

Prepared in cooperation with the Federal Emergency Management Agency

Flood Study of the Suncook River in Epsom, Pembroke, and Allenstown, New Hampshire, 2009



Scientific Investigations Report 2010–5127

Cover. Photograph looking downstream at area of Suncook River avulsion, Epsom, New Hampshire.
(Photograph taken on June 18, 2008)

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By Robert H. Flynn

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

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KEN SALAZAR, Secretary

U.S. Geological Survey
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Conversion Factors, Datum, and Abbreviations

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square mile (mi ²)	2.590	square kilometer (km ²)
Volume		
cubic yard (yd ³)	0.7646	cubic meter (m ³)
Flow rate		
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft ³ /s)	0.02832	cubic meter per second (m ³ /s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F}=(1.8\times^{\circ}\text{C})+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$^{\circ}\text{C}=(^{\circ}\text{F}-32)/1.8$$

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

OTHER ABBREVIATIONS USED IN REPORT

ADCP	Acoustic Doppler Current Profiler
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FIS	Flood Insurance Study
GPS	Global Positioning System
HEC-RAS	Hydrologic Engineering Center River Analysis System
NFIP	National Flood Insurance Program
NHDOT	New Hampshire Department of Transportation
NWIS	National Water Information System
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

Flood Study of the Suncook River in Epsom, Pembroke, and Allenstown, New Hampshire, 2009

By Robert H. Flynn

Abstract

On May 15, 2006, a breach in the riverbank caused an avulsion in the Suncook River in Epsom, NH. The breach in the riverbank and subsequent avulsion changed the established flood zones along the Suncook River; therefore, a new flood study was needed to reflect this change and aid in flood recovery and restoration. For this flood study, the hydrologic and hydraulic analyses for the Suncook River were conducted by the U.S. Geological Survey, in cooperation with the Federal Emergency Management Agency.

This report presents water-surface elevations and profiles determined using the U.S. Army Corps of Engineers one-dimensional Hydrologic Engineering Center River Analysis System model, also known as HEC-RAS. Steady-state water-surface profiles were developed for the Suncook River from its confluence with the Merrimack River in the Village of Suncook (in Allenstown and Pembroke, NH) to the upstream corporate limit of the town of Epsom, NH (approximately 15.9 river miles). Floods of magnitudes that are expected to be equaled or exceeded once on the average during any 2-, 5-, 10-, 25-, 50-, 100-, or 500-year period (recurrence interval) were modeled using HEC-RAS. These flood events are referred to as the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year floods and have a 50-, 20-, 10-, 4-, 2-, 1-, and 0.2-percent chance, respectively, of being equaled or exceeded during any year. The 10-, 50-, 100-, and 500-year flood events are important for flood-plain management, determination of flood-insurance rates, and design of structures such as bridges and culverts. The analyses in this study reflect flooding potentials that are based on existing conditions in the communities of Epsom, Pembroke, and Allenstown at the time of completion of this study (2009). Changes in the 100-year recurrence-interval flood elevation from the 1979 flood study were typically less than 2 feet with the exception of a location 900 feet upstream from the avulsion that, because of backwater from the dams in the abandoned channel, was 12 feet higher in the 1979 flood study than in this study.

Introduction

The Suncook River drains a group of lakes to the south of Lake Winnepesaukee and flows for approximately 30 mi to the Merrimack River at a location between Concord and Manchester, NH (fig. 1). Floods typically occur along the Suncook and Little Suncook Rivers during the spring, fall, and winter. Some of the most severe flooding in early spring is a result of snowmelt and heavy rains in conjunction with river ice. Major flooding in the fall is a result of heavy rainfall associated with tropical storms. Large thunderstorms can result in rapid runoff and flooding in the downstream reaches of small streams.

Two floods in March 1936 resulted in the largest flood of record for the Suncook River. A combination of saturated ground, warm temperatures, snowmelt, and heavy rains from the second flood, following the filling of lakes and reservoirs and high river flows from the first flood, resulted in a peak flow of 12,900 ft³/s at the U.S. Geological Survey (USGS) streamgage Suncook River at Depot Road in North Chichester, NH (streamgage number 01089500), hereinafter referred to as the Suncook River streamgage. The March 1936 peak flow was determined to be between a 100- and 500-year event (Flynn, 2008; Olson, 2007) and remains the largest flood of record at the Suncook River streamgage.

From May 13 to 16, 2006, central and southern New Hampshire were flooded as a result of rainfall in excess of 8.8 in. (measured in Concord, NH) over a 4-day period. During the storm, flooding, along with streambed and streambank erosion and deposition, was substantial at several locations in the state. As a result of the flood damage, a presidential disaster declaration was made on May 25, 2006, for the New Hampshire counties of Rockingham, Hillsborough, Strafford, Merrimack, Belknap, Carroll, and Grafton. In response to this declaration, the USGS, in cooperation with the Federal Emergency Management Agency (FEMA), measured or computed flood data at 65 streamgages within the disaster declaration area (Olson, 2007). On the basis of surveyed high-water marks, the peak flow at the Suncook River streamgage for the May 2006 event was determined to be 7,600 ft³/s (Olson, 2007), the third largest flood of record at this streamgage. This flow was determined from the Suncook

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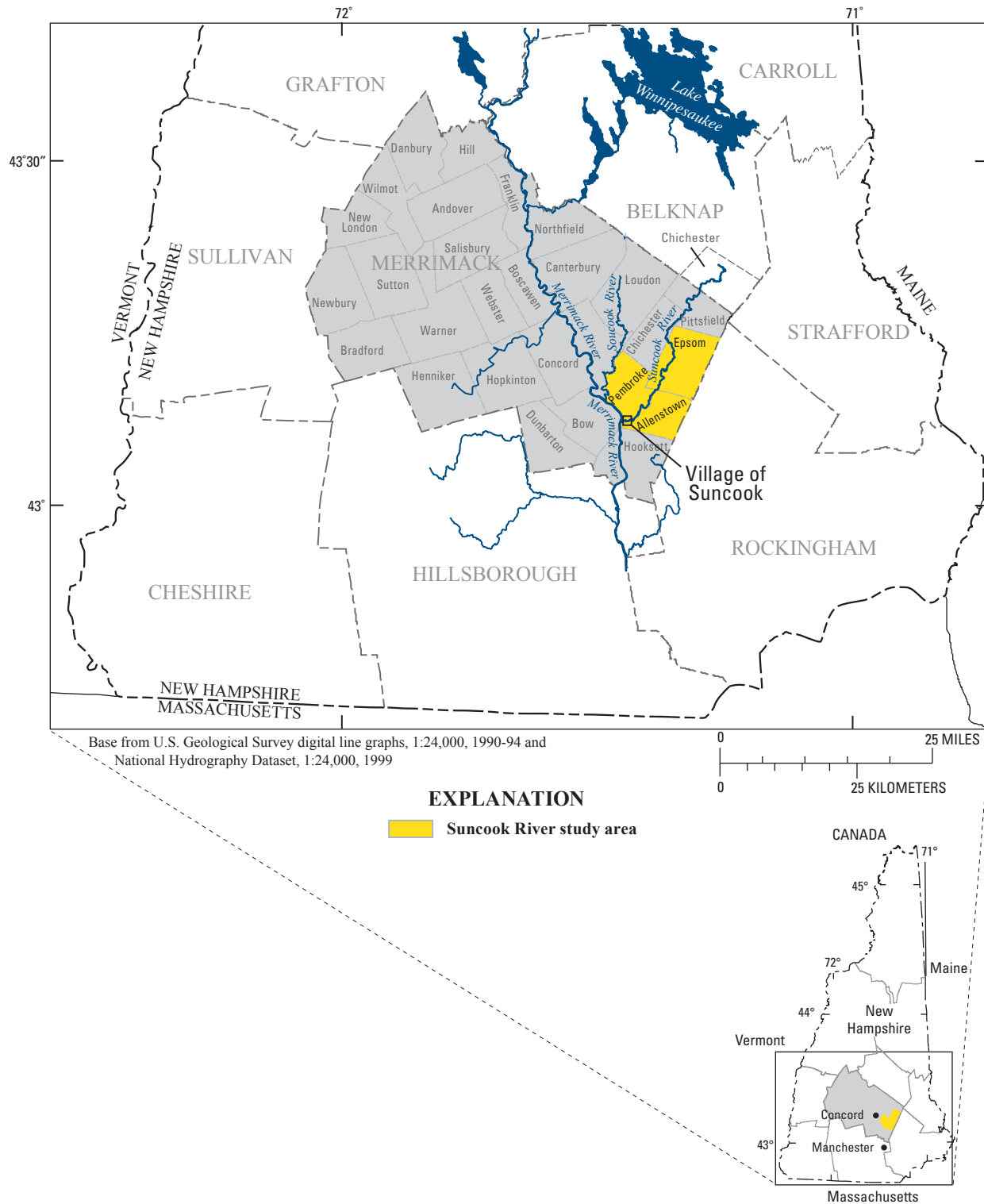


Figure 1. Extent of the flood study of the Suncook River in Epsom, Pembroke, and Allenstown, NH.

River streamgauge rating curve (stage/flow relation) that was extended above 4,500 ft³/s on the basis of a slope-area and contracted-opening measurement at 15.27 ft for the flood peak of 12,900 ft³/s on March 19, 1936.

On May 15, 2006, a breach in the riverbank south of U.S. Route 4 and east of State Route 28 created an avulsion in the Suncook River in Epsom, NH (fig. 2). An avulsion refers to the abandonment of a river channel and the formation of a new river channel. Prior to the breach, the Suncook River flowed southward around Bear Island in Epsom, NH, in two stream reaches that joined to the west of Round Pond. The breach during the May 2006 flood created a new channel upstream from Bear Island and two dams at the north end of Bear Island, with the new channel rejoining the old channel to the east of Bear Island. After May 16, there was no flow in the western and northeastern reach of the Suncook River around Bear Island. Instead, the Suncook River created a path through a gravel and sand pit resulting in a channel to the east of its former location (fig. 2). The new channel through the former gravel and sand pit created by the breach of May 15, 2006, was 0.42 mi (2,220 ft) in length, whereas the abandoned

primary east channel was 0.87 mi (4,595 ft) in length. The abandoned west channel was 1.14 mi (6,040 ft) in length; the total length of abandoned channel was 2.01 mi. The length of the new channel of the Suncook River from the location upstream from the former confluence with the abandoned channel (upstream from the avulsion), through the former sand and gravel pit, back into the east channel and to the downstream location of the confluence at the abandoned west channel (southern end of Bear Island) was 1.02 mi (5,407 ft). As a result of the reduction in total stream length, from 2.01 to 1.02 mi, the average gradient of the Suncook River increased approximately 40 percent between the upstream and downstream locations of the abandoned channels. Because of this increased gradient, the average velocity of the river will increase, which is expected to increase the ability of the river to erode the riverbed and banks.

The breach and subsequent avulsion also affected sediment induction into the Suncook River because of the new path of the river through the sand and gravel pit. It was estimated that 150,000 yd³ of sediment were introduced into the Suncook River as a result of the new channel (Wittkop,

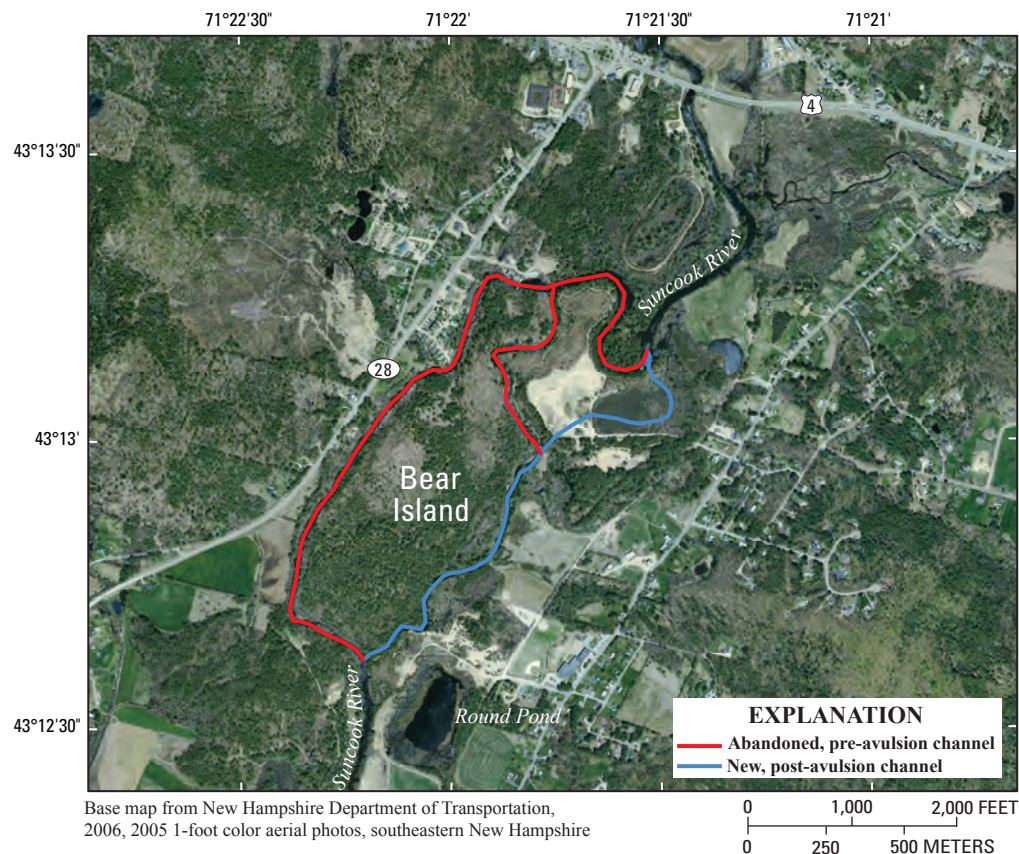


Figure 2. Pre-avulsion aerial imagery with the new and abandoned channels of the May 2006 Suncook River avulsion, Epsom, NH.

2006). Sheets of silt and sand, up to 5 ft thick, were deposited downstream from the avulsion channel, and this deposition is expected to decrease channel depth and increase the frequency of overbank flooding. In the avulsion area and upstream, downcutting of the stream continues to occur because of the increased gradient of the Suncook River and the convergence of flow.

From April 16 to 18, 2007, southeastern New Hampshire experienced severe flooding as a result of a storm that stalled off the New England coast and deposited, in some locations, more than 7 in. of rainfall on an existing snowpack. As a result of this flood event, a presidential disaster declaration was made for Grafton, Hillsborough, Merrimack, Rockingham, and Strafford Counties in New Hampshire. On May 10, 2007, Belknap County was added to the disaster declaration. In response to this declaration, the USGS, in cooperation with FEMA, measured or computed flood data at 57 streamgages and 4 ungaged locations within and adjacent to the disaster areas (Flynn, 2008). On the basis of hydraulic models calibrated with surveyed high-water marks, the peak flow at the USGS Suncook River streamgage for the April 2007 event was determined by indirect methods to be 10,600 ft³/s and to have a recurrence interval of between 100 and 500 years (Flynn, 2008). This flood peak was the second largest flood of record at this streamgage. The May 2006 flood peak was subsequently estimated to be 6,600 ft³/s on the basis of the original rating curve extended with the April 2007 peak. The 2006 peak flow was determined to have a recurrence interval of between 25 and 50 years. The May 2006 and April 2007 flood peaks were listed by the USGS as “extremes outside period of record.”

Although the recurrence interval represents the long-term average period between floods of a specific magnitude, floods can recur at short intervals and within the same year. The probability of experiencing a flood of a given magnitude increases when periods greater than 1 year are considered. For example, the probability of a flood that equals or exceeds the 100-year flood (1-percent chance of annual exceedance) in any 50-year period is approximately 40 percent (4 in 10), and for any 90-year period, the probability increases to approximately 60 percent (6 in 10). The analyses reported herein reflect flooding potentials that are based on conditions in the communities at the time this study was completed (2009).

