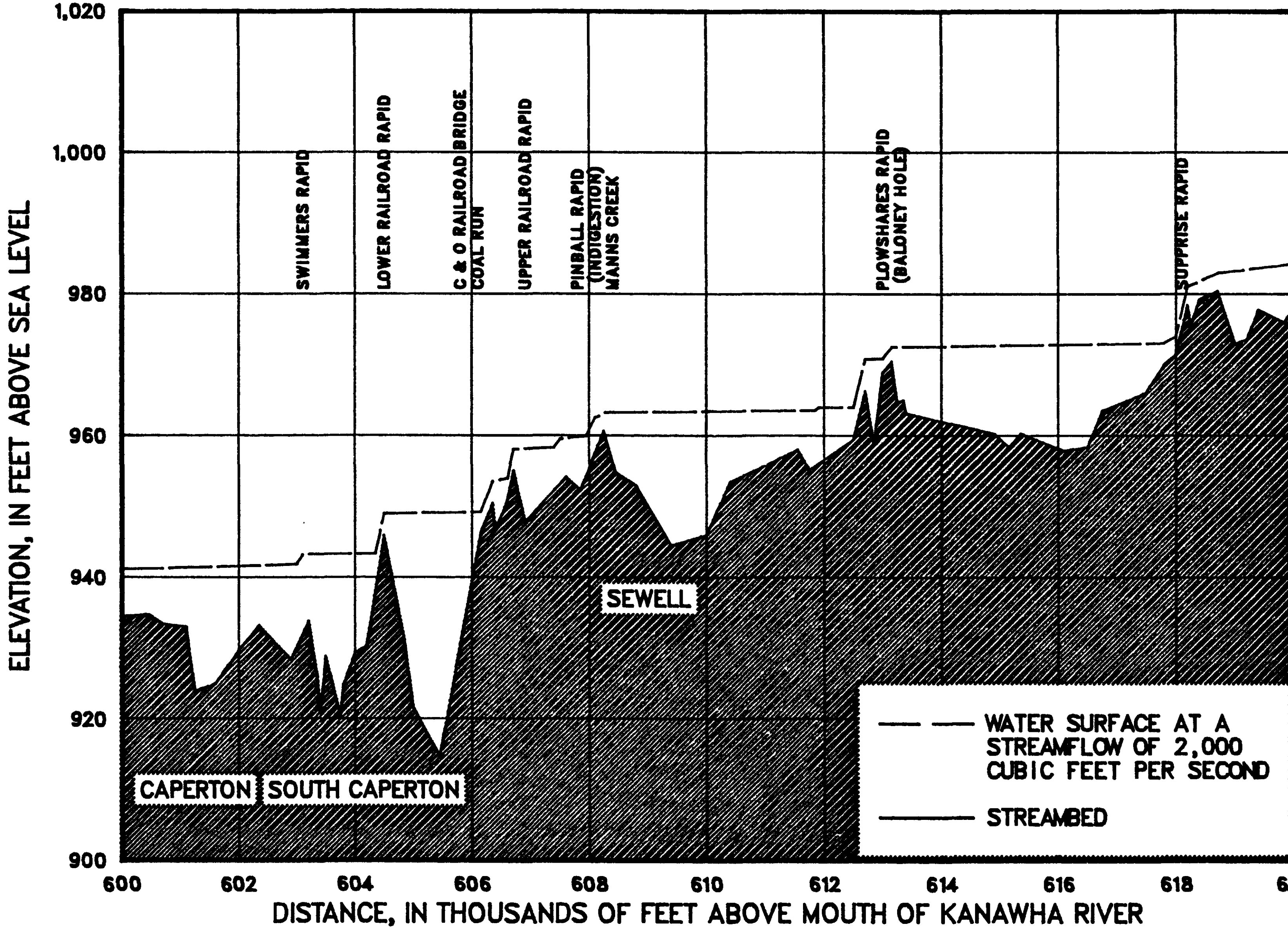

Figure 13.--Water-surface and streambed profiles in the New River Gorge National River.