The breach in the riverbank and subsequent avulsion changed the established flood zones along the Suncook River as defined by the U.S. Department of Housing and Urban Development Federal Insurance Administration (1978a, 1978b, 1978c); therefore, new flood maps were needed to reflect this change to the impact of the Suncook River on property and homes in the communities along the river. The current effective FEMA Flood Insurance Rate Maps (FIRMs) and Flood Insurance Studies (FISs) for Allenstown (U.S. Department of Housing and Urban Development Federal Insurance Administration, 1978a), Epsom (U.S. Department of Housing and Urban Development Federal Insurance Administration, 1978b) and Pembroke (U.S. Department

of Housing and Urban Development Federal Insurance Administration, 1978c) contain detailed 100- and 500-year flood-hazard areas that are no longer valid because of the breach and updated hydrology and topographic data, and need to be updated. This flood study to update the 100- and 500-year flood elevations was conducted by the USGS in cooperation with FEMA. Updated elevations and flood-plain maps for the Suncook River can be used by state and local officials to guide the redevelopment and replacement of damaged infrastructure and the allocation of state and federal recovery resources, and to ensure that effective mitigation measures are in place to avoid future flood losses.

Purpose and Scope

This report provides updated flood elevations for the Suncook River as a result of the May 2006 and April 2007 floods and the May 2006 avulsion. This study area included the Suncook River from the confluence with the Merrimack River to the upstream corporate limit of the town of Epsom (15.9 mi) in Merrimack County, NH (fig. 1). The results of this study may be used to update the previous FISs and FIRMs for the towns of Allenstown, Epsom, and Pembroke, NH (U.S. Department of Housing and Urban Development Federal Insurance Administration, 1978a, 1978b, 1978c; respectively), and may be used to update existing flood-plain regulations as part of the National Flood Insurance Program (NFIP). The information also can be used by local and regional planners to further promote sound land use and flood-plain development.

Floods that are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) have been recognized as having special importance for flood-plain management and for flood-insurance rates and were modeled in this study. These events, commonly termed the 10-, 50-, 100-, and 500-year floods, have a 10-, 2-, 1-, and 0.2-percent chance, respectively, of being equaled or exceeded during any year. In addition, the 2-, 5-, and 25-year (recurrence interval) flood events and the peak flood of April 16–18, 2007, were modeled in this study. The 2-, 5-, and 25-year floods have a 50-, 20-, and 4-percent chance, respectively, of being equaled or exceeded during any year.

Description of the Study Area

The Suncook River flows through the towns of Epsom, Pembroke, and Allenstown, NH, in southeastern Merrimack County, which is in south-central New Hampshire (fig. 1). State Route 28 is parallel to the Suncook River and connects the towns of Epsom, Pembroke, and Allenstown. The Suncook River originates to the south of Lake Winnepesaukee, is approximately 39 mi long, and flows in a southerly direction. Its confluence with the Merrimack River is in the Village of Suncook, NH, which is located within the towns of Allenstown and Pembroke, NH. The drainage area is 154 mi²

at the USGS Suncook River streamgauge in North Chichester, NH, and 255.7 mi² at the confluence of the Suncook River with the Merrimack River in the Village of Suncook, NH.

The town of Epsom comprises 34.5 mi² of land area and 0.1 mi² of inland water area. The population of Epsom was 4,567 in 2007 (New Hampshire Employment Security, Economic and Labor Market Information Bureau, 2009b) or approximately 132 people per square mile. The population of Epsom increased 66 percent between 1980 and 2007.

The town of Pembroke includes the Villages of North Pembroke and Suncook and comprises 22.6 mi² of land area and 0.2 mi² of inland water area. The population of Pembroke was 7,353 in 2007 (New Hampshire Employment Security, Economic and Labor Market Information Bureau, 2009c) or approximately 322 people per square mile. The population of Pembroke increased 51 percent between 1980 and 2007.

The town of Allenstown includes the Village of Suncook and comprises 20.5 mi² of land area and 0.1 mi² of inland water area. The population of Allenstown was 4,943 in 2007 (New Hampshire Employment Security, Economic and Labor Market Information Bureau, 2009a) or approximately 240 people per square mile. The population of Allenstown increased 12 percent between 1980 and 2007.

The Little Suncook River, a tributary to the Suncook River, originates east of Epsom at Northwood Lake and flows westerly to its confluence with the Suncook River downstream from U.S. Route 4 (fig. 3). The drainage area at the mouth of the Little Suncook River is approximately 41 mi² (U.S. Department of Housing and Urban Development Federal Insurance Administration, 1978b). Numerous other small streams flow into these two rivers. In general, the flood plains along the Suncook and Little Suncook Rivers are sparsely developed with the exception of areas near the intersection of the Suncook River and U.S. Route 4, the intersection of the Suncook River and U.S. Route 3, downstream through the Village of Suncook, and near Gossville and Epsom along the Little Suncook River.

The prevailing winds in Epsom, Pembroke, and Allenstown are from the northwest and result in cold, dry air in the winter and cool, dry air in the summer. Strong winds from the south occur in July and August, and winds from the east typically coincide with summer and winter storms (National Climate Data Center, 2008). Precipitation falls on an average of 1 day out of 3 during the year; the frequency is slightly higher for April and May and slightly lower for August to October. Easterly winds and especially northeasterly

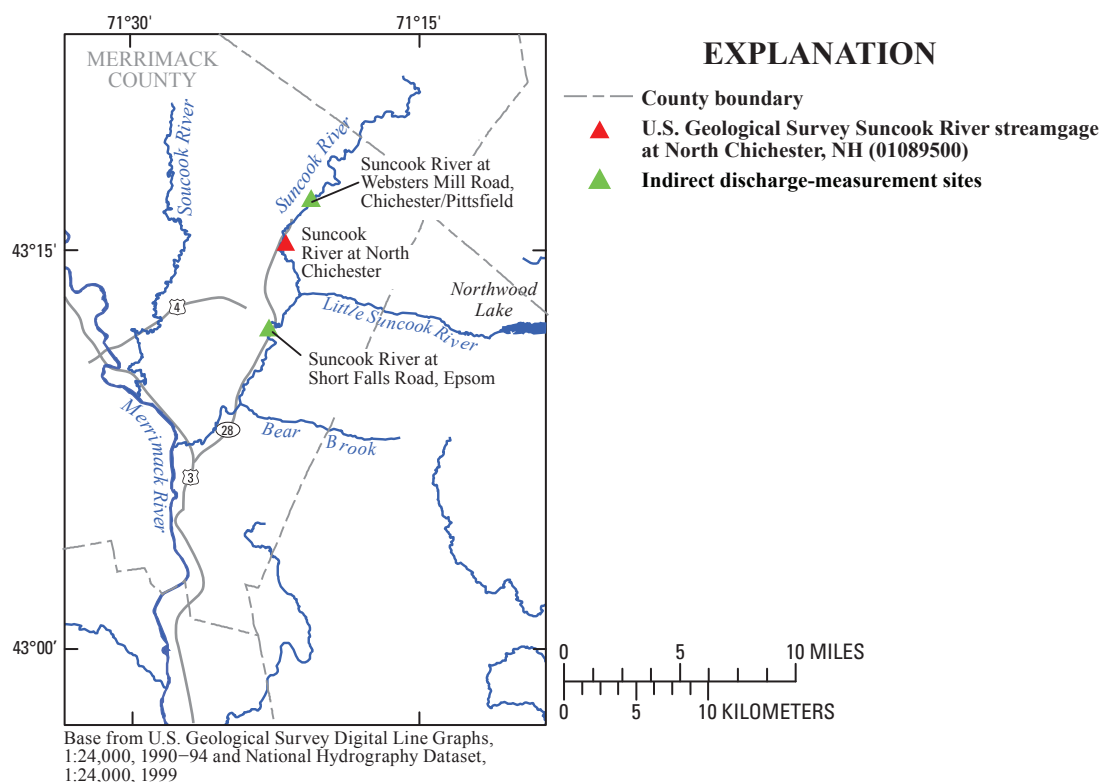


Figure 3. Location of the Suncook River streamgauge at North Chichester, NH (01089500), and indirect discharge locations for the determination of the April 2007 flood peak on the Suncook River.

winds are associated with the more substantial rains and heavier snowfalls. Snow cover typically lasts from mid-December until the last week of March, although bare ground is not a rarity in the winter. Rain, sleet, or freezing rain may also occur during the winter (National Climate Data Center, 2008).

The average daily maximum and minimum temperatures for July in Concord, NH, are 82.2 and 57.2°F, respectively. The average daily maximum and minimum temperatures for January in Concord are 31.1 and 10.7°F, respectively. Average annual precipitation in Concord for 1979–2008 (rain, snow, and sleet) is 37.9 in. Average annual snowfall in Concord for 1979–2008 is 63.8 in. (National Climate Data Center, 2008).

The topography of Epsom, Pembroke, and Allenstown is hilly and characterized by stratified and unstratified material transported by and deposited from retreating glacial ice. The flood plains adjacent to the rivers are comprised of alluvial silt overlying glacial outwash. The predominant soil group is composed primarily of well-drained sandy loam in glacial till. Kames, terraces, deltas, and outwash plains are glacial landforms common to this area. Elevations range from 192 ft (NGVD 29) at the confluence of the Suncook and Merrimack Rivers to 1,413 ft (NGVD 29) at the summit of Fort Mountain in Epsom. Wetland areas throughout the three towns serve as the headwaters for many smaller streams.

The Suncook River has no major flood-control structures. The Pittsfield Mill Dams in Pittsfield, NH, Buck Street Dam in Pembroke, NH, and Webster, Pembroke, and China Mill Dams in the Village of Suncook are all run-of-river dams and do not act as flood-control dams. The Webster, Pembroke, and China Mill Dams are used for hydroelectric power generation. These dams do little to attenuate major flood peaks.

Flood Mapping and Flood-Plain Management Applications

The 100- and 500-year flood-plain and floodway boundaries have been delineated using the flood elevations determined at 160 cross sections along the river. To provide a national standard without regional discrimination, the 1-percent annual exceedance probability (100-year) flood has been adopted by FEMA as the base flood for purposes of flood-plain management. The 0.2-percent annual exceedance probability (500-year) flood is used to indicate additional areas of flood risk in the community.

The floodway is the channel of a stream plus any adjacent flood-plain areas that must be kept free of encroachment so that the 100-year recurrence-interval flood can be carried without substantial increases in flood heights. Minimum federal standards limit such increases to 1.0 ft provided that hazardous velocities are not produced. The floodway presented in this study was computed for certain stream segments on the basis of equal conveyance reduction from each side of the flood plain. Floodway widths were computed at cross sections. Encroachment on flood plains, such as structures and fill,

reduces flood-carrying capacity, increases flood heights and velocities, and increases flood hazards in areas beyond the encroachment itself. One aspect of flood-plain management involves balancing the economic gain from flood-plain development against the resulting increase in flood hazard. For purposes of the NFIP, delineation of a floodway can assist local communities in this aspect of flood-plain management.

The floodways in this study are presented as a minimum standard that can be adopted directly by the towns. The area between the floodway and 100-year flood-plain boundaries is termed the floodway fringe. The floodway fringe encompasses that part of the flood plain that could be completely obstructed without increasing the water-surface elevation of the 100-year flood by more than 1.0 ft at any point.

The 1-ft contour-interval data (Eastern Topographics, 2007) were created for the reach of the Suncook River from U.S. Route 4 to approximately 0.25 mi downstream from the Short Falls Road bridge. These 1-ft contour-interval data extended out to 660 ft on either side of this reach. The 4-ft contour-interval data (Eastern Topographics, 2008) were created for the reach of the Suncook River from the Short Falls Road bridge to the confluence with the Merrimack River. These 4-ft contour-interval data extended out to 1,000 ft on either side of the Suncook River. In areas beyond the extent of the 1- and 4-ft contour-interval data, 10- and 20-ft contour interval USGS Digital Orthophoto Quadrangles produced at a scale of 1:24,000 referenced to the horizontal datum of NAD 83 and the vertical datum of NGVD 29 (U.S. Geological Survey, 1967a, 1967b, 1968, 1981) were used to delineate the extent of flooding on the 100- and 500-year flood map for the Suncook River.

The base map for the delineation of the floodway and the 100- and 500-year floods (appendix 4) was created using black and white aerial photographic imagery collected by Eastern Topographics (2007) in May 2007 (post-avulsion) along the Suncook River and 1-ft-resolution color aerial photographic imagery of southeastern New Hampshire (New Hampshire Department of Transportation, 2006) collected for the New Hampshire Department of Transportation (NHDOT) in May 2005 (pre-avulsion) for areas outside the extent of the Eastern Topographics (2007) imagery.

Methods Used to Determine Flood Data

Hydrologic and hydraulic analyses were used to determine the flood data required for this flood study of the Suncook River. The U.S. Army Corps of Engineers (USACE) step-backwater flow model, Hydrologic Engineering Center River Analysis System model (HEC-RAS) (U.S. Army Corps of Engineers, 2008a), was used for the determination of water-surface elevations at surveyed cross sections and, subsequently, flood profiles for the selected recurrence-interval floods along the study reach. The water-surface elevations determined with HEC-RAS were used to create the flood map

delineating the extent of the 100- and 500-year floods. Input for the HEC-RAS model required the collection of hydraulic and hydrologic field data to characterize channel geometry and flow. Hydraulic data included river cross-section surveys at 160 locations and structural surveys at 7 bridges and 5 inline (dam) structures. Hydrologic data included analysis of streamflow data from the Suncook River streamgage that incorporated peak-flow data determined by indirect methods in 2006 and 2007 (Olson, 2007; Flynn, 2008; respectively). The Suncook River HEC-RAS model was calibrated to the flood of April 2007 using high-water-mark data collected after that flood along with the flood peak flow determined by indirect methods at the Suncook River streamgage.

All FISs and FIRMs are referenced to a specific vertical datum. The vertical datum provides a starting point against which flood, ground, and structure elevations can be referenced and compared. All structure, ground, and flood elevations given in this flood-study report and map are referenced to the NGVD 29, unless otherwise noted. The coordinate system used for the production of the digital flood map is New Hampshire State Plane referenced to the NAD 83 and NGVD 29. A description of the reference marks used in this study is presented in appendix 3.

Field Data Collection

After the April 16–18, 2007, flood, high-water-mark information, indicating peak flood stage, was collected upstream from, downstream from, and at the former USGS Suncook River streamgage (Flynn, 2008). The high-water marks consisted of debris lines, wash lines, seed lines, or mud/silt lines left behind by the peak water elevation during the flood. The peak-flood-stage data at flagged high-water marks and field-surveyed cross sections were referenced to NGVD 29 through closed level-loop surveying techniques from either a known reference datum or from a reference datum established using a Leica System 1200 Global Positioning System (GPS) with 3-mm (0.01-ft) horizontal accuracy and 10-mm (0.03-ft) vertical accuracy in static mode (Leica Geosystems, 2008).

Cross sections for the 15.9-mi study reach of the Suncook River were from field surveys conducted in the summer of 2008. Valley and below-water cross-section data for the Suncook River were obtained from field measurements. Additional valley cross-section data were obtained using 1-ft (Eastern Topographics, 2007) and 4-ft (Eastern Topographics, 2008) contour-interval data created from aerial photogrammetry collected in May 2007 and April 2008. All bridges, dams, and culverts were field-surveyed to obtain elevation data and structural geometry. Bridge, dam, and culvert cross-section data were collected at close intervals upstream and downstream from bridges and dams in order to compute the potential backwater effects of these structures. Between the Short Falls Road bridge and the Buck Street Dams, cross-section and profile data were collected using a

GPS in conjunction with an Acoustic Doppler Current Profiler (ADCP) (Mueller and Wagner, 2009).

Indirect Determination of Peak Flow for the Suncook River Flood of April 2007

The Suncook River streamgage was active from 1919 to 1920, 1922 to 1927, and 1929 to 1977. Because the Suncook River streamgage was inactive from 1978 to October 2007, it was not active during the two peak-flow events in May 2006 and April 2007 but was re-activated in November 2007. After the May 2006 and April 2007 floods, high-water-mark information was collected by the USGS at the Suncook River streamgage (Olson, 2007; Flynn, 2008). These data were used to estimate the flood peak flow for these events on the basis of the rating curve established for the streamgage for the period of record prior to 1977. Additional high-water-mark information was collected upstream and downstream from the Suncook River streamgage after the April 2007 flood (Flynn, 2008).

Initially, a peak flow of 15,000 ft³/s was extrapolated for the April 16–18, 2007, flood at the Suncook River streamgage on the basis of the high-water-mark data and the rating curve. Subsequently, determinations of indirect flow were made at locations upstream and downstream from the discontinued streamgage, and a flow of 10,600 ft³/s was determined to be the peak flow for the April 16–18, 2007, flood at the Suncook River streamgage (Flynn, 2008). This peak flow was estimated at this streamgage on the basis of the flow/drainage-area relations between two indirectly determined (Matthai, 1967) April 2007 flood-peak flows. The April 2007 flood-peak indirect flow determinations were made at the Websters Mill Road bridge in Chichester/Pittsfield and at the Short Falls Road bridge in Epsom (fig. 3), which have drainage areas of 137 and 210 mi², respectively. The high-water marks upstream and downstream from each bridge, the bridge-opening geometry, and channel and flood-plain cross sections upstream and downstream from the bridge were surveyed, and the values were input to the HEC-RAS model. Flows were selected iteratively as input to the HEC-RAS model (U.S. Army Corps of Engineers, 2005) so that the resulting water-surface elevation output from the program matched the high-water marks surveyed upstream and downstream from each of the bridges. The upper end of the rating curve (stage/discharge relation) at the Suncook River streamgage has likely shifted since it was determined from the March 19, 1936, flood data when a flow of 12,900 ft³/s at a gage height of 15.27 ft was ascertained by slope-area and contracted-opening methods. The shift in the upper end of the stage/discharge rating curve is likely because of a greater amount of vegetation on the right overbank in 2007 than in 1936 (as seen in USGS photographs on file at the New Hampshire-Vermont Water Science Center) and the construction of a weir control along with the removal of a channel island downstream from the Suncook River streamgage in the summer of 1937.

Hydrologic Analyses

Hydrologic analyses were used to establish the peak flow-frequency relations for the Suncook River. For this flood study, peak-flow frequencies for the Suncook River were estimated by Flynn (2008) using a log-Pearson Type III analysis described in Bulletin 17B “Guidelines for Determining Flood Flow Frequency” (U.S. Interagency Advisory Committee on Water Data, 1982). Bulletin 17B provides procedures for weighting station skews, for determining historical peaks, and for detecting and treating outliers and trends. Data from the USGS Suncook River streamgage were used for computing the frequency curve. The USGS computer program PeakFQ (U.S. Geological Survey, 2008a) was used to analyze peak-flow frequency. The peak-flow data used as input to the PeakFQ program were retrieved from the National Water Information System (NWIS) (U.S. Geological Survey, 2008b).

To determine the peak flow-frequency curves for selected Suncook River locations, the relation between drainage areas at the streamgage and the ungaged locations (equation 1) was determined and applied to the log-Pearson Type III peak flow-frequency curve determined at the Suncook River streamgage.

$$Q/Q_g = (A/A_g)^n, \quad (1)$$

where,

- Q is the flow at the ungaged site,
- Q_g is the flow at the USGS streamgage,
- A is the drainage area at the ungaged site,
- A_g is the drainage area at the USGS streamgage,
- and
- n is the drainage-area adjustment value of 0.94.

The exponent n in equation 1 was determined through a drainage-area relation between two indirectly determined April 2007 peak flows at locations upstream and downstream from the Suncook River streamgage (Flynn, 2008).

Hydraulic Analyses

Analyses of the hydraulic characteristics of flooding were carried out to provide estimates of the elevations of floods at the selected recurrence intervals. The hydraulic analyses for this study were based on an assumption of unobstructed flow. As a result, the flood elevations shown in the profiles are considered valid if hydraulic structures remain unobstructed, operate properly, and do not fail. Starting water-surface elevations for the Suncook River HEC-RAS (U.S. Army

Corps of Engineers, 2008a) flood model were based on normal-depth analysis, which is the depth at which flow is steady and hydraulic characteristics are uniform. The model computational procedure is based on the solution of the one-dimensional energy equation (U.S. Army Corps of Engineers, 2008b). Energy losses are evaluated by friction (Manning’s equation) and contraction and expansion. The momentum equation is used in situations where the water surface is rapidly varied. These situations include mixed flow-regime calculations (i.e., hydraulic jumps), hydraulics of bridges, and evaluating profiles at river confluences (stream junctions). In those areas where the analysis indicated supercritical flow conditions, critical depth was assumed for the flood elevation because of the inherent instability of supercritical flow. The Suncook River HEC-RAS flood model was calibrated using 22 high-water marks flagged and surveyed along the Suncook River (table 4) following the flood of April 2007 (Flynn, 2008).

Manning’s “ n ” roughness factors (Barnes, 1967; Arcement and Schneider, 1989), used in the hydraulic computations, were assigned on the basis of engineering judgment and field observations of the stream and flood-plain areas. The channel and overbank Manning’s “ n ” values for the Suncook River study reach ranged from 0.02 to 0.09 in the channel and from 0.02 to 0.12 on the channel overbanks.

The Suncook River flood-study base-map elevations for the 100-year recurrence-interval flood elevations (also known as the base flood elevation or BFE) were compared to the 1978 FIS 100-year recurrence-interval floods elevations at selected locations (table 5). It is important to note that the Suncook River channel elevations have changed in many locations downstream from the avulsion since the 1978 FISs due to several factors, including newer techniques and methods in the HEC-RAS step-backwater model. Other factors affecting the channel elevations and the delineation of flood boundaries for the selected recurrence-interval floods in this flood study are:

- The peak discharges for the selected recurrence-interval floods have been updated since the 1978 FIS with additional flow data available at the Suncook River streamgage,
- 1- and 4-ft contour-interval data were used for flood delineation in this study; the 1978 FIS used the best-available mapping of 20-ft contour-interval data,
- More detailed field-survey information was collected at the structures and in the channel and a greater number of cross sections were surveyed in the field in 2008 than for the 1978 FISs.

Flood Elevations

Suncook River flood-study drainage areas and peak flows adjusted for selected locations on the Suncook River that were used as input for the HEC-RAS model are given in table 1. Suncook River streamgage peak recurrence-interval flows were determined in a previous study (Flynn, 2008).

The resulting flood elevations from the HEC-RAS flood analyses for the Suncook River are shown in table 2 and appendix 1 for the 10-, 50-, 100-, and 500-year recurrence-interval floods. Flood elevations are shown in table 3 and appendix 2 for the 2-, 5-, and 25-year recurrence-interval floods and for the flood of April 2007. Selected cross-section locations used in the hydraulic analyses are shown in the flood profiles in appendixes 1 and 2. Upstream and downstream geographical limits of the study area are indicated on the flood profiles.

The HEC-RAS model calibration of the April 2007 flood to the 22 surveyed high-water marks (table 4) yielded an average elevation difference of 0.30 ft (approximately 3.6 in.) and a standard deviation of 0.81. A comparison of the HEC-RAS model calibration of the April 2007 flood to the 13 surveyed high-water marks rated as “good” in table 4 yielded an average

elevation difference of 0.14 ft (approximately 1.7 in.) and a standard deviation of 0.55. Discrepancies between model and field results may be due to model assumptions or in the case of field-surveyed high-water marks, a field elevation higher than that modeled may be due to debris in the river, which can cause a higher localized water surface. A field elevation lower than that modeled may be due to an elevation from a mark type (seed, wash, debris, or silt lines) carried to a lower elevation as the flood waters receded.

For the selected locations shown in table 5, the average 100-year recurrence-interval flood elevation was 0.28 ft (approximately 3.3 in.) lower in this 2009 flood study than in the 1978 FISs. Locations for comparison were selected where water-surface-elevation data were determined in both the 1978 FISs and the current study. Selected table 5 BFEs for the 2009 flood study are also shown in table 6.

The results of the water-surface computations are tabulated for selected cross sections for the Suncook River (table 6) with all increases in the 100-year recurrence-interval flood elevation limited to a maximum of 1.0 ft. For areas between cross sections, the floodway boundaries were interpolated. The computed floodway is shown on the flood map in appendix 4. A listing of stream velocities at selected cross sections is provided in table 6.

Table 1. Drainage areas and peak recurrence-interval flows for selected locations on the Suncook River in Epsom, Pembroke, and Allenstown, NH.

[mi², square miles; ft³/s, cubic feet per second]

Location	Drainage area (mi ²)	Peak flow (ft ³ /s)							
		2-year	5-year	10-year	25-year	50-year	100-year	500-year	April 2007
At Suncook River streamgage	154.4	2,230	3,550	4,680	6,430	7,990	9,820	15,300	10,600
At U.S. Route 4 in Epsom	161.2	2,320	3,700	4,870	6,690	8,330	10,200	15,900	11,000
Below Little Suncook River	200.9	2,850	4,550	5,990	8,230	10,240	12,600	19,600	13,600
At Short Falls Road in Epsom	210.1	2,980	4,740	6,250	8,590	10,700	13,100	20,400	14,200
Above Bear Brook	219.3	3,100	4,940	6,510	8,940	11,100	13,700	21,300	14,700
Below Bear Brook	236.4	3,330	5,310	6,990	9,590	11,900	14,700	22,800	15,800
At U.S. Route 28 bridge	240.1	3,370	5,380	7,090	9,730	12,100	14,900	23,200	16,100
At U.S. Route 3 in Suncook	255.2	3,570	5,700	7,510	10,300	12,800	15,700	24,500	17,000
At mouth of Suncook River	255.7	3,580	5,710	7,520	10,300	12,800	15,800	24,600	17,000

Summary

Two rainfall events in May 2006 and April 2007 resulted in severe flooding of the Suncook River. More than 8.8 inches of precipitation from May 13 to 16, 2006, resulted in a flood that lead to an avulsion of a streambank and a new reach location for part of the Suncook River. More than 7 inches of precipitation from April 16 to 18, 2007, resulted in another flood. Both floods transported large quantities of gravel, sand, silt, and clay downstream. This 2009 flood study by the U.S. Geological Survey, in cooperation with the Federal Emergency Management Agency, was undertaken to help guide state and local officials in redevelopment and replacement of damaged infrastructure, allocation of state and federal recovery resources, and in ensuring that effective mitigation measures are in place to avoid future flood losses.

Water-surface elevations and profiles are presented in this report that were determined using the U.S. Army Corps of Engineers one-dimensional Hydrologic Engineering Center River Analysis System (HEC-RAS) model for the Suncook River from its confluence with the Merrimack River in the Village of Suncook, NH, to the upstream corporate limit of the town of Epsom, NH (approximately 15.9 miles). Floods of magnitudes that are expected to be equaled or exceeded once on the average during any 10-, 50-, 100-, or 500-year period (recurrence interval) were modeled using HEC-RAS because these floods are considered important for flood-plain management, determination of flood-insurance rates, and design of structures, such as bridges and culverts. In addition, floods of magnitudes that are expected to be equaled or exceeded once on the average during any 2-, 5-, and 25-year period (recurrence interval) and the April 2007 flood were modeled using HEC-RAS. The analyses in this study reflect the flooding potentials based on conditions in the communities of Epsom, Pembroke, and Allenstown at the time of completion of this study (2009). Changes in the 100-year recurrence interval flood elevation from the 1979 flood study were typically less than 2 feet, with the exception of a location 900 feet upstream from the avulsion which, due to backwater from the dams in the abandoned channel, was 12 feet higher in 1979 than in the present study.

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Table 2. Cross sections and the 10-, 50-, 100-, and 500-year recurrence-interval flood data for Suncook River in Epsom, Pembroke, and Allenstown, NH.

[Location of cross sections A–DW are in appendix 4, where scale permits, and in appendix 1; ft, feet; NGVD 29, National Geodetic Vertical Datum of 1929]

Suncook River cross section	Cumulative distance upstream ¹ (ft)	Minimum channel elevation (ft above NGVD 29)	Annual exceedance probability flood elevation (ft above NGVD 29)			
			10 percent (10-year)	2 percent (50-year)	1 percent (100-year)	0.2 percent (500-year)
A	0	181.57	² 195.1	² 197.0	² 198.3	² 205.0
B	477	183.54	² 195.1	² 197.0	² 198.3	² 205.0
C	804	184.00	² 195.1	² 197.0	² 198.3	² 205.0
D	1,681	196.62	201.59	202.98	203.68	205.49
E	2,043	198.43	206.50	209.69	211.77	220.33
F	2,193	204.12	209.56	211.36	212.46	220.28
G	2,507	214.79	233.46	236.30	237.27	239.38
H	3,079	219.73	233.26	235.84	236.61	237.91
I	3,401	242.10	256.21	261.07	263.51	273.85
J	3,467	242.20	256.47	261.10	263.70	274.04
K	3,880	250.58	260.26	263.19	265.16	274.38
L	3,934	251.54	260.59	263.58	265.50	274.59
M	4,433	258.46	266.27	268.42	269.44	273.05
N	4,507	259.63	267.43	269.59	270.61	273.09
O	4,640	263.45	278.41	280.21	281.07	282.93
P	4,886	265.02	278.51	280.46	281.41	283.61
Q	5,126	265.07	278.79	280.89	281.90	284.28
R	5,283	263.79	278.84	280.98	282.01	284.45
S	5,575	269.45	278.88	281.05	282.10	284.60
T	5,860	268.32	278.60	280.55	281.49	283.68
U	6,045	270.65	278.51	280.28	281.11	282.85
V	6,172	268.84	279.96	282.62	286.44	290.08
W	6,935	274.18	280.82	282.99	286.71	290.41
X	6,945	274.18	281.75	283.70	286.80	291.69
Y	7,981	270.26	284.85	287.76	289.45	292.70
Z	9,331	267.96	285.67	289.00	290.76	294.26
AA	10,614	270.63	285.95	289.30	291.05	294.58
AB	11,542	270.97	286.30	289.80	291.42	294.94
AC	12,282	269.33	286.49	290.02	291.64	295.21
AD	15,482	266.90	287.08	290.74	292.39	295.99
AE	17,581	267.70	287.58	291.01	292.58	296.06
AF	19,123	268.58	287.93	291.41	292.99	296.50
AG	22,592	271.35	288.56	291.96	293.56	297.21
AH	23,529	270.36	288.68	291.89	293.59	297.23
AI	24,763	272.96	289.32	292.28	293.64	297.26
AJ	25,387	273.31	289.51	292.32	293.67	297.27
AK	26,696	273.13	289.89	292.47	293.63	297.08
AL	27,674	275.27	290.25	293.11	294.31	297.60
AM	28,253	277.21	290.50	293.44	294.71	298.11
AN	28,443	279.58	290.76	293.83	295.13	298.54
AO	28,766	281.21	291.31	294.34	295.65	299.01
AP	28,851	279.83	291.59	294.55	295.82	299.12
AQ	29,063	283.13	296.36	298.76	300.71	303.25
AR	29,088	283.13	296.37	298.78	300.73	303.28

Table 2. Cross sections and the 10-, 50-, 100-, and 500-year recurrence-interval flood data for Suncook River in Epsom, Pembroke, and Allenstown, NH.—Continued

[Location of cross sections A–DW are in appendix 4, where scale permits, and in appendix 1; ft, feet; NGVD 29, National Geodetic Vertical Datum of 1929]