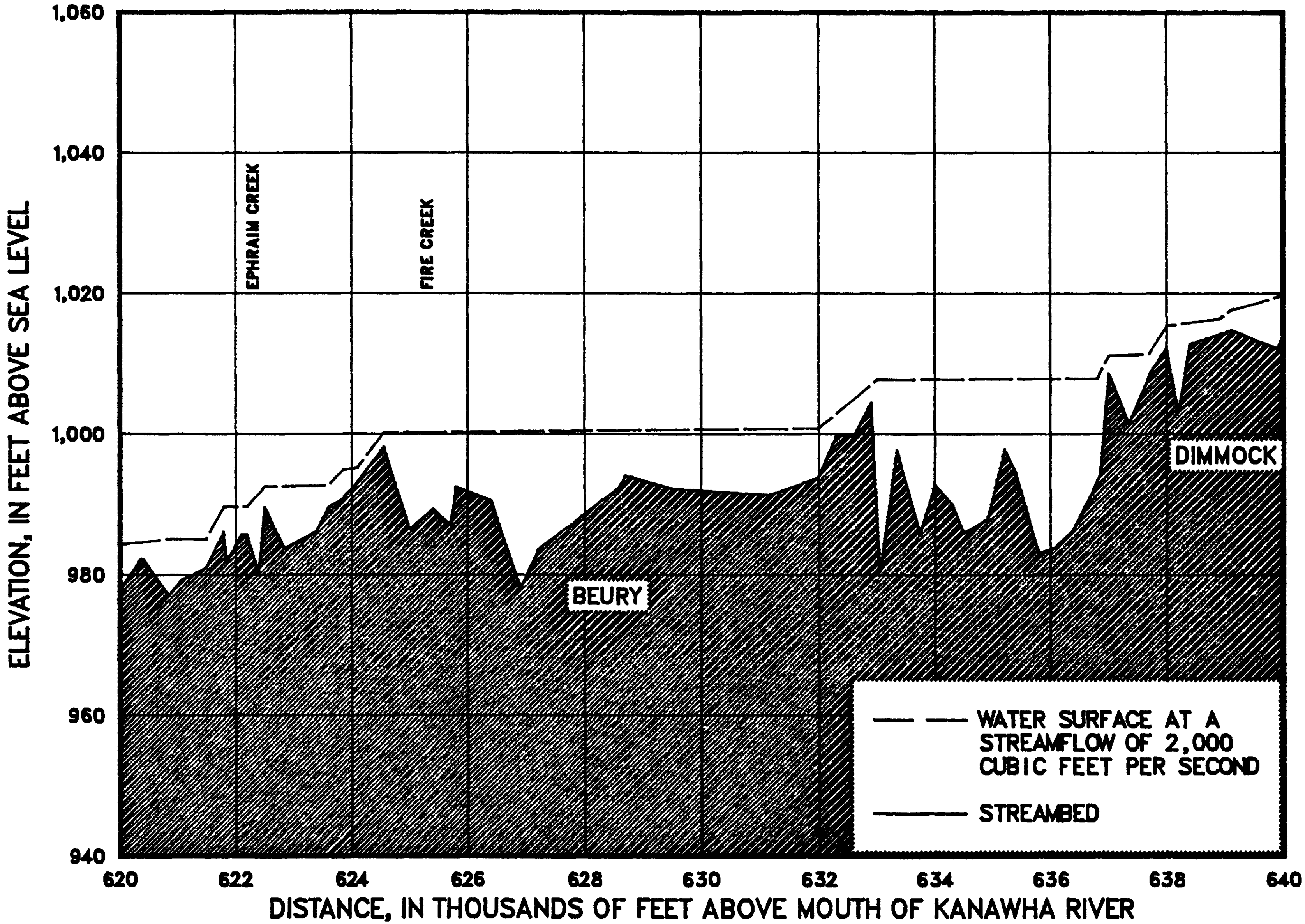

Figure 14.---Water-surface and streambed profiles in the New River Gorge National River.

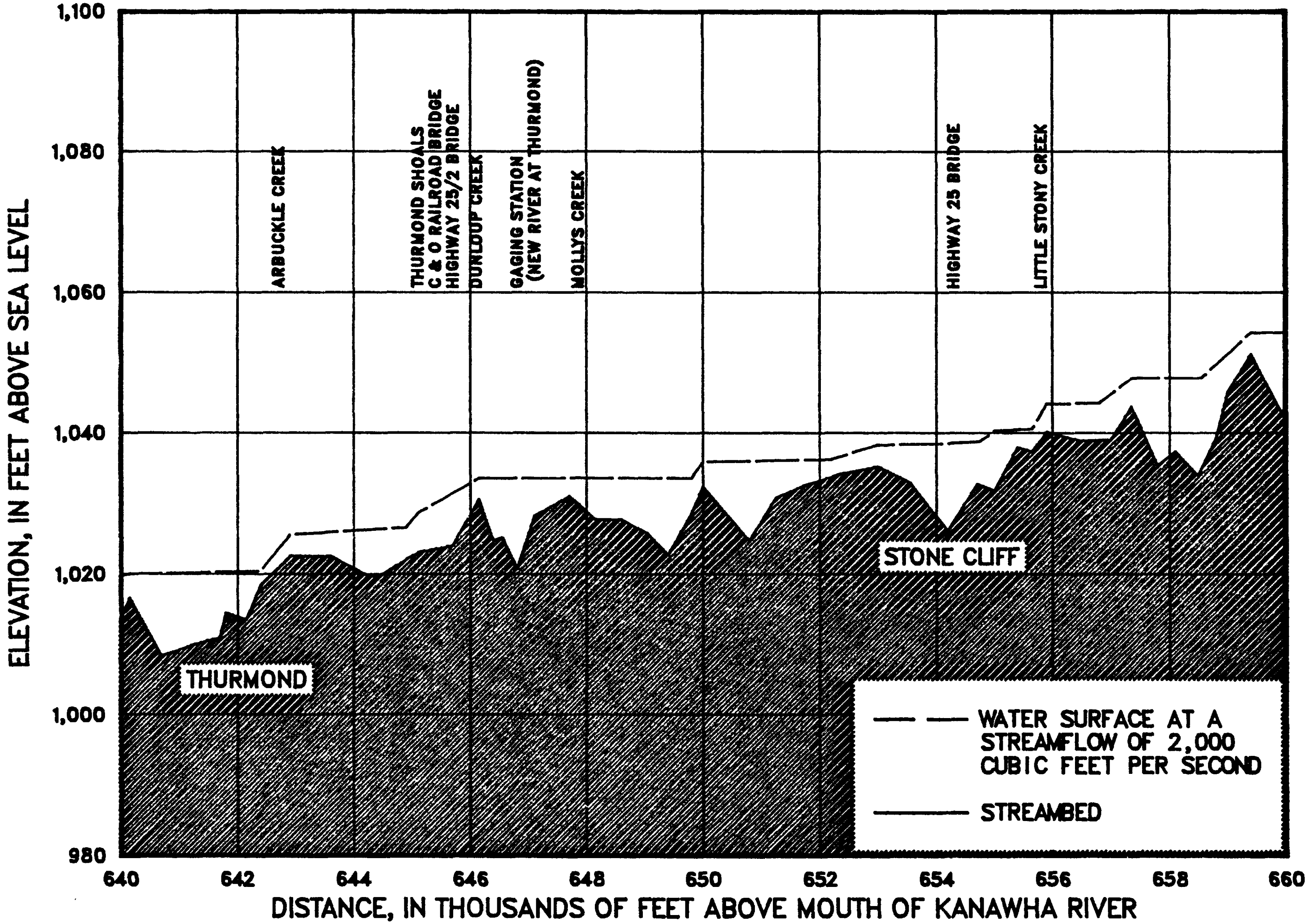

Figure 15.---Water-surface and streambed profiles in the New River Gorge National River.