Suncook River cross section	Cumulative distance upstream ¹ (ft)	Minimum channel elevation (ft above NGVD 29)	Annual exceedance probability flood elevation (ft above NGVD 29)			
			10 percent (10-year)	2 percent (50-year)	1 percent (100-year)	0.2 percent (500-year)
AS	29,216	280.40	296.37	298.73	300.63	303.05
AT	29,346.5	279.21	296.42	298.90	300.95	303.80
AU	29,599.5	279.10	296.40	298.81	300.78	303.46
AV	30,714.5	279.32	296.51	298.99	300.93	303.57
AW	31,746.5	276.97	296.70	299.37	301.39	304.42
AX	33,141.5	276.47	296.89	299.58	301.55	304.58
AY	34,226.5	279.64	297.11	299.97	301.93	305.11
AZ	34,926.5	277.09	297.13	299.92	301.85	304.99
BA	35,562.5	278.13	297.46	300.41	302.33	305.61
BB	36,077.5	278.99	297.55	300.55	302.47	305.77
BC	36,612.5	275.28	297.77	300.83	302.73	306.06
BD	37,932.5	280.62	298.14	301.36	303.28	306.67
BE	38,425.5	279.70	298.33	301.53	303.41	306.80
BF	39,120.5	277.56	298.62	301.89	303.76	307.23
BG	39,860.5	277.90	298.72	301.99	303.85	307.38
BH	40,505.5	284.98	298.94	302.31	304.18	307.60
BI	41,065.5	285.20	299.20	302.52	304.36	307.80
BJ	41,898.5	278.65	299.39	302.67	304.48	307.90
BK	43,018.5	284.04	299.73	303.00	304.78	308.22
BL	43,740.5	279.70	300.06	303.39	305.17	308.68
BM	44,820.5	285.93	300.34	303.72	305.48	308.99
BN	45,160.5	286.48	300.56	304.07	305.87	309.39
BO	45,723.5	278.21	300.87	304.42	306.16	309.61
BP	46,355.5	286.15	300.97	304.51	306.24	309.76
BQ	46,730.5	280.10	301.26	304.93	306.70	310.26
BR	47,374.5	286.45	301.46	305.21	307.00	310.57
BS	48,052.5	283.65	301.59	305.27	307.03	310.54
BT	48,852.5	282.55	301.90	305.61	307.37	310.94
BU	50,157.5	285.85	302.47	306.22	307.96	311.58
BV	50,623.5	286.80	302.69	306.53	308.31	312.02
BW	50,828.5	271.36	302.76	306.60	308.38	312.09
BX	51,080.5	287.32	302.71	306.52	308.28	311.95
BY	51,304.5	290.47	303.22	307.30	309.19	313.69
BZ	51,974.5	289.81	303.84	308.01	309.95	314.56
CA	52,462.5	289.73	304.13	308.29	310.22	314.88
CB	53,599.5	289.59	304.27	308.39	310.32	314.97
CC	54,414.5	293.58	304.41	308.46	310.38	315.02
CD	55,868.5	292.55	304.51	308.50	310.41	315.04
CE	56,344.5	294.28	304.53	308.51	310.42	315.04
CF	56,879.5	294.58	304.57	308.52	310.43	315.05
CG	57,635.5	295.63	304.59	308.52	310.43	315.05
CH	58,326.5	296.89	304.66	308.54	310.44	315.06
CI	58,366.5	296.89	304.68	308.55	310.45	315.07

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Table 2. Cross sections and the 10-, 50-, 100-, and 500-year recurrence-interval flood data for Suncook River in Epsom, Pembroke, and Allenstown, NH.—Continued

[Location of cross sections A–DW are in appendix 4, where scale permits, and in appendix 1; ft, feet; NGVD 29, National Geodetic Vertical Datum of 1929]

Suncook River cross section	Cumulative distance upstream ¹ (ft)	Minimum channel elevation (ft above NGVD 29)	Annual exceedance probability flood elevation (ft above NGVD 29)			
			10 percent (10-year)	2 percent (50-year)	1 percent (100-year)	0.2 percent (500-year)
CJ	59,098.5	296.17	304.80	308.58	310.47	315.08
CK	59,428.5	296.20	304.87	308.59	310.47	315.08
CL	59,963.5	296.75	305.38	308.72	310.55	315.12
CM	60,519.5	299.31	305.88	308.79	310.59	315.13
CN	61,159.5	298.38	306.02	308.68	310.58	315.10
CO	61,867.5	299.16	310.09	311.27	311.82	315.41
CP	62,546.5	299.17	311.20	312.77	313.45	316.16
CQ	63,034.5	299.49	311.98	313.89	314.70	317.03
CR	63,474.5	300.55	312.92	315.11	315.98	317.87
CS	63,794.5	301.23	313.53	315.93	316.81	318.59
CT	64,131.5	302.17	313.59	315.83	316.58	317.99
CU	64,399.5	303.38	313.93	316.30	317.13	318.72
CV	64,631.5	303.48	314.40	317.01	318.02	320.30
CW	64,892.5	304.21	314.55	317.22	318.27	320.80
CX	65,149.5	303.58	314.85	317.45	318.52	321.07
CY	65,882.5	306.19	316.01	318.57	319.56	322.02
CZ	65,892.5	306.19	315.98	318.49	319.46	321.89
DA	66,028.5	306.36	316.33	319.02	320.11	322.61
DB	66,139.5	304.28	316.60	319.37	320.46	322.83
DC	66,344.5	306.08	316.94	319.60	320.66	322.95
DD	66,626.5	311.42	317.92	320.48	321.54	323.96
DE	66,928.5	316.36	323.30	325.06	325.97	328.28
DF	67,650.5	313.22	326.66	329.46	330.75	333.97
DG	68,732.5	302.68	327.83	331.22	332.75	336.35
DH	69,551.5	320.98	328.13	332.17	333.83	337.23
DI	69,782.5	321.52	332.55	334.91	335.88	341.14
DJ	70,007.5	323.77	334.03	336.77	337.77	342.35
DK	70,500.5	321.28	334.62	337.24	338.10	342.42
DL	70,812.5	321.91	334.65	337.34	338.21	342.46
DM	71,388.5	320.78	335.07	337.51	338.36	342.53
DN	71,616.5	319.60	335.11	337.52	338.38	342.54
DO	72,165.5	322.38	335.23	337.62	338.47	342.57
DP	74,512.5	320.25	336.44	338.67	339.51	342.99
DQ	74,550.5	320.25	336.59	338.89	339.76	343.15
DR	75,308.5	322.18	336.88	339.26	340.16	343.46
DS	76,282.5	322.43	337.30	339.79	340.77	344.09
DT	78,388.5	323.63	338.44	341.09	342.12	345.27
DU	79,630.5	321.38	339.12	341.62	342.62	345.64
DV	81,371.5	324.51	340.08	342.40	343.36	346.23
DW	83,918.5	326.19	340.88	343.19	344.17	346.97

¹ Feet above confluence with Merrimack River.

² Backwater from Merrimack River.

Table 3. Cross sections and the 2-, 5-, 25-year recurrence-interval and April 2007 flood data for Suncook River in Epsom, Pembroke, and Allenstown, NH.

[Location of cross sections A–DW are in appendix 4, where scale permits, and in appendix 1; ft, feet; NGVD 29, National Geodetic Vertical Datum of 1929]

Suncook River cross section	Cumulative distance upstream ¹ (ft)	Channel elevation (ft above NGVD 29)	Annual exceedance probability flood elevation (ft above NGVD 29)			
			50 percent (2-year)	20 percent (5-year)	4 percent (25-year)	April 2007
A	0	181.57	186.44	187.25	188.76	190.04
B	477	183.54	188.82	189.62	190.94	192.17
C	804	184.00	189.81	190.83	192.56	194.53
D	1,681	196.62	200.32	201.05	202.36	203.93
E	2,043	198.43	204.23	205.56	207.80	212.63
F	2,193	204.12	207.87	208.83	210.57	213.23
G	2,507	214.79	230.67	232.27	235.13	237.62
H	3,079	219.73	230.61	232.13	234.80	236.87
I	3,401	242.10	251.35	254.09	258.86	264.51
J	3,467	242.20	254.09	255.68	258.60	264.77
K	3,880	250.58	257.59	259.11	261.64	266.00
L	3,934	251.54	257.82	259.40	262.04	266.33
M	4,433	258.46	264.08	265.38	267.46	269.82
N	4,507	259.63	265.25	266.55	268.65	270.96
O	4,640	263.45	276.66	277.68	279.40	281.41
P	4,886	265.02	276.68	277.74	279.57	281.80
Q	5,126	265.07	276.81	277.95	279.94	282.30
R	5,283	263.79	276.83	277.99	280.02	282.42
S	5,575	269.45	276.85	278.02	280.07	282.53
T	5,860	268.32	276.75	277.82	279.67	281.86
U	6,045	270.65	276.77	277.78	279.49	281.44
V	6,172	268.84	277.54	278.93	281.41	286.91
W	6,935	274.18	279.14	280.08	281.82	287.19
X	6,945	274.18	279.88	280.97	282.87	287.31
Y	7,981	270.26	281.73	283.54	286.52	289.96
Z	9,331	267.96	282.14	284.17	287.58	291.34
AA	10,614	270.63	282.30	284.40	287.88	291.63
AB	11,542	270.97	282.46	284.67	288.31	291.99
AC	12,282	269.33	282.57	284.83	288.52	292.22
AD	15,482	266.90	282.96	285.36	289.20	292.98
AE	17,581	267.70	283.32	285.87	289.56	293.14
AF	19,123	268.58	283.52	286.17	289.95	293.56
AG	22,592	271.35	284.00	286.75	290.67	294.15
AH	23,529	270.36	284.37	286.96	290.75	294.18
AI	24,763	272.96	284.86	287.62	291.28	294.22
AJ	25,387	273.31	285.08	287.83	291.46	294.25
AK	26,696	273.13	285.51	288.23	291.79	294.16
AL	27,674	275.27	285.78	288.55	292.27	294.82
AM	28,253	277.21	286.00	288.78	292.53	295.24
AN	28,443	279.58	286.20	289.01	292.83	295.68
AO	28,766	281.21	287.39	289.71	293.30	296.18
AP	28,851	279.83	288.00	290.09	293.51	296.34
AQ	29,063	283.13	294.24	295.47	297.61	301.13
AR	29,088	283.13	294.24	295.47	297.62	301.15

Table 3. Cross sections and the 2-, 5-, 25-year recurrence-interval and April 2007 flood data for Suncook River in Epsom, Pembroke, and Allenstown, NH.—Continued

[Location of cross sections A–DW are in appendix 4, where scale permits, and in appendix 1; ft, feet; NGVD 29, National Geodetic Vertical Datum of 1929]

Suncook River cross section	Cumulative distance upstream ¹ (ft)	Channel elevation (ft above NGVD 29)	Annual exceedance probability flood elevation (ft above NGVD 29)			
			50 percent (2-year)	20 percent (5-year)	4 percent (25-year)	April 2007
AS	29,216	280.40	294.25	295.48	297.59	301.04
AT	29,346.5	279.21	294.27	295.52	297.69	301.42
AU	29,599.5	279.10	294.27	295.51	297.64	301.22
AV	30,714.5	279.32	294.31	295.58	297.80	301.36
AW	31,746.5	276.97	294.39	295.73	298.09	301.88
AX	33,141.5	276.47	294.46	295.86	298.31	302.04
AY	34,226.5	279.64	294.54	296.02	298.63	302.44
AZ	34,926.5	277.09	294.58	296.06	298.61	302.36
BA	35,562.5	278.13	294.70	296.29	299.05	302.86
BB	36,077.5	278.99	294.75	296.37	299.17	303.00
BC	36,612.5	275.28	294.85	296.55	299.43	303.27
BD	37,932.5	280.62	295.03	296.84	299.89	303.84
BE	38,425.5	279.70	295.18	297.03	300.08	303.97
BF	39,120.5	277.56	295.34	297.27	300.41	304.33
BG	39,860.5	277.90	295.41	297.37	300.52	304.42
BH	40,505.5	284.98	295.53	297.54	300.80	304.76
BI	41,065.5	285.20	295.79	297.82	301.03	304.95
BJ	41,898.5	278.65	296.01	298.04	301.20	305.06
BK	43,018.5	284.04	296.28	298.36	301.54	305.36
BL	43,740.5	279.70	296.50	298.65	301.91	305.76
BM	44,820.5	285.93	296.71	298.90	302.22	306.07
BN	45,160.5	286.48	296.84	299.08	302.50	306.47
BO	45,723.5	278.21	297.00	299.33	302.85	306.75
BP	46,355.5	286.15	297.07	299.43	302.95	306.83
BQ	46,730.5	280.10	297.24	299.66	303.31	307.31
BR	47,374.5	286.45	297.37	299.83	303.57	307.61
BS	48,052.5	283.65	297.54	300.00	303.65	307.63
BT	48,852.5	282.55	297.77	300.28	303.98	307.97
BU	50,157.5	285.85	298.22	300.81	304.59	308.57
BV	50,623.5	286.80	298.37	300.99	304.86	308.94
BW	50,828.5	271.36	298.43	301.07	304.94	309.00
BX	51,080.5	287.32	298.40	301.03	304.87	308.90
BY	51,304.5	290.47	298.72	301.44	305.52	309.88
BZ	51,974.5	289.81	299.39	302.06	306.19	310.66
CA	52,462.5	289.73	299.64	302.34	306.47	310.94
CB	53,599.5	289.59	300.01	302.52	306.58	311.04
CC	54,414.5	293.58	300.59	302.80	306.67	311.09
CD	55,868.5	292.55	301.51	303.00	306.72	311.12
CE	56,344.5	294.28	301.59	303.04	306.73	311.13
CF	56,879.5	294.58	301.88	303.15	306.75	311.14
CG	57,635.5	295.63	301.99	303.19	306.75	311.14
CH	58,326.5	296.89	302.29	303.36	306.78	311.15
CI	58,366.5	296.89	302.33	303.40	306.80	311.16

Table 3. Cross sections and the 2-, 5-, 25-year recurrence-interval and April 2007 flood data for Suncook River in Epsom, Pembroke, and Allenstown, NH.—Continued

[Location of cross sections A–DW are in appendix 4, where scale permits, and in appendix 1; ft, feet; NGVD 29, National Geodetic Vertical Datum of 1929]

Suncook River cross section	Cumulative distance upstream ¹ (ft)	Channel elevation (ft above NGVD 29)	Annual exceedance probability flood elevation (ft above NGVD 29)			
			50 percent (2-year)	20 percent (5-year)	4 percent (25-year)	April 2007
CJ	59,098.5	296.17	302.54	303.59	306.85	311.18
CK	59,428.5	296.20	302.75	303.73	306.86	311.17
CL	59,963.5	296.75	303.61	304.56	307.08	311.25
CM	60,519.5	299.31	304.51	305.34	307.25	311.28
CN	61,159.5	298.38	305.06	305.41	307.10	311.27
CO	61,867.5	299.16	307.55	309.17	311.07	312.23
CP	62,546.5	299.17	308.58	310.30	312.19	313.75
CQ	63,034.5	299.49	309.20	311.00	313.13	315.03
CR	63,474.5	300.55	309.85	311.80	314.21	316.31
CS	63,794.5	301.23	310.33	312.33	314.94	317.11
CT	64,131.5	302.17	310.49	312.42	314.93	316.82
CU	64,399.5	303.38	310.80	312.74	315.33	317.41
CV	64,631.5	303.48	311.17	313.14	315.92	318.39
CW	64,892.5	304.21	311.35	313.29	316.10	318.67
CX	65,149.5	303.58	311.79	313.63	316.34	318.92
CY	65,882.5	306.19	313.08	314.82	317.52	319.94
CZ	65,892.5	306.19	313.07	314.79	317.46	319.83
DA	66,028.5	306.36	313.36	315.11	317.90	320.53
DB	66,139.5	304.28	313.53	315.34	318.21	320.86
DC	66,344.5	306.08	314.01	315.75	318.49	321.05
DD	66,626.5	311.42	315.35	316.79	319.39	321.94
DE	66,928.5	316.36	321.76	322.68	324.24	326.33
DF	67,650.5	313.22	323.80	325.48	328.23	331.26
DG	68,732.5	302.68	324.42	326.43	329.73	333.34
DH	69,551.5	320.98	326.12	327.17	330.49	334.46
DI	69,782.5	321.52	329.82	331.38	333.99	336.26
DJ	70,007.5	323.77	330.89	332.79	335.54	338.20
DK	70,500.5	321.28	331.34	333.31	336.19	338.48
DL	70,812.5	321.91	331.33	333.26	336.28	338.58
DM	71,388.5	320.78	331.88	333.87	336.49	338.73
DN	71,616.5	319.60	331.98	333.94	336.52	338.75
DO	72,165.5	322.38	332.14	334.07	336.63	338.83
DP	74,512.5	320.25	333.08	335.23	337.74	339.86
DQ	74,550.5	320.25	333.16	335.35	337.94	340.12
DR	75,308.5	322.18	333.40	335.60	338.28	340.52
DS	76,282.5	322.43	333.78	336.00	338.75	341.16
DT	78,388.5	323.63	334.77	337.07	340.00	342.53
DU	79,630.5	321.38	335.51	337.81	340.61	343.01
DV	81,371.5	324.51	336.47	338.83	341.45	343.75
DW	83,918.5	326.19	337.39	339.67	342.22	344.56

¹ Feet above confluence with Merrimack River.

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Table 4. Surveyed and HEC-RAS-modeled April 2007 elevations of flood high-water marks for the Suncook River, NH.

[HWM, high-water mark; ft, feet; NGVD 29, National Geodetic Vertical Datum of 1929; US, upstream; DS, downstream]

HWM name	Location of HWM relative to lettered cross sections	Latitude (N, decimal degrees)	Longitude (W, decimal degrees)	Town	Suncook field-surveyed elevation at HWM (ft above NGVD 29)	Suncook HEC-RAS model elevation at HWM (ft above NGVD 29)	Difference between field and model elevation (ft)	HWM rating	HWM type
sunhwm6	81 ft US of G	43.12990	71.45518	Allenstown (Suncook)	236.22	237.51	1.29	Fair	Seed line
sunhwm7	37 ft US of O	43.12938	71.44982	Allenstown (Suncook)	280.78	281.47	0.69	Fair	Wash line
sunhwm9	30 ft US of V	43.13060	71.44550	Allenstown (Suncook)	285.11	286.92	1.81	Poor	Seed line
sunhwm12	294 ft US of W	43.13219	71.44283	Allenstown	288.93	287.97	-0.96	Fair	Wash line
sunhwm13	At AC	43.13660	71.43085	Allenstown	291.69	292.22	0.53	Good	Silt line
sunhwm18	755 ft US of AE	43.14331	71.42523	Allenstown	293.05	293.08	0.03	Good	Seed line
sunhwm20	83 ft DS of AO	43.15884	71.40630	Allenstown	297.17	296.05	-1.12	Good	Seed line
sunhwm22	At DS face of abandoned Buck St. bridge	43.15957	71.40665	Allenstown	298.02	298.82	0.8	Fair	Debris line
sunhwm23	At AQ	43.15967	71.40658	Allenstown	299.17	301.13	1.96	Fair	Debris line
sunhwm26	At AU	43.16063	71.40569	Allenstown	299.85	301.22	1.37	Good	Silt line
sunhwm27	58 ft US of AW	43.16594	71.40455	Allenstown	301.45	301.89	0.44	Good	Seed line
sunhwm28	98 ft DS of AZ	43.17179	71.39785	Pembroke	302.33	302.36	0.03	Good	Seed line
sunhwm29	At BA	43.17284	71.39644	Pembroke	302.65	302.86	0.21	Good	Seed line
sunhwm30	215 ft US of BC	43.17599	71.39454	Pembroke	303.43	303.36	-0.07	Good	Seed line
sunhwm31	70 ft DS of BM	43.18979	71.38192	Epsom	306.13	306.05	-0.08	Good	Seed line
sunhwm32	At BT	43.19566	71.38341	Epsom	308.1	307.97	-0.13	Good	Seed line
sunhwm33	At BX	43.20207	71.38300	Epsom	308.65	308.9	0.25	Good	Seed line
sunhwm34	51 ft DS of BY	43.20224	71.38233	Epsom	309.50	309.66	0.16	Fair	Wash line
sunhwm35	At BY	43.20235	71.38183	Epsom	309.81	309.88	0.07	Good	Seed line
sunhwm36	54 ft DS of CH	43.20375	71.37122	Epsom	311.10	311.15	0.05	Fair	Silt line
sunhwm38	At DI	43.22705	71.35659	Epsom	337.65	337.97	0.32	Good	Seed line
sunhwm40	At DH	43.22618	71.35427	Epsom	335.48	334.46	-1.02	Fair	Seed line

Table 5. 1978 FIS and 2009 flood study 100-year flood elevations for selected locations in the Suncook River in Epsom, Pembroke, and Allenstown, NH.

[FIS, Flood Insurance Study; BFE, base flood elevation (100-year recurrence-interval flood); ft, feet; NGVD 29, National Geodetic Vertical Datum of 1929; US, upstream; DS, downstream; XS, cross section]

Location on flood-study base map	1978 FIS BFE elevation (ft above NGVD 29)	Flood study BFE elevation (ft above NGVD 29)	Difference between 1978 FIS and flood-study elevation (ft above NGVD 29) ¹
XS E	206	211.8	5.8
BFE 215	214	215	1
XS G	238	237.3	-0.7
US face of Main Street bridge	262	260	-2
BFE 270	269	270	1
55 ft US of XS O	284	281.2	-2.8
21 ft DS of BFE 285	284	285	1
XS V	286	286.4	0.4
320 ft US of BFE 290	289	290	1
320 ft US of XS AA	290	291.2	1.2
950 ft US of XS AD	291	292.4	1.4
XS AG	293	293.6	0.6
XS AK	294	293.6	-0.4
BFE 295	295	295	0
BFE 300	300	300	0
XS AT	305	301	-4
XS AX	306	301.6	-4.4
BFE 306	307	306	-1
BFE 307	307	307	0
XS BW	307	308.4	1.4
XS BX	308	308.3	0.3
US face of Short Falls Road bridge	309	308.5	-0.5
170 ft DS XS BZ	310	310	0
231 ft DS XS CM	311	310.5	-0.5
BFE 313	312	313	1
370 ft DS XS DH	339	334	-5
BFE 338	339	338	-1
BFE 339	340	339	-1
BFE 340	341	340	-1
600 ft US of XS DS	342	341.2	-0.8
XS DV	343	343.4	0.4

¹ A positive number means that the stream BFE is higher in this study than in the 1978 FIS, and a negative number means that the stream BFE is lower in this study than in the 1978 FIS.

Table 6. Cross sections, 100-year recurrence-interval, and floodway data for Suncook River in Epsom, Pembroke, and Allenstown, NH.[ft, feet; ft², square feet; ft/s, feet per second; NGVD 29, National Geodetic Vertical Datum of 1929]

Flooding source		Floodway			Base flood water-surface elevation			
Cross section	Cumulative distance upstream ¹ (ft)	Width (ft)	Section area (ft ²)	Mean velocity (ft/s)	Regulatory (ft above NGVD 29)	Without floodway (ft above NGVD 29)	With floodway (ft above NGVD 29)	Increase (ft)
A	0	387.5	1,707.0	9.2	² 198.3	189.82	189.87	0.05
B	477	270.8	1,385.1	11.4	² 198.3	191.97	191.97	0
C	804	322.9	2,507.8	6.3	² 198.3	194.19	194.19	0
D	1,681	231.2	1,211.5	13.0	203.68	203.68	203.68	0
E	2,043	141.0	1,295.2	12.2	211.77	211.77	211.77	0
F	2,193	174.0	1,138.7	13.8	212.46	212.46	212.47	0.01
G	2,507	149.0	3,006.3	5.2	237.27	237.27	237.59	0.32
H	3,079	84.2	1,371.8	11.5	236.61	236.61	237.09	0.48
I	3,401	79.0	1,456.0	10.8	263.51	263.51	263.7	0.2
J	3,467	148.0	1,878.2	8.4	263.7	263.7	264.7	1.0
K	3,880	236.0	2,395.8	6.6	265.16	265.16	266.02	0.86
L	3,934	214.0	2,200.1	7.2	265.5	265.5	266.29	0.8
M	4,433	153.4	1,056.8	14.9	269.44	269.44	269.43	0
N	4,507	153.5	1,058.6	14.9	270.61	270.61	270.62	0
O	4,640	212.2	2,367.9	6.7	281.07	281.07	281.07	0
P	4,886	320.4	2,632.2	6.0	281.41	281.41	281.42	0.01
Q	5,126	380.8	4,350.7	3.6	281.9	281.9	281.9	0
R	5,283	451.0	5,645.4	2.8	282.01	282.01	282.01	0
S	5,575	920.0	7,809.2	2.0	282.1	282.1	282.1	0
T	5,860	241.0	1,930.3	8.2	281.49	281.49	281.49	0
U	6,045	187.5	1,307.8	12.0	281.11	281.11	281.12	0.01
V	6,172	149.0	2,321.1	6.4	286.44	286.44	286.49	0.05
W	6,935	149.0	1,492.9	10.0	286.71	286.71	286.80	0.09
X	6,945	149.0	1,505.7	9.9	286.8	286.8	286.89	0.09
Y	7,981	124.0	1,867.7	8.0	289.45	289.45	289.78	0.34
Z	9,331	181.4	2,798.5	5.3	290.76	290.76	291.15	0.39
AA	10,614	139.0	2,523.9	5.9	291.05	291.05	291.52	0.47
AB	11,542	186.0	3,107.5	4.8	291.42	291.42	292.12	0.70
AC	12,282	165.0	2,984.6	5.0	291.64	291.64	292.36	0.71
AD	15,482	933.0	9,180.9	1.6	292.39	292.39	293.18	0.79
AE	17,581	212.1	3,278.0	4.5	292.58	292.58	293.46	0.89
AF	19,123	155.0	3,042.2	4.9	292.99	292.99	293.93	0.94
AG	22,592	1,518.2	15,498.9	1.0	293.56	293.56	294.51	0.94
AH	23,529	1,536.6	13,447.5	1.1	293.59	293.59	294.53	0.94
AI	24,763	1,878.9	12,068.3	1.2	293.64	293.64	294.58	0.94
AJ	25,387	1,916.4	9,708.4	1.5	293.67	293.67	294.61	0.94
AK	26,696	144.7	2,403.1	6.2	293.63	293.63	294.57	0.94

Table 6. Cross sections, 100-year recurrence-interval, and floodway data for Suncook River in Epsom, Pembroke, and Allenstown, NH.—Continued[ft, feet; ft², square feet; ft/s, feet per second; NGVD 29, National Geodetic Vertical Datum of 1929]

Flooding source		Floodway			Base flood water-surface elevation			
Cross section	Cumulative distance upstream ¹ (ft)	Width (ft)	Section area (ft ²)	Mean velocity (ft/s)	Regulatory (ft above NGVD 29)	Without floodway (ft above NGVD 29)	With floodway (ft above NGVD 29)	Increase (ft)
AL	27,674	148.7	2,459.8	6.1	294.31	294.31	295.2	0.88
AM	28,253	188.0	2,683.1	5.5	294.71	294.71	295.64	0.93
AN	28,443	294.8	3,969.5	3.8	295.13	295.13	296.07	0.94
AO	28,766	354.6	3,307.1	4.5	295.65	295.65	296.56	0.91
AP	28,851	272.4	2,730.1	5.5	295.82	295.82	296.68	0.86
AQ	29,063	317.6	3,132.9	4.8	300.71	300.71	300.74	0.03
AR	29,088	333.6	3,325.5	4.5	300.73	300.73	300.75	0.02
AS	29,216	207.3	2,735.1	5.4	300.63	300.63	300.66	0.03
AT	29,346.5	208.0	2,730.1	5.4	300.95	300.95	300.96	0.01
AU	29,599.5	119.8	2,106.0	7.0	300.78	300.78	300.81	0.03
AV	30,714.5	103.1	1,857.6	7.9	300.92	300.92	300.97	0.05
AW	31,746.5	110.9	2,126.1	6.9	301.39	301.39	301.49	0.10
AX	33,141.5	137.2	2,468.1	5.9	301.54	301.54	301.96	0.42
AY	34,226.5	148.0	2,633.6	5.6	301.93	301.93	302.28	0.35
AZ	34,926.5	98.0	1,941.5	7.6	301.85	301.85	302.31	0.46
BA	35,562.5	147.6	2,753.6	5.0	302.33	302.33	303.09	0.76
BB	36,077.5	133.0	2,403.1	5.5	302.47	302.47	303.22	0.75
BC	36,612.5	161.0	2,985.4	4.4	302.73	302.73	303.62	0.89
BD	37,932.5	269.5	3,472.3	3.8	303.27	303.27	304.09	0.82
BE	38,425.5	264.8	3,516.5	3.7	303.41	303.41	304.31	0.90
BF	39,120.5	308.7	4,529.2	2.9	303.76	303.76	304.70	0.94
BG	39,860.5	516.5	5,213.7	2.5	303.84	303.84	304.84	1.00
BH	40,505.5	502.5	6,360.6	2.4	304.17	304.17	305.07	0.90
BI	41,065.5	543.9	6,693.7	2.1	304.36	304.36	305.28	0.92
BJ	41,898.5	413.1	5,144.0	2.6	304.48	304.48	305.47	0.99
BK	43,018.5	309.6	4,301.7	3.3	304.77	304.77	305.77	1.00
BL	43,740.5	260.5	4,250.1	3.1	305.16	305.16	306.14	0.98
BM	44,820.5	159.6	2,586.4	5.1	305.48	305.48	306.46	0.98
BN	45,160.5	228.7	3,015.4	4.3	305.87	305.87	306.81	0.94
BO	45,723.5	184.4	3,463.7	3.8	306.16	306.16	307.11	0.95
BP	46,355.5	140.1	2,426.9	5.4	306.23	306.23	307.19	0.96
BQ	46,730.5	212.2	3,490.0	3.8	306.70	306.70	307.61	0.91
BR	47,374.5	402.3	4,727.3	2.8	306.99	306.99	307.85	0.86
BS	48,052.5	189.6	3,168.9	4.1	307.02	307.02	308.00	0.98
BT	48,852.5	239.1	3,468.5	3.8	307.36	307.36	308.34	0.98
BU	50,157.5	240.8	3,255.5	4.0	307.95	307.95	308.86	0.91
BV	50,623.5	297.7	4,622.5	2.8	308.30	308.30	309.11	0.81

Table 6. Cross sections, 100-year recurrence-interval, and floodway data for Suncook River in Epsom, Pembroke, and Allenstown, NH.—Continued[ft, feet; ft², square feet; ft/s, feet per second; NGVD 29, National Geodetic Vertical Datum of 1929]