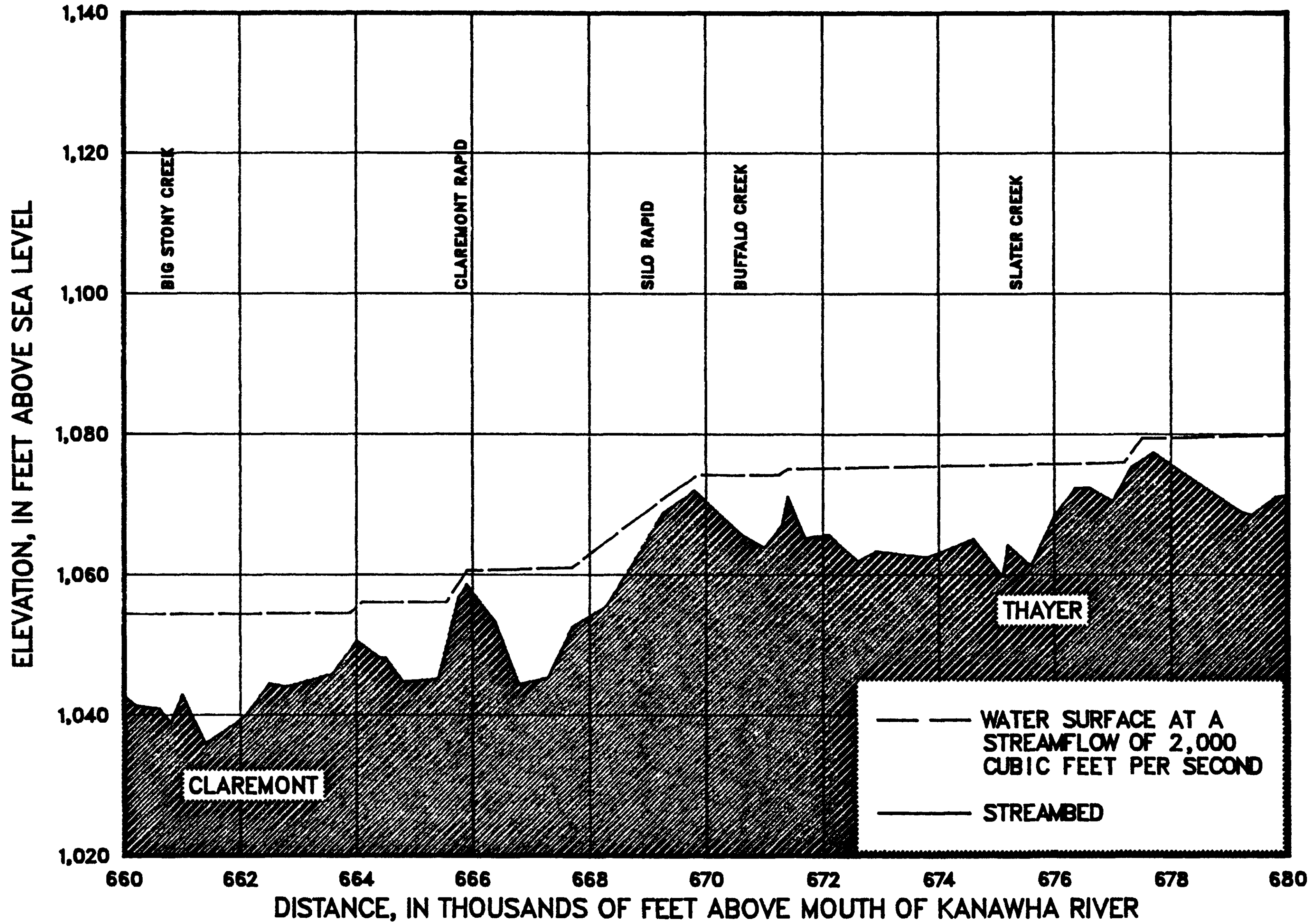

Figure 16.--Water-surface and streambed profiles in the New River Gorge National River.

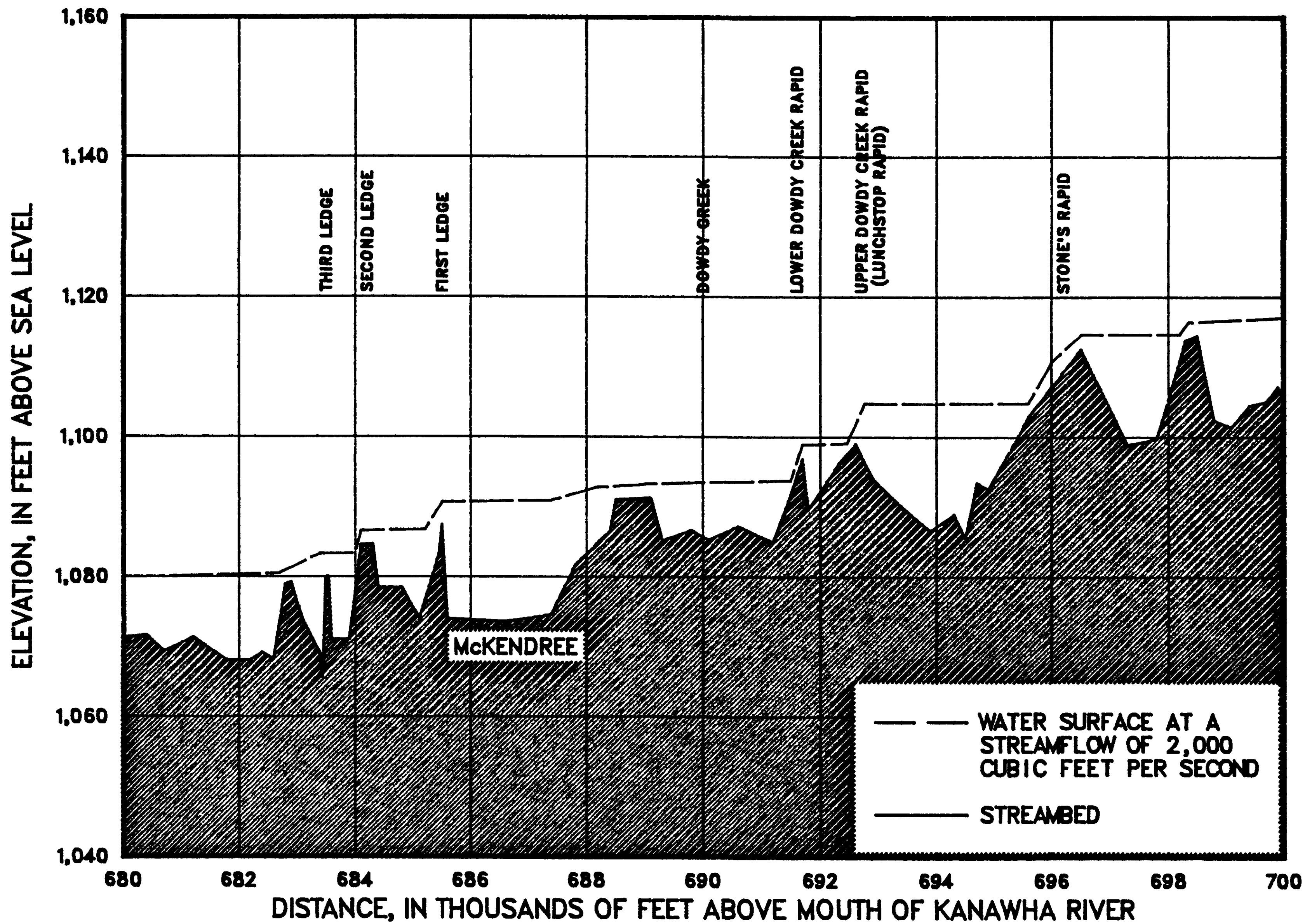

Figure 17.---Water-surface and streambed profiles in the New River Gorge National River.