Flooding source		Floodway			Base flood water-surface elevation			
Cross section	Cumulative distance upstream ¹ (ft)	Width (ft)	Section area (ft ²)	Mean velocity (ft/s)	Regulatory (ft above NGVD 29)	Without floodway (ft above NGVD 29)	With floodway (ft above NGVD 29)	Increase (ft)
BW	50,828.5	302.7	8,158.7	1.6	308.37	308.37	309.26	0.89
BX	51,080.5	194.9	3,660.3	3.6	308.27	308.27	309.15	0.88
BY	51,304.5	156.6	2,020.0	6.2	309.19	309.19	309.95	0.76
BZ	51,974.5	243.3	3,484.7	3.6	309.94	309.94	310.52	0.58
CA	52,462.5	456.7	6,733.7	1.9	310.22	310.22	310.88	0.66
CB	53,599.5	509.7	6,345.9	2.0	310.32	310.32	311.05	0.73
CC	54,414.5	564.0	6,552.2	1.9	310.38	310.38	311.28	0.89
CD	55,868.5	2,183.0	24,461.2	0.5	310.40	310.40	311.40	1.00
CE	56,344.5	2,197.9	23,020.7	0.6	310.41	310.41	311.41	1.00
CF	56,879.5	2,699.9	28,973.8	0.4	310.42	310.42	311.42	1.00
CG	57,635.5	1,589.8	16,522.3	0.8	310.42	310.42	311.42	1.00
CH	58,326.5	1,291.8	14,011.0	0.9	310.44	310.44	311.44	1.00
CI	58,366.5	1,303.9	13,805.1	0.9	310.44	310.44	311.44	1.00
CJ	59,098.5	1,466.9	14,105.0	0.9	310.47	310.47	311.47	1.00
CK	59,428.5	818.6	7,457.9	1.7	310.46	310.46	311.46	1.00
CL	59,963.5	1,005.8	7,939.2	1.6	310.55	310.55	311.55	1.00
CM	60,519.5	914.4	6,572.4	1.9	310.58	310.58	311.58	1.00
CN	61,159.5	381.0	2,500.6	5.0	310.57	310.57	311.48	0.91
CO	61,867.5	345.5	2,096.5	6.0	311.82	311.82	312.82	1.00
CP	62,546.5	240.0	1,786.0	7.0	313.45	313.45	314.25	0.80
CQ	63,034.5	240.5	1,888.5	6.7	314.7	314.7	315.48	0.78
CR	63,474.5	251.1	2,187.9	5.8	315.98	315.98	316.82	0.83
CS	63,794.5	463.0	3,941.7	3.2	316.81	316.81	317.79	0.98
CT	64,131.5	154.0	1,726.3	7.3	316.58	316.58	317.58	1.00
CU	64,399.5	144.4	1,671.7	7.5	317.13	317.13	317.99	0.86
CV	64,631.5	123.0	1,499.2	8.4	318.02	318.02	318.24	0.22
CW	64,892.5	176.3	2,036.7	6.2	318.27	318.27	319.21	0.94
CX	65,149.5	183.6	1,963.3	6.4	318.52	318.52	319.51	0.99
CY	65,882.5	162.8	1,826.6	6.9	319.56	319.56	320.48	0.92
CZ	65,892.5	143.4	1,656.2	7.6	319.46	319.46	320.38	0.92
DA	66,028.5	149.0	1,883.5	6.7	320.11	320.11	320.81	0.70
DB	66,139.5	230.8	2,528.4	5.0	320.46	320.46	321.29	0.83
DC	66,344.5	156.2	1,856.2	6.8	320.66	320.66	321.44	0.78
DD	66,626.5	138.6	1,181.1	10.7	321.54	321.54	322.21	0.67
DE	66,928.5	133.0	1,034.3	12.2	325.97	325.97	325.97	0
DF	67,650.5	141.6	1,990.9	6.3	330.75	330.75	331.16	0.41
DG	68,732.5	119.7	1,972.9	5.2	332.75	332.75	333.02	0.27

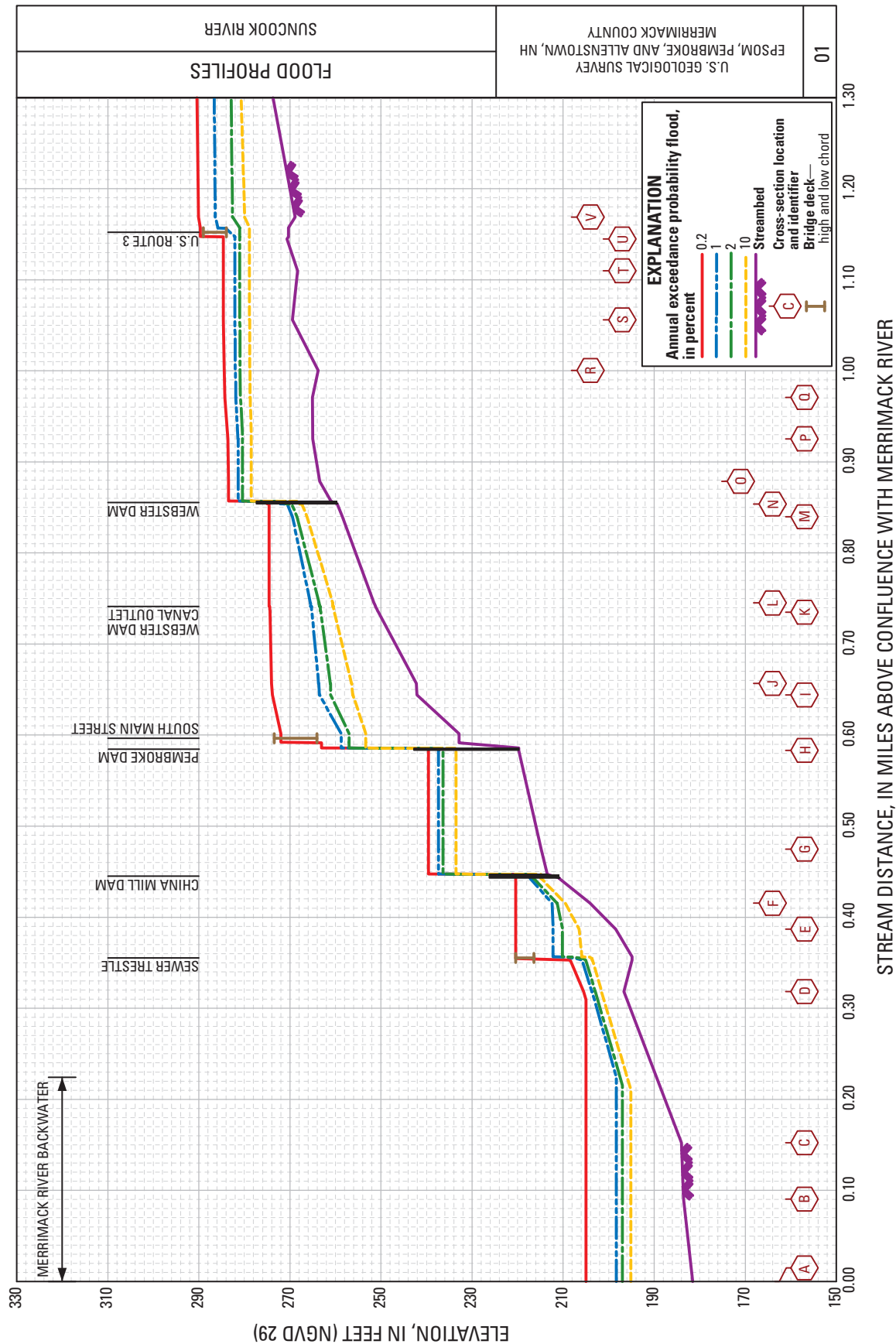
Table 6. Cross sections, 100-year recurrence-interval, and floodway data for Suncook River in Epsom, Pembroke, and Allenstown, NH.—Continued[ft, feet; ft², square feet; ft/s, feet per second; NGVD 29, National Geodetic Vertical Datum of 1929]

Flooding source		Floodway			Base flood water-surface elevation			
Cross section	Cumulative distance upstream ¹ (ft)	Width (ft)	Section area (ft ²)	Mean velocity (ft/s)	Regulatory (ft above NGVD 29)	Without floodway (ft above NGVD 29)	With floodway (ft above NGVD 29)	Increase (ft)
DH	69,551.5	557.2	1,590.1	6.4	333.83	333.83	334.11	0.28
DI	69,782.5	921.3	3,512.6	2.8	337.5	337.5	337.5	0
DJ	70,007.5	700.5	2,653.5	3.7	337.77	337.77	337.77	0
DK	70,500.5	886.0	5,619.4	1.8	338.1	338.1	338.1	0
DL	70,812.5	843.0	4,793.1	2.1	338.21	338.21	338.21	0
DM	71,388.5	677.8	4,220.9	2.3	338.36	338.36	338.36	0
DN	71,616.5	670.0	4,870.1	2.0	338.38	338.38	338.49	0.11
DO	72,165.5	474.0	2,905.7	3.4	338.47	338.47	338.56	0.09
DP	74,512.5	109.0	1,466.0	6.7	339.51	339.51	339.98	0.47
DQ	74,550.5	170.0	2,019.8	4.9	339.76	339.76	340.36	0.60
DR	75,308.5	216.6	2,479.9	4.0	340.16	340.16	340.86	0.70
DS	76,282.5	223.6	2,645.5	3.7	340.77	340.77	341.57	0.80
DT	78,388.5	563.2	5,146.8	1.9	342.12	342.12	343.07	0.94
DU	79,630.5	604.8	4,846.4	2.0	342.62	342.62	343.61	0.99
DV	81,371.5	733.8	6,301.8	1.6	343.36	343.36	344.35	0.99
DW	83,918.5	307.4	3,246.9	3.0	344.17	344.17	345.16	0.99

¹ Feet upstream from confluence with Merrimack River (1 mile = 5,280 ft).² Backwater from Merrimack River.

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Appendix 1. Suncook River 10-, 2-, 1- and 0.2-Percent Annual Exceedance Probability Flood Profiles (10-, 50-, 100-, and 500-Year Recurrence-Interval Floods, respectively)



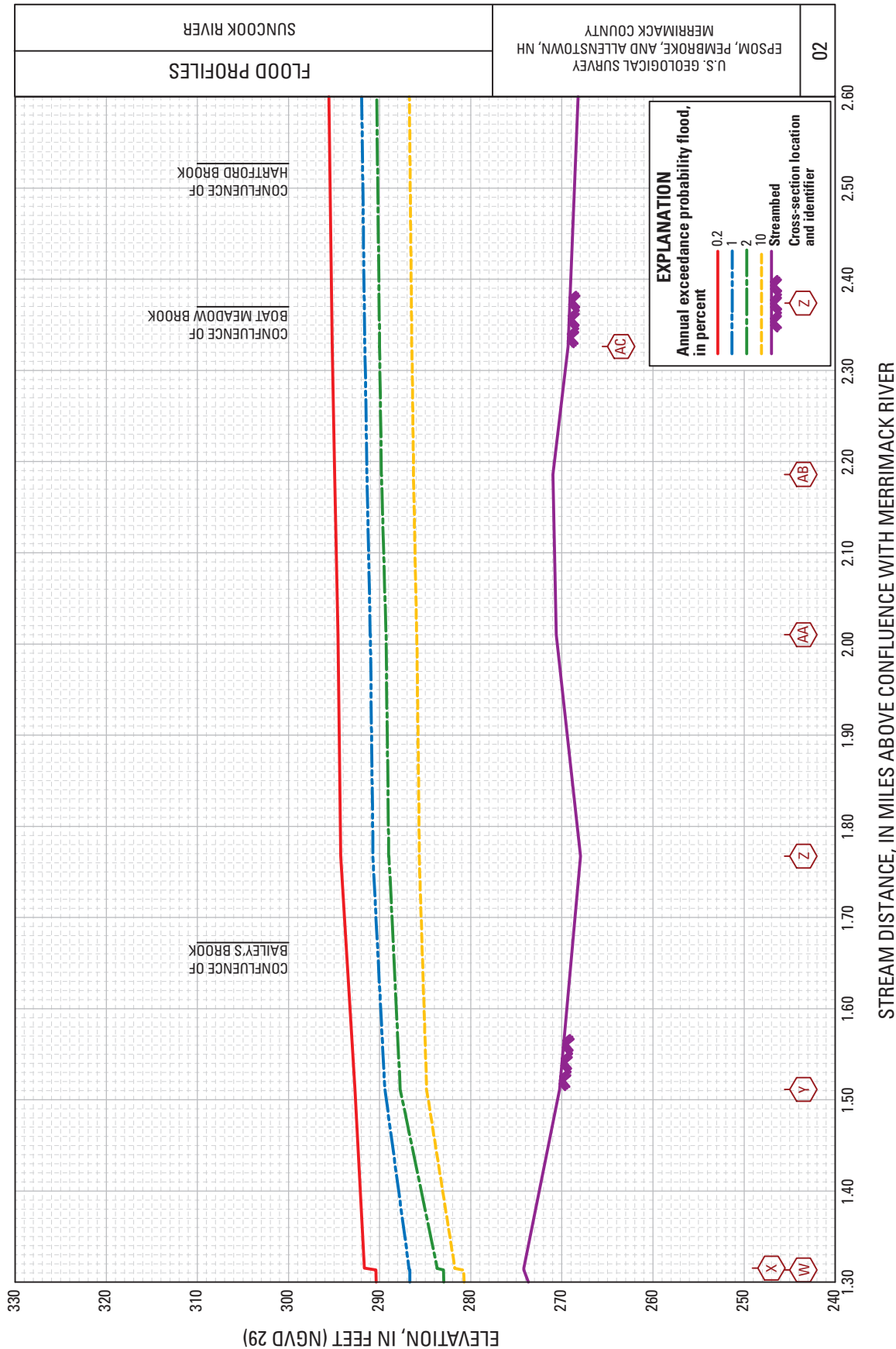


Figure 1–2. Suncook River 10-, 2-, 1-, and 0.2-percent annual chance flood profiles (10-, 50-, 100-, and 500-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figure 4–1. Detailed cross-section information shown in table 2.

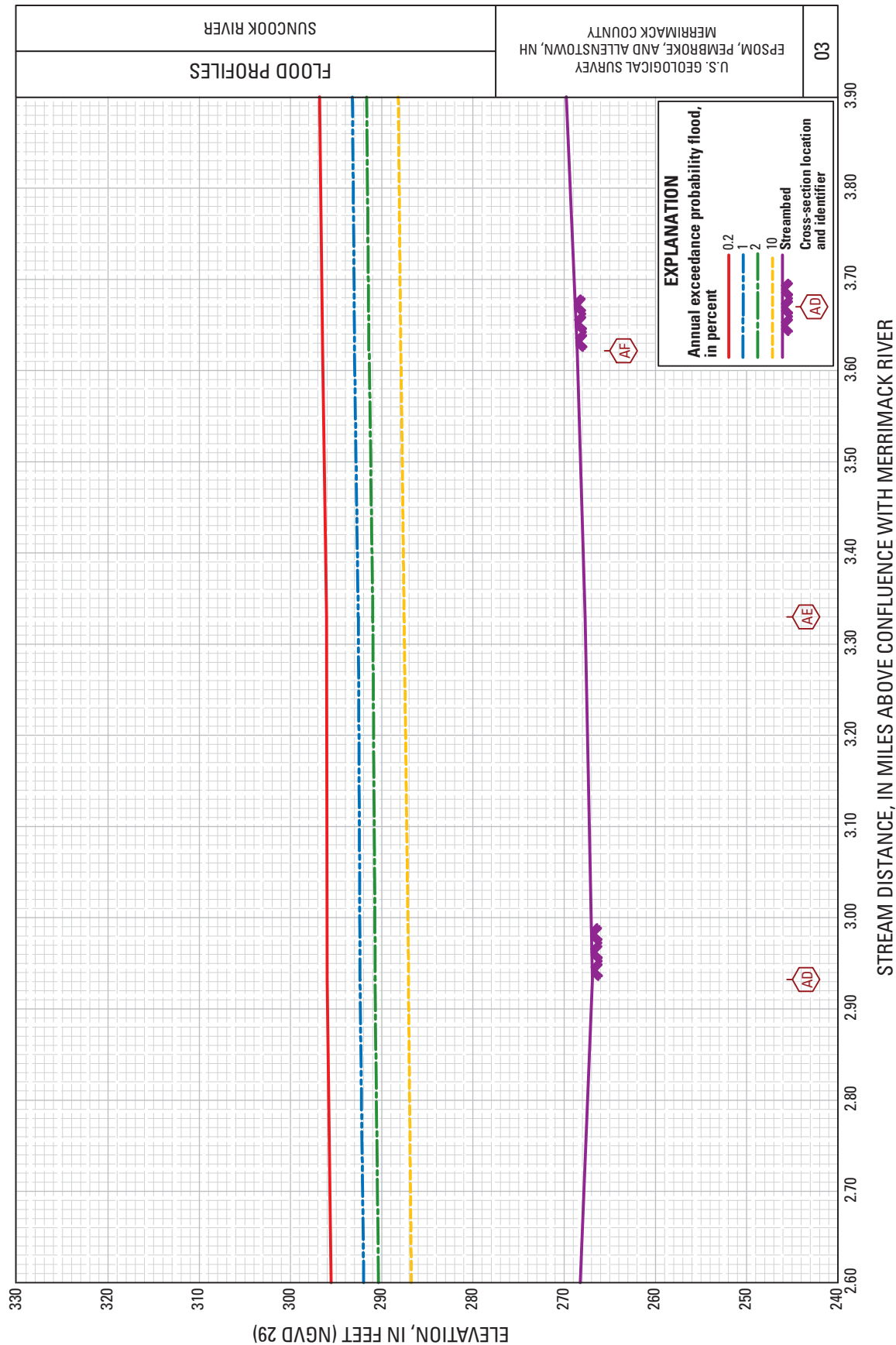


Figure 1–3. Suncook River 10-, 2-, 1-, and 0.2-percent annual chance flood profiles (10-, 50-, 100-, and 500-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figure 4–2. Detailed cross-section information shown in table 2.