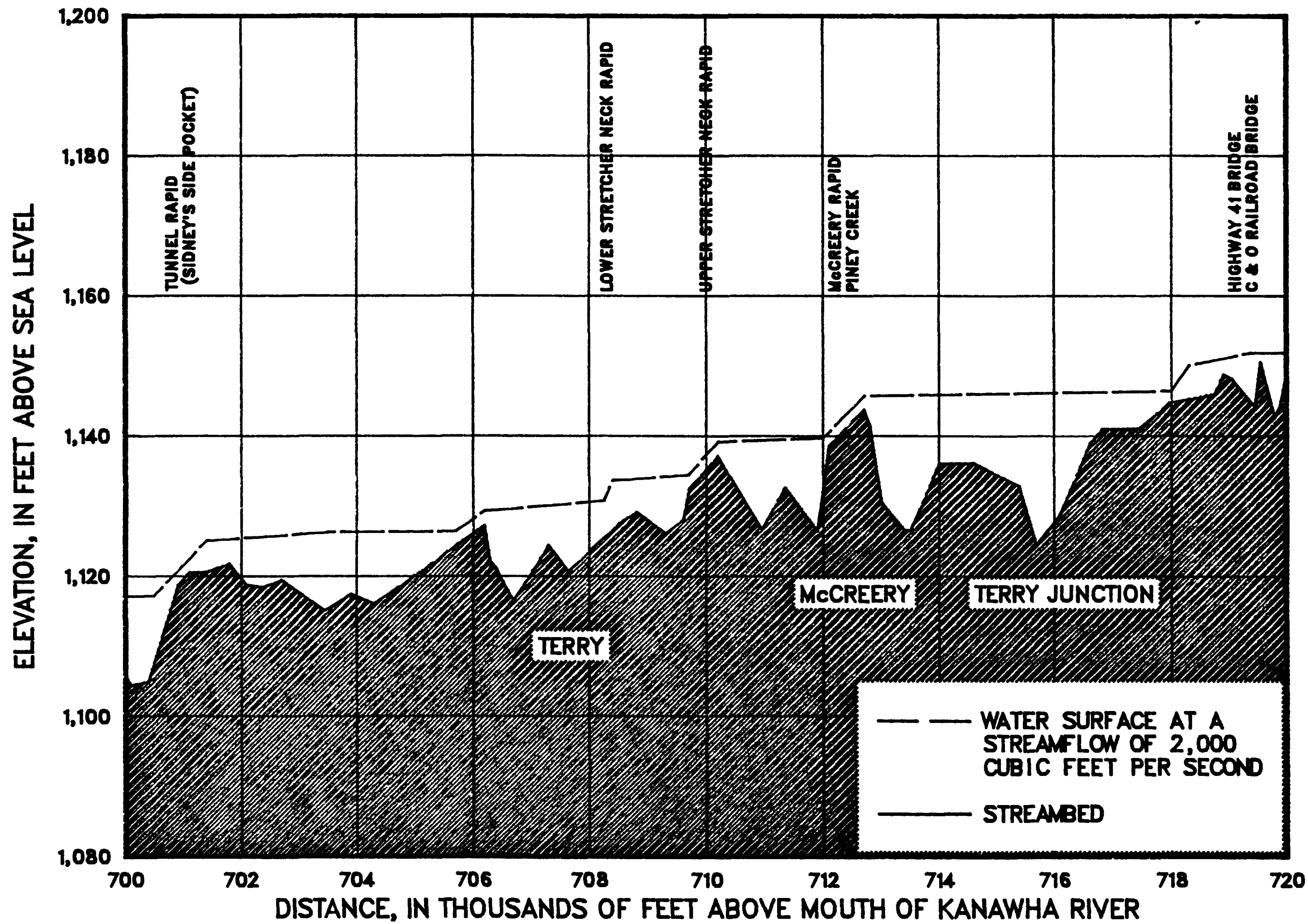

Figure 18.--Water-surface and streambed profiles in the New River Gorge National River.