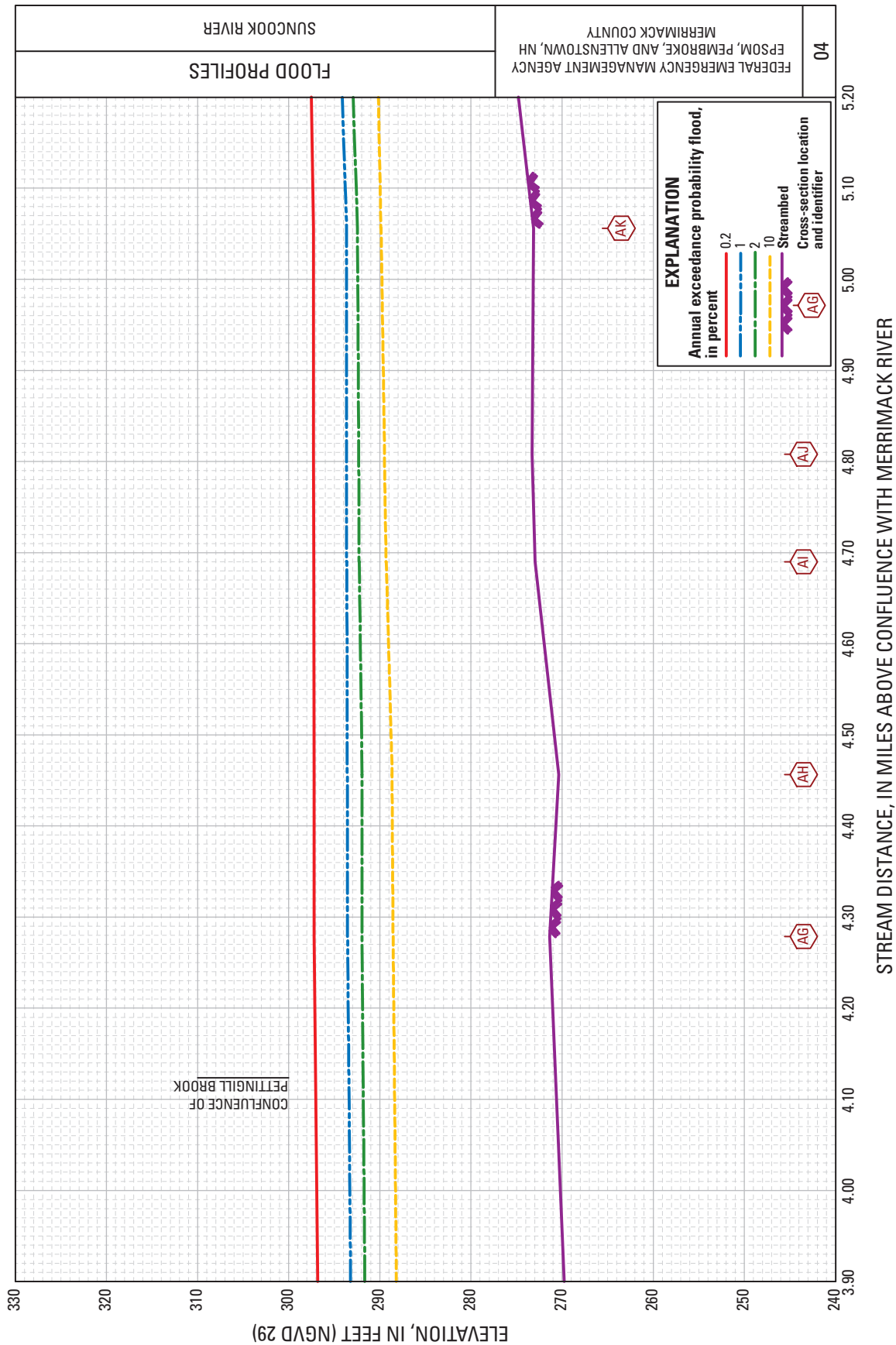
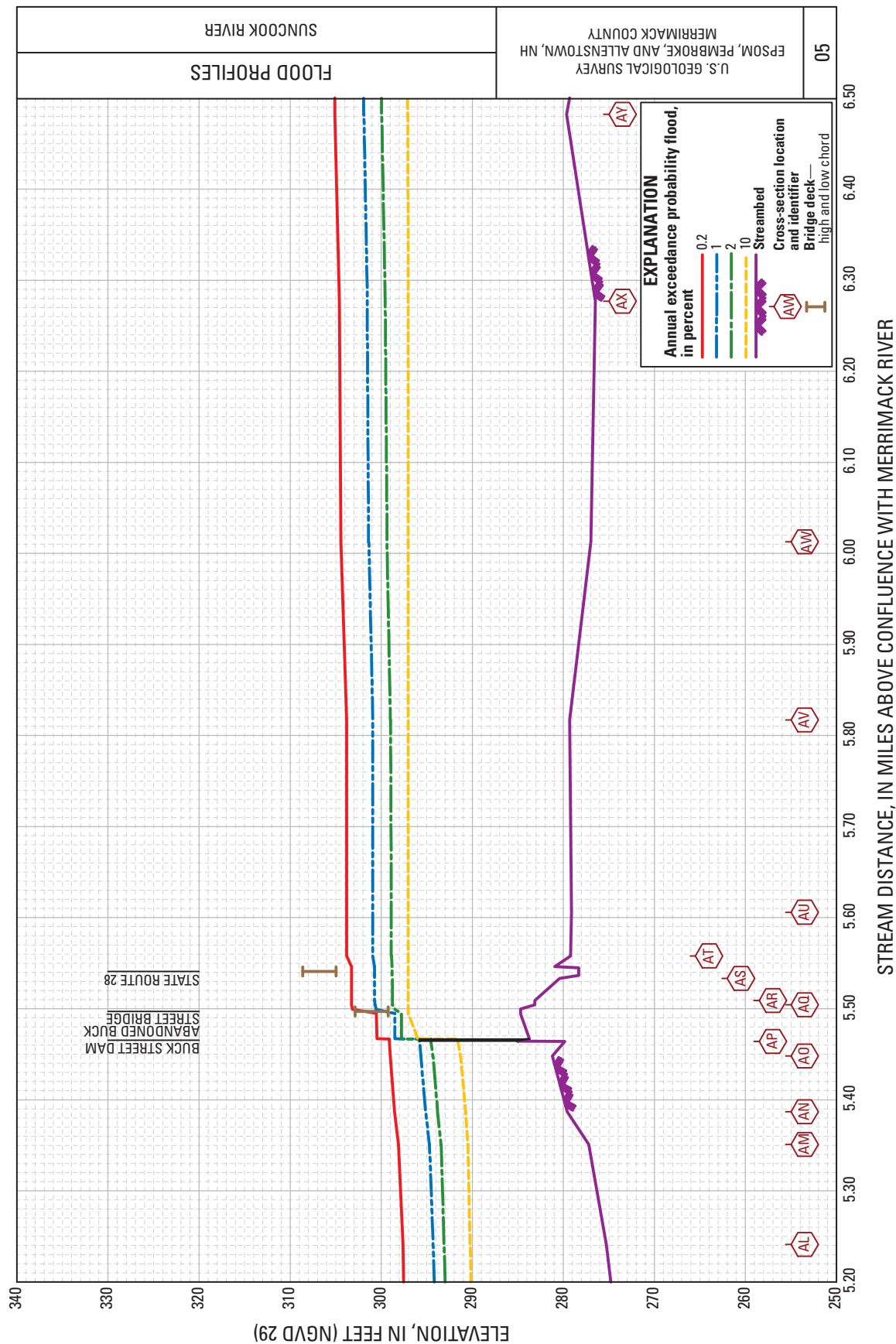
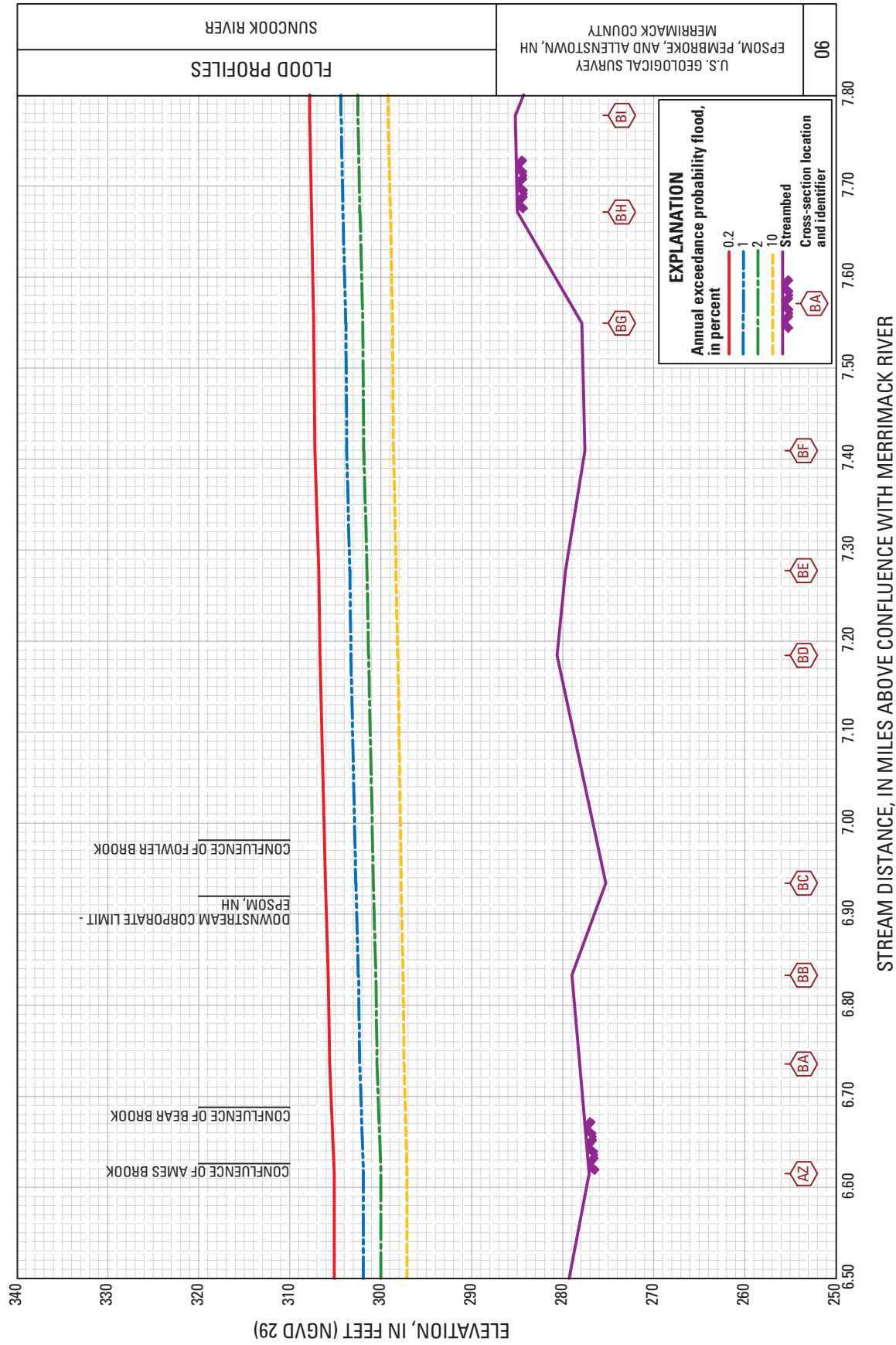


Figure 1-4. Suncook River 10-, 2-, 1-, and 0.2-percent annual chance flood profiles (10-, 50-, 100-, and 500-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figure 4-2. Detailed cross-section information shown in table 2.





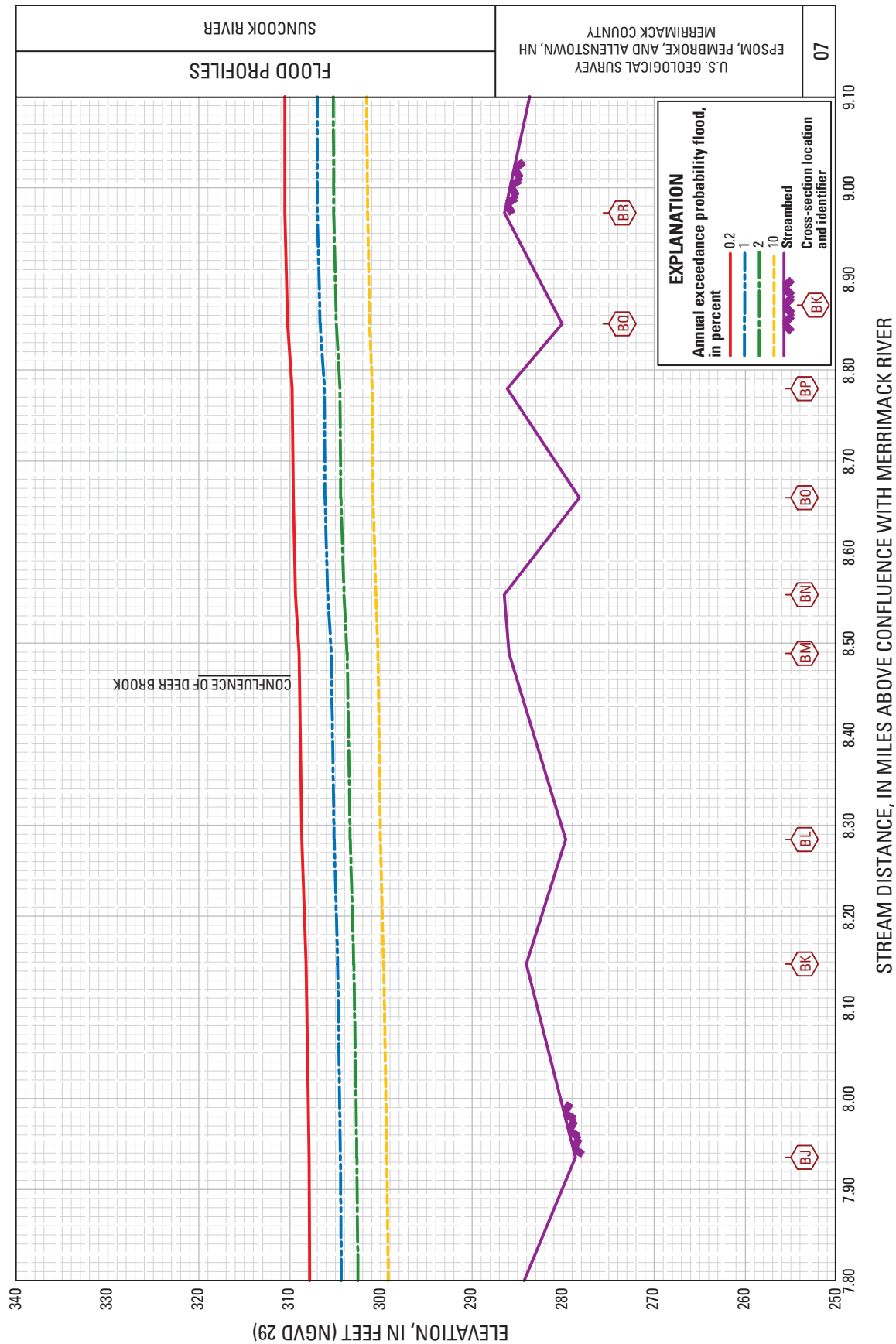


Figure 1-7. Suncook River 10-, 2-, 1-, and 0.2-percent annual chance flood profiles (10-, 50-, 100-, and 500-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figures 4-4 and 4-5. Detailed cross-section information shown in table 2.