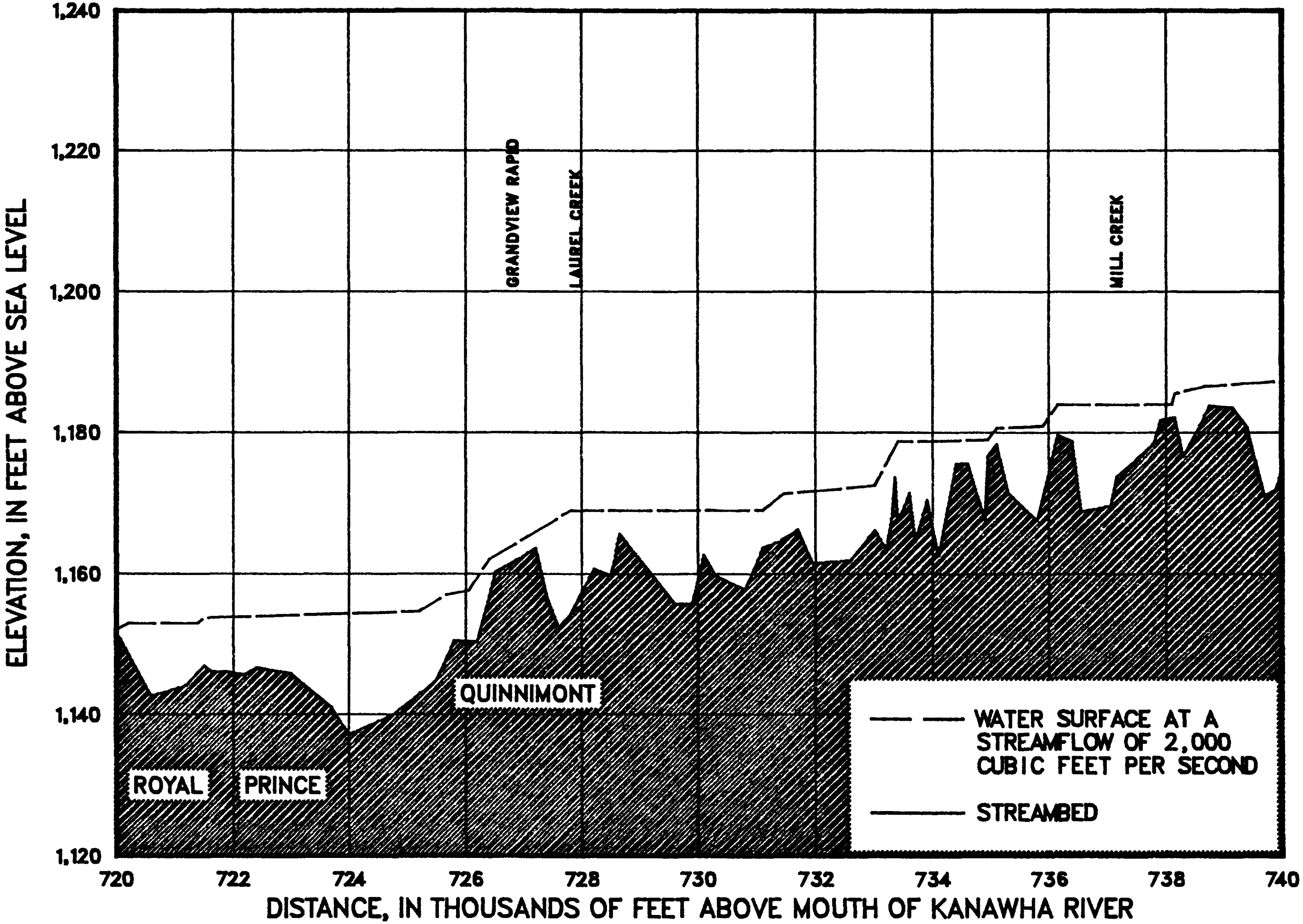

Figure 19.--Water-surface and streambed profiles in the New River Gorge National River.

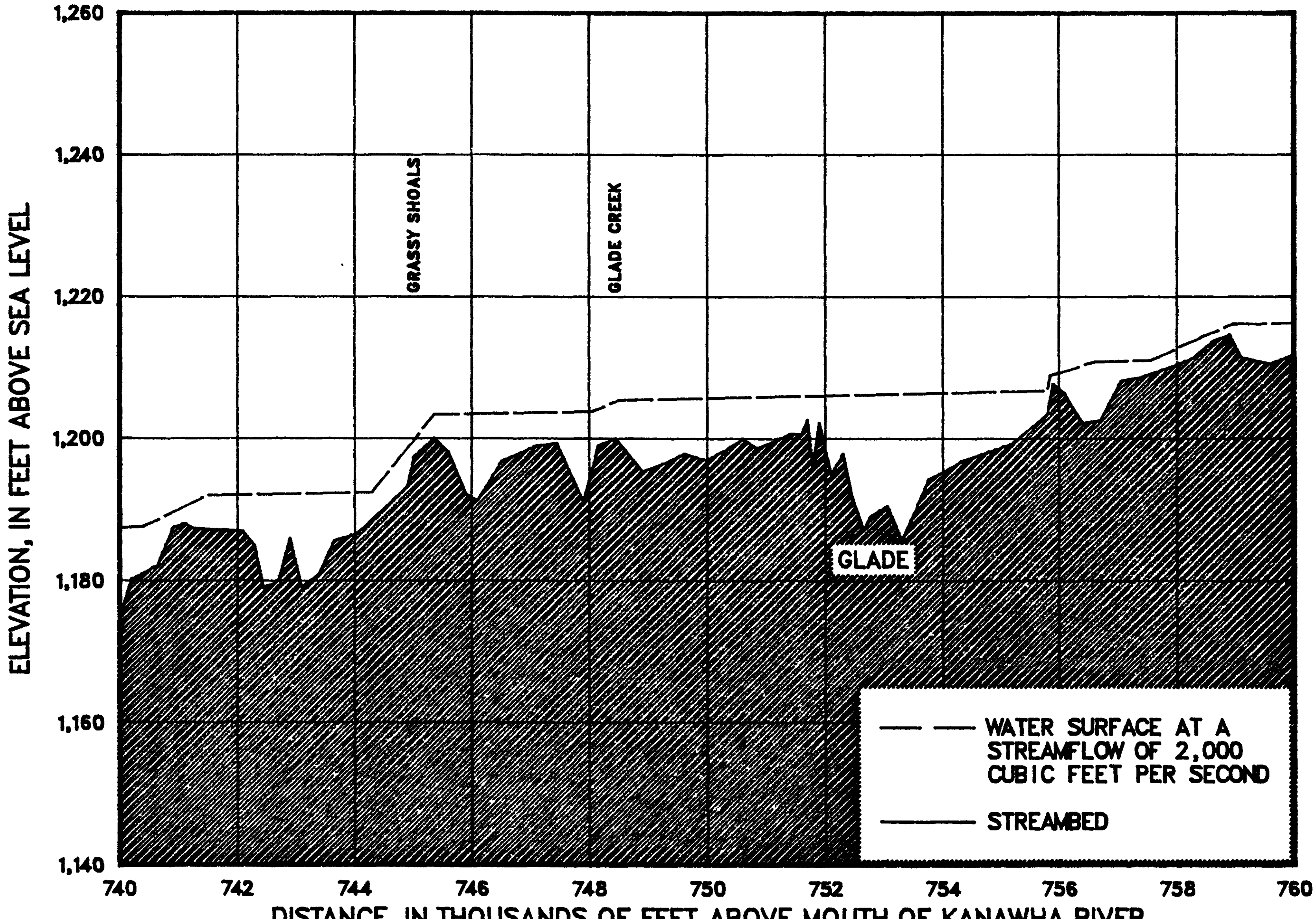

Figure 20.--Water-surface and streambed profiles in the New River Gorge National River.

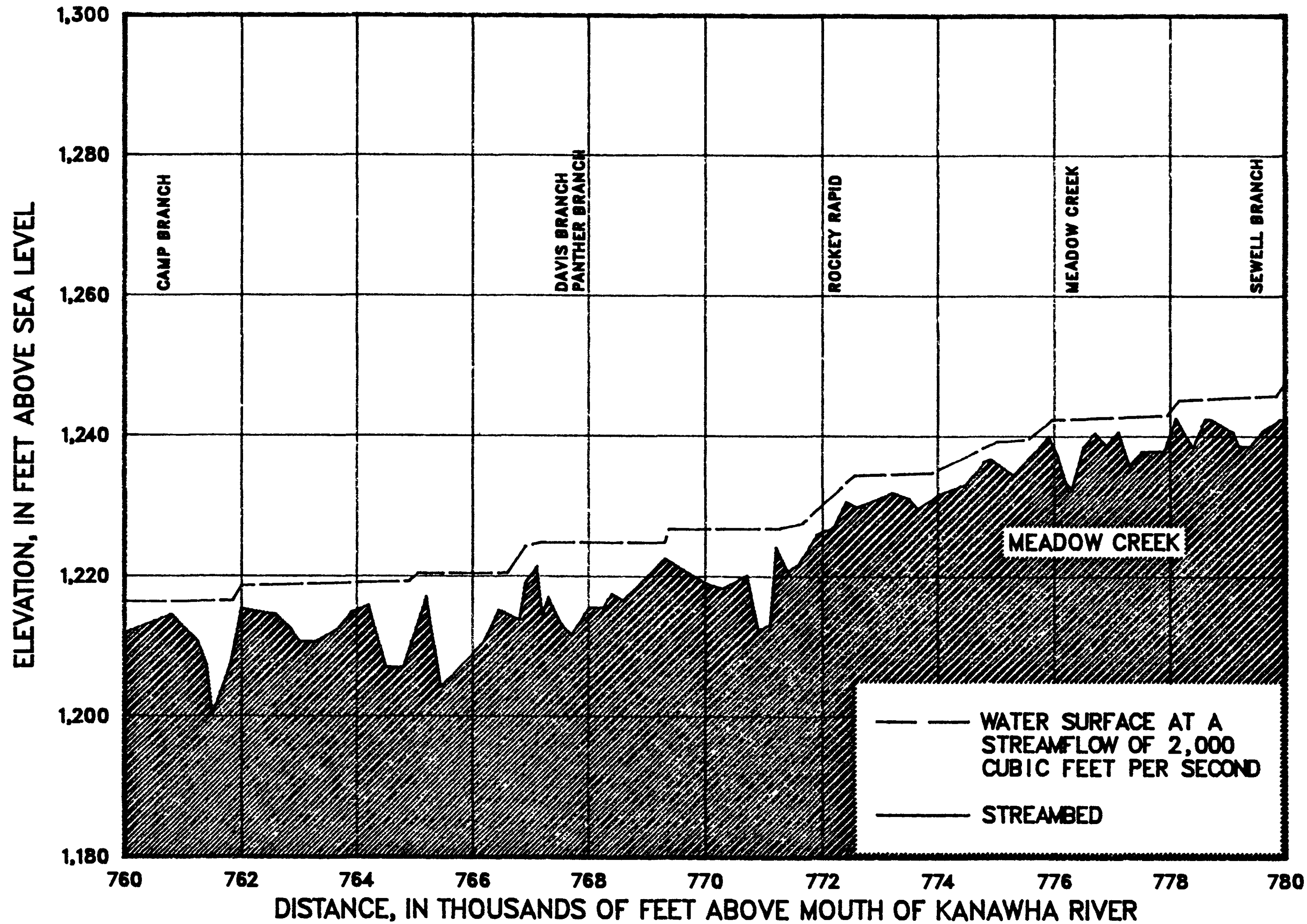

Figure 21.--Water-surface and streambed profiles in the New River Gorge National River.

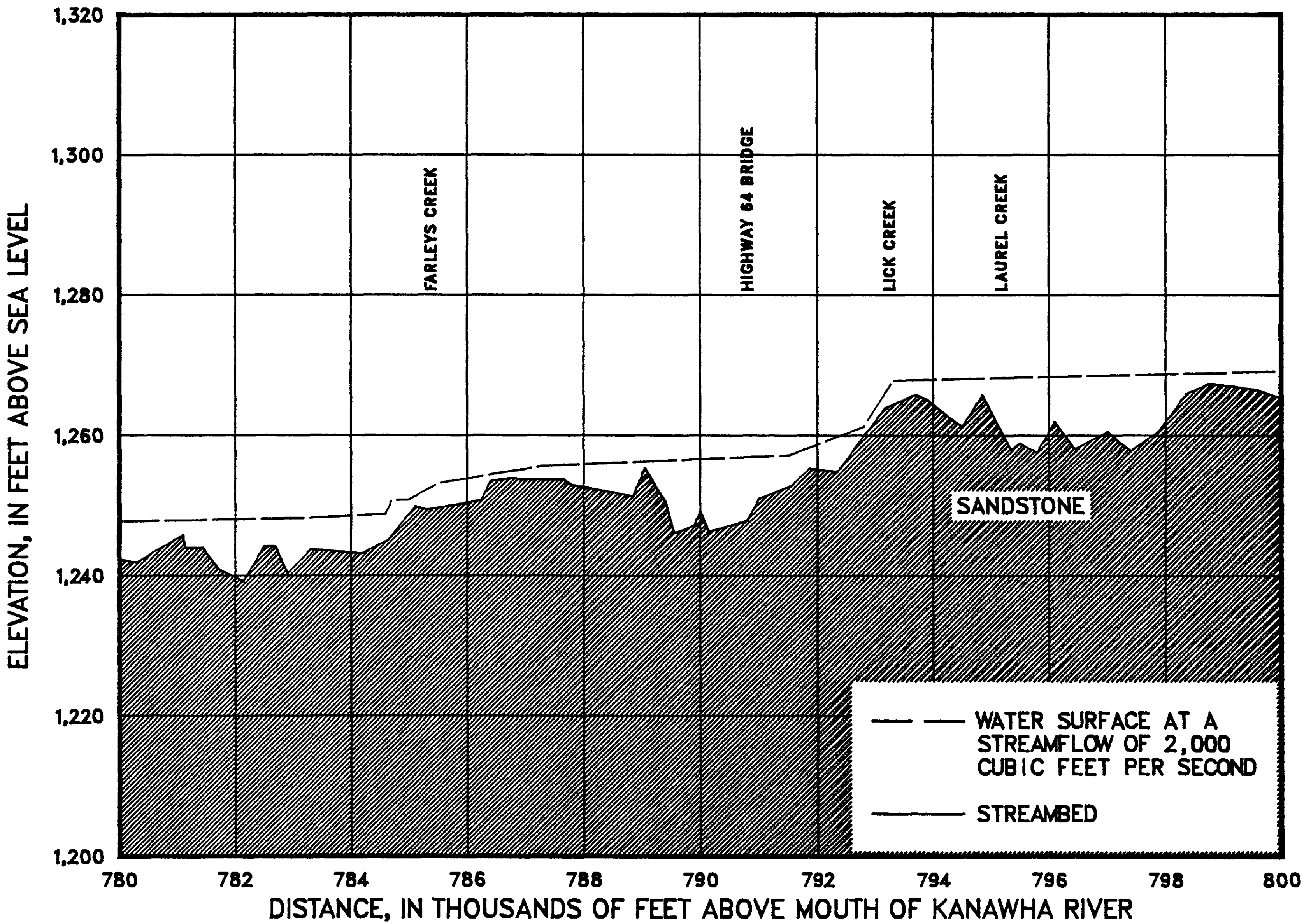

Figure 22.--Water-surface and streambed profiles in the New River Gorge National River.

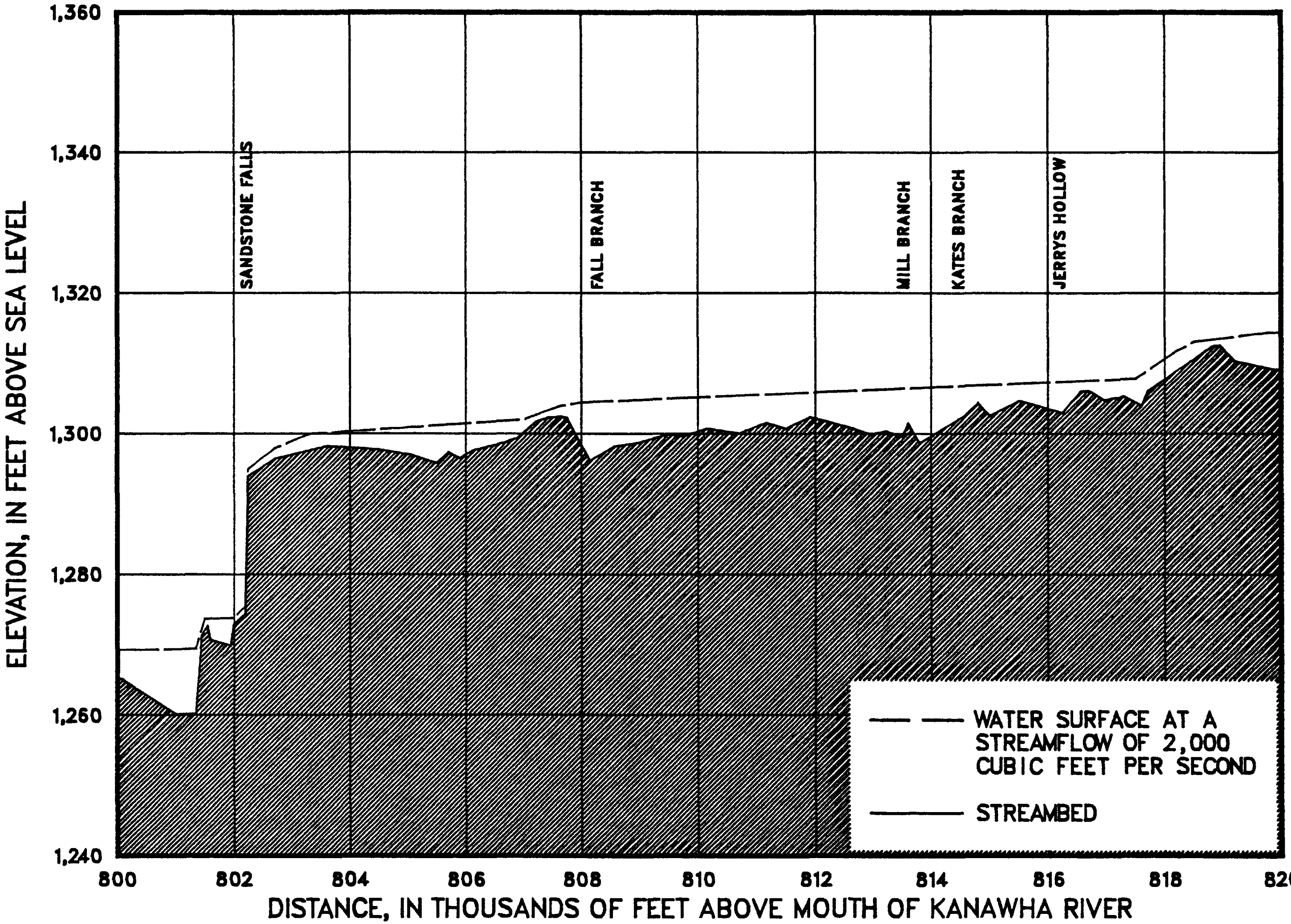

Figure 23.--Water-surface and streambed profiles in the New River Gorge National River.

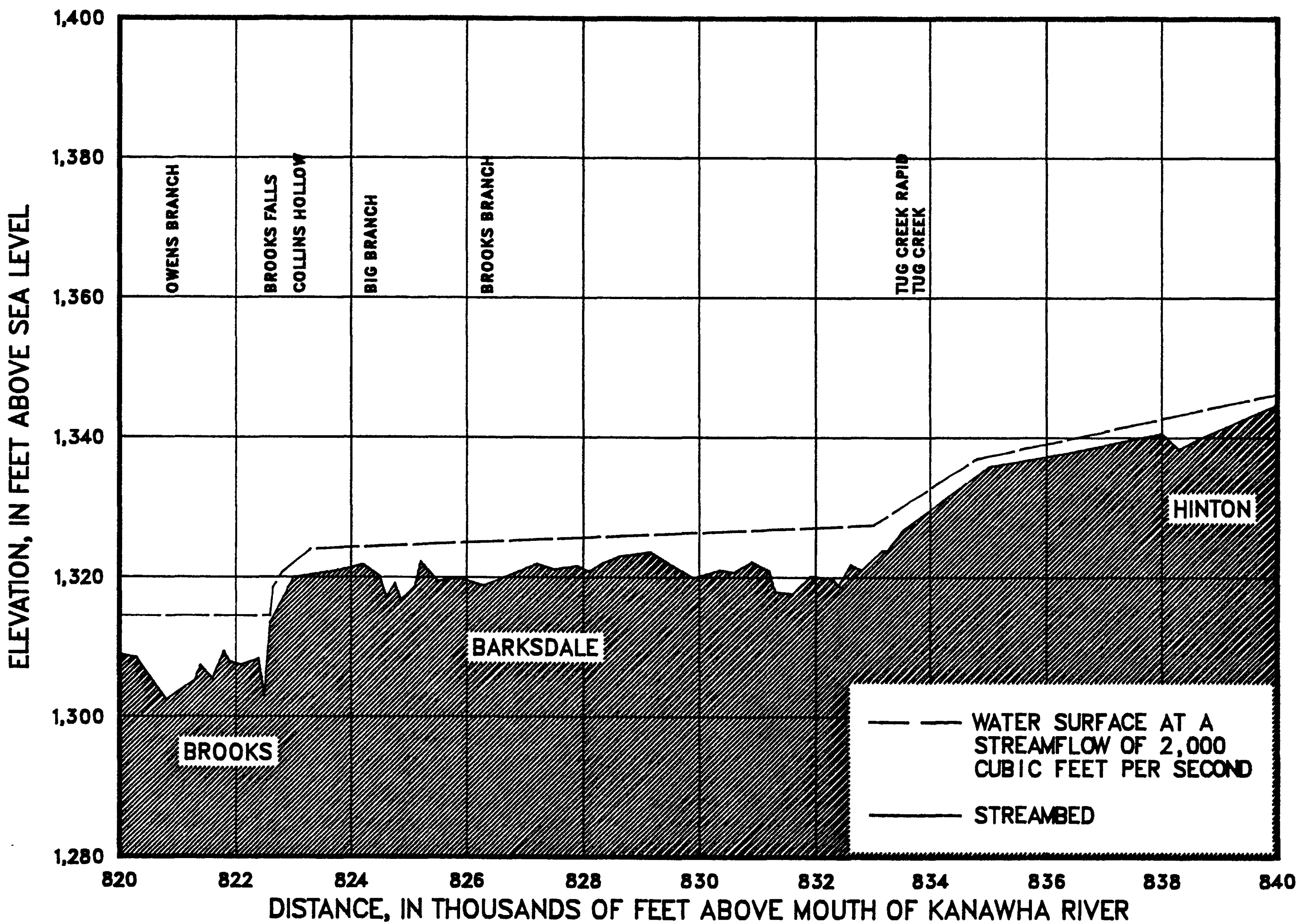

Figure 24.--Water-surface and streambed profiles in the New River Gorge National River.

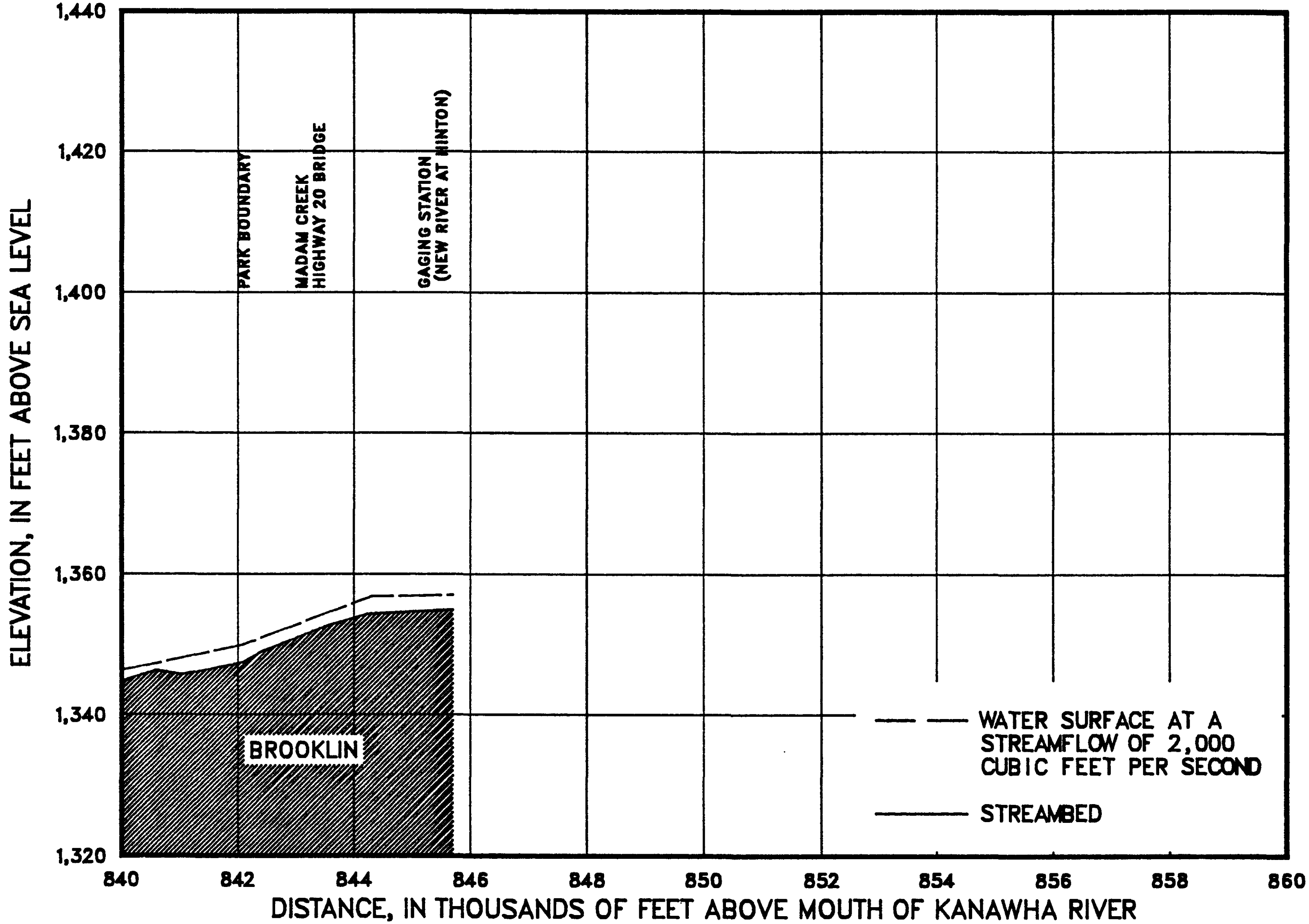

Figure 25.--Water-surface and streambed profiles in the New River Gorge National River.

SUMMARY

The National Park Service is responsible for conserving and preserving as a free flowing stream the lower New River as defined by Public Law 95-625. The data presented in this report will be used to apply flow and solute-transport models to study the effects of an accidental spill of a soluble contaminant in the New River within the boundaries of the New River Gorge National River.

Traveltime of flood waves between any two points on the study reach were determined from graphs developed in the report 'Traveltimes of flood waves on the New River between Hinton and Hawks Nest, West Virginia' (Appel, 1983). Graphs used to determine traveltime and changes in peak concentration of soluble materials under steady-flow conditions between locations in the study reach were taken from the report 'Traveltime and dispersion in the New River, Hinton to Gauley Bridge, West Virginia' (Appel and Moles, 1987).

Two measurements investigating the effects of streamflow changes on the traveltime and dispersion characteristics of dye were conducted. The first measurement increased the flow rate 160 percent and the second measurement decreased the flow rate 50 percent. The change in flow moved through the dye cloud between Prince and Stone Cliff. The dye cloud became shorter in length with increased flow and longer with decreased flow. After changes in flow rates occurred, the traveltime and rate of dispersion became those relative to the new flow.

Stage/streamflow relations are provided for seven sites. Rating sites were selected so that the general changes in stream geometry along the study reach were defined. Stages can be converted to elevations above sea level by adding the elevation of the datum.

Profiles of the water surface at approximately a streamflow of 2,000 ft^3/s and the streambed were used to select cross-section locations that define area changes in the study reach. Estimates of ground elevations for river cross sections were evaluated for the model from aerial photography, topographic maps, rating curves, and water-surface and streambed profiles.

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