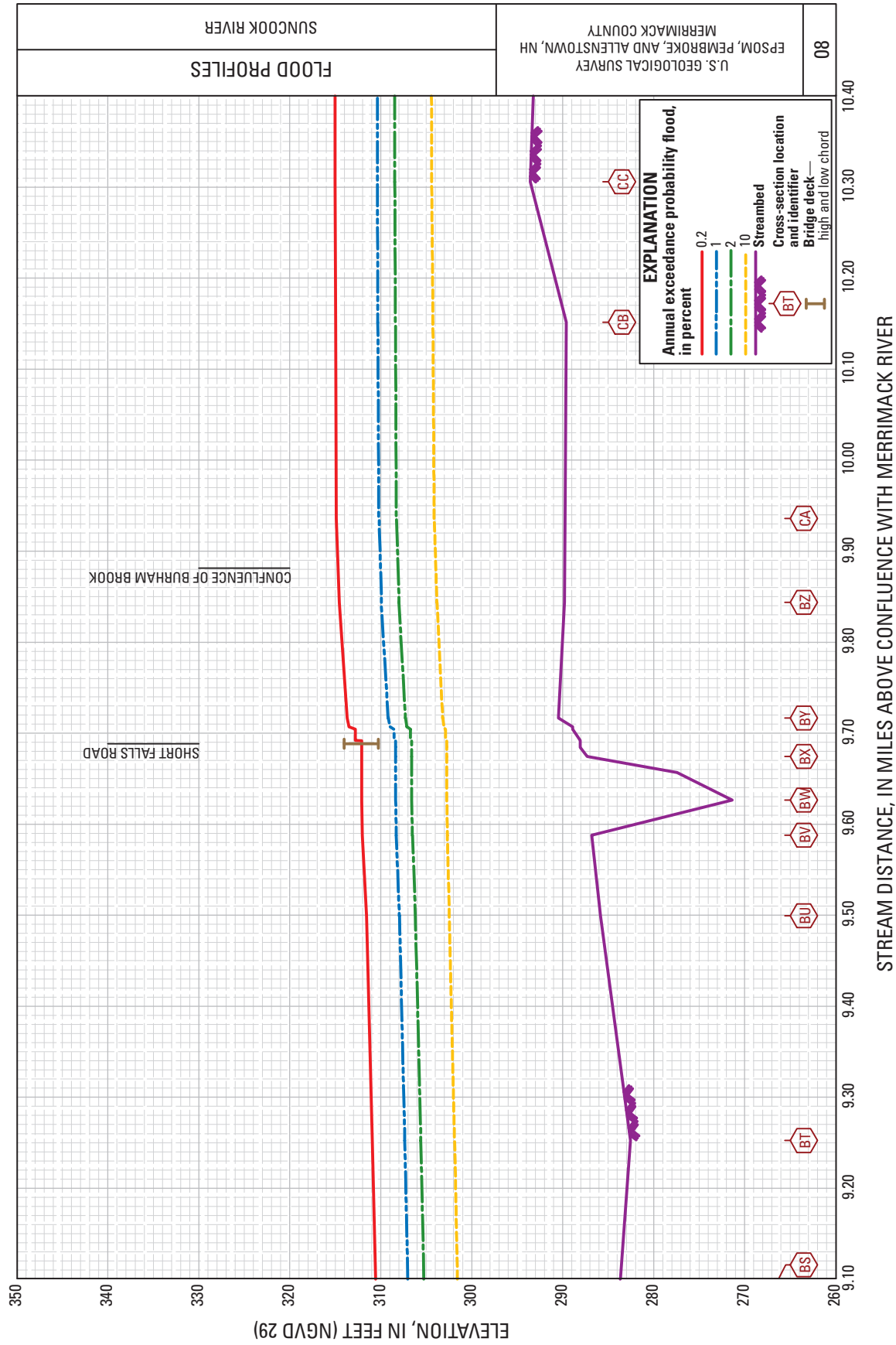


Figure 1-8. Suncook River 10-, 2-, 1-, and 0.2-percent annual chance flood profiles (10-, 50-, 100-, and 500-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figure 4–5. Detailed cross-section information shown in table 2.

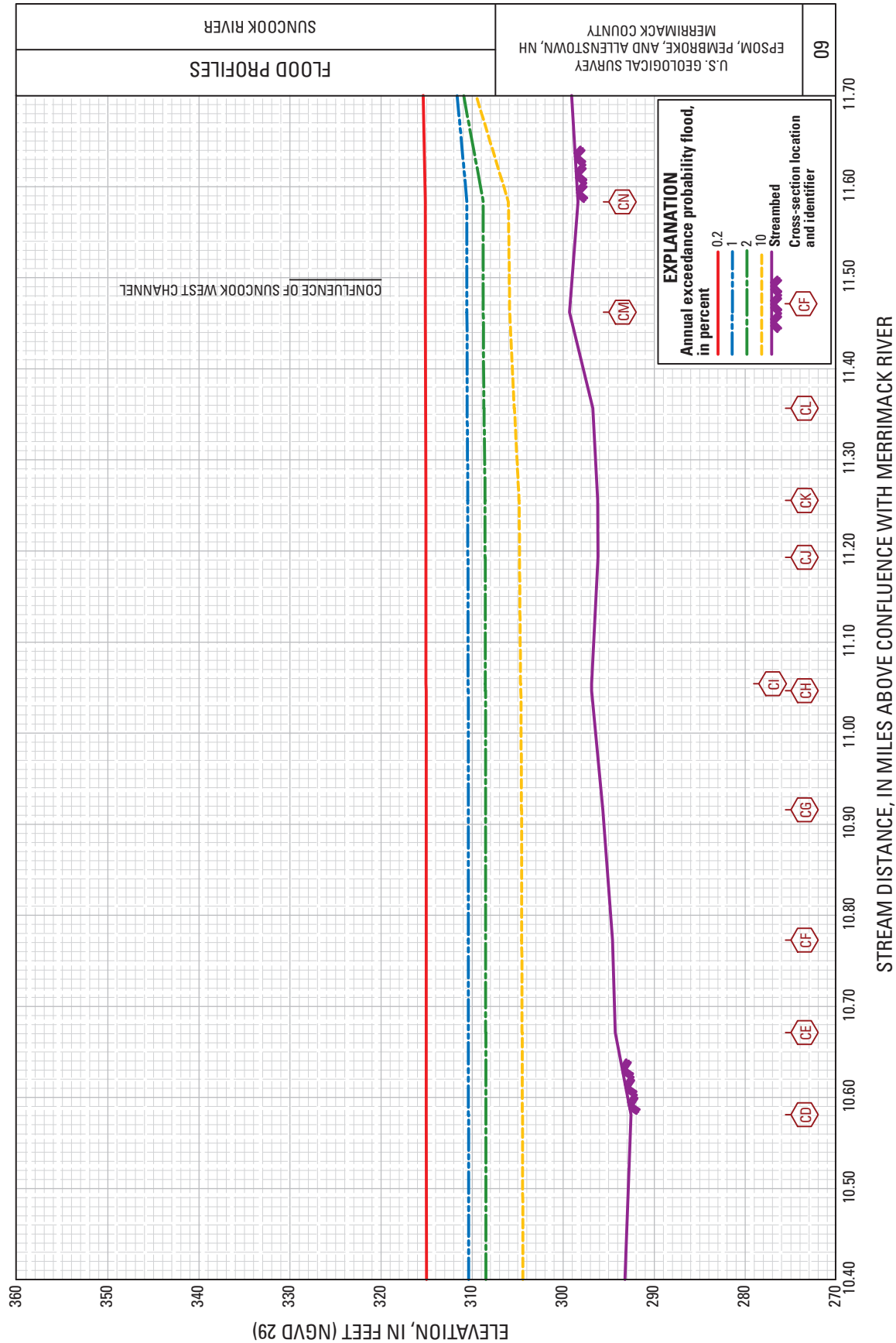


Figure 1-9. Suncook River 10-, 2-, 1-, and 0.2-percent annual chance flood profiles (10-, 50-, 100-, and 500-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figure 4-5. Detailed cross-section information shown in table 2.

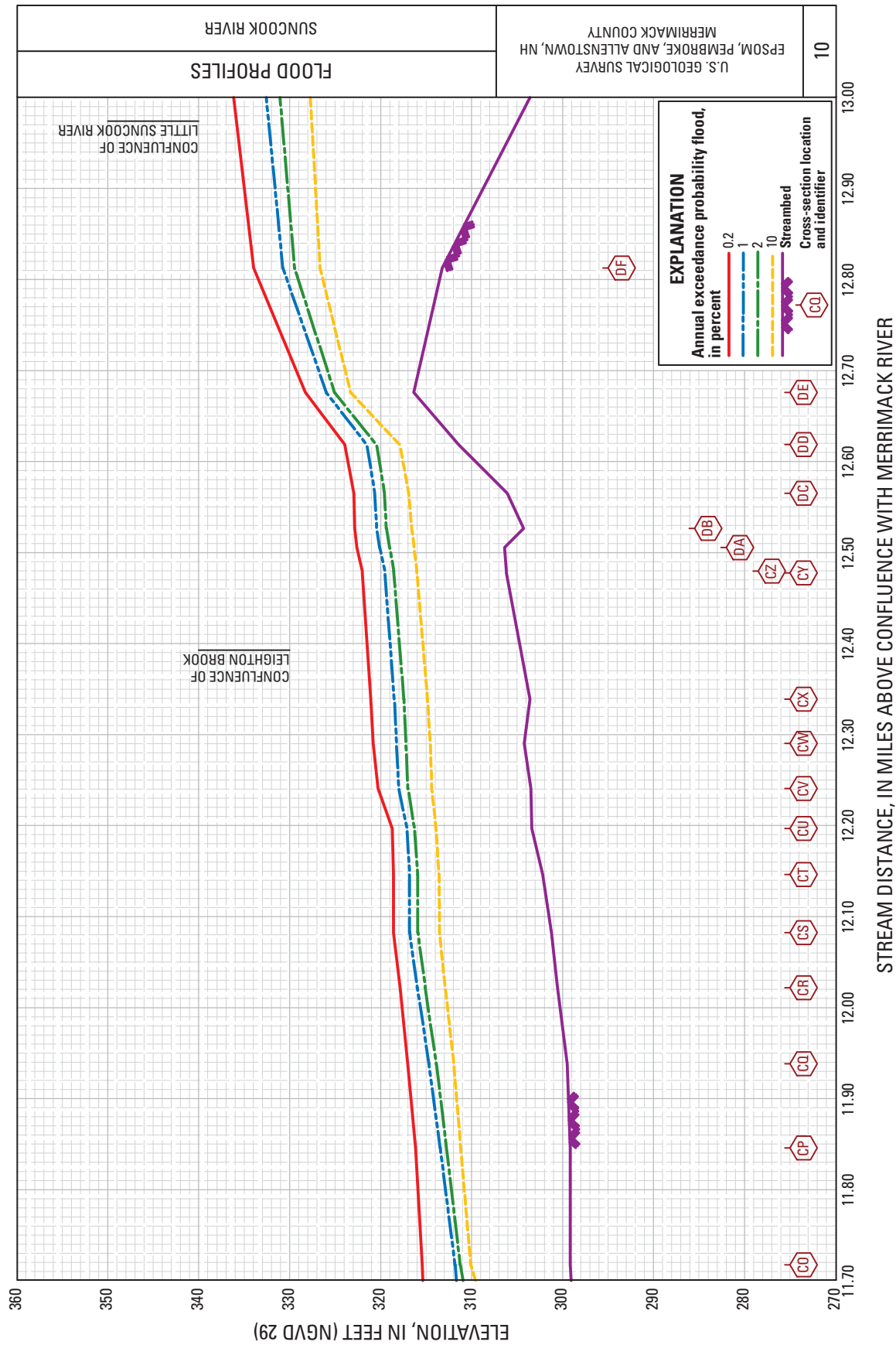
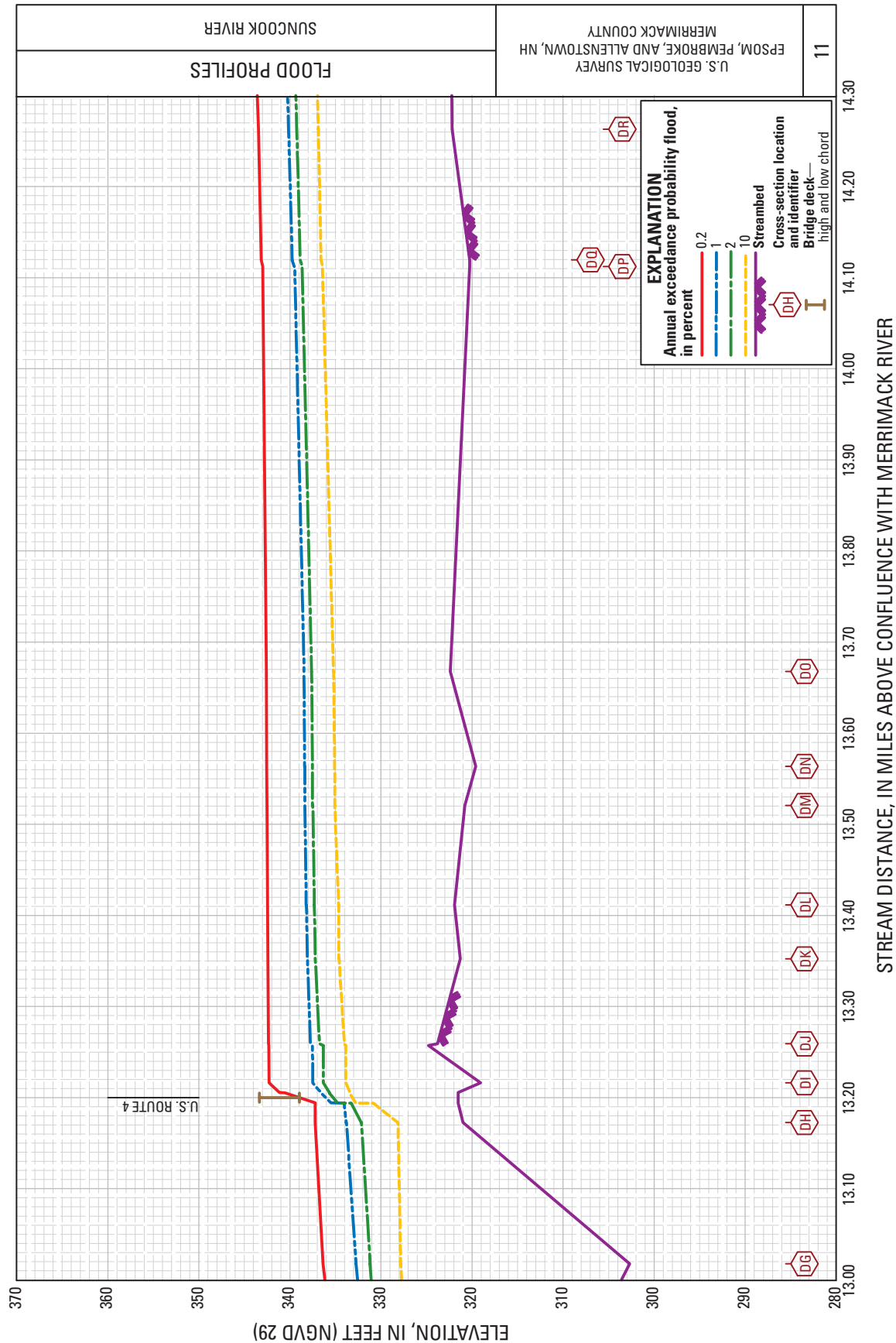


Figure 1–10. Suncook River 10-, 2-, 1-, and 0.2-percent annual chance flood profiles (10-, 50-, 100-, and 500-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figure 4–6. Detailed cross-section information shown in table 2.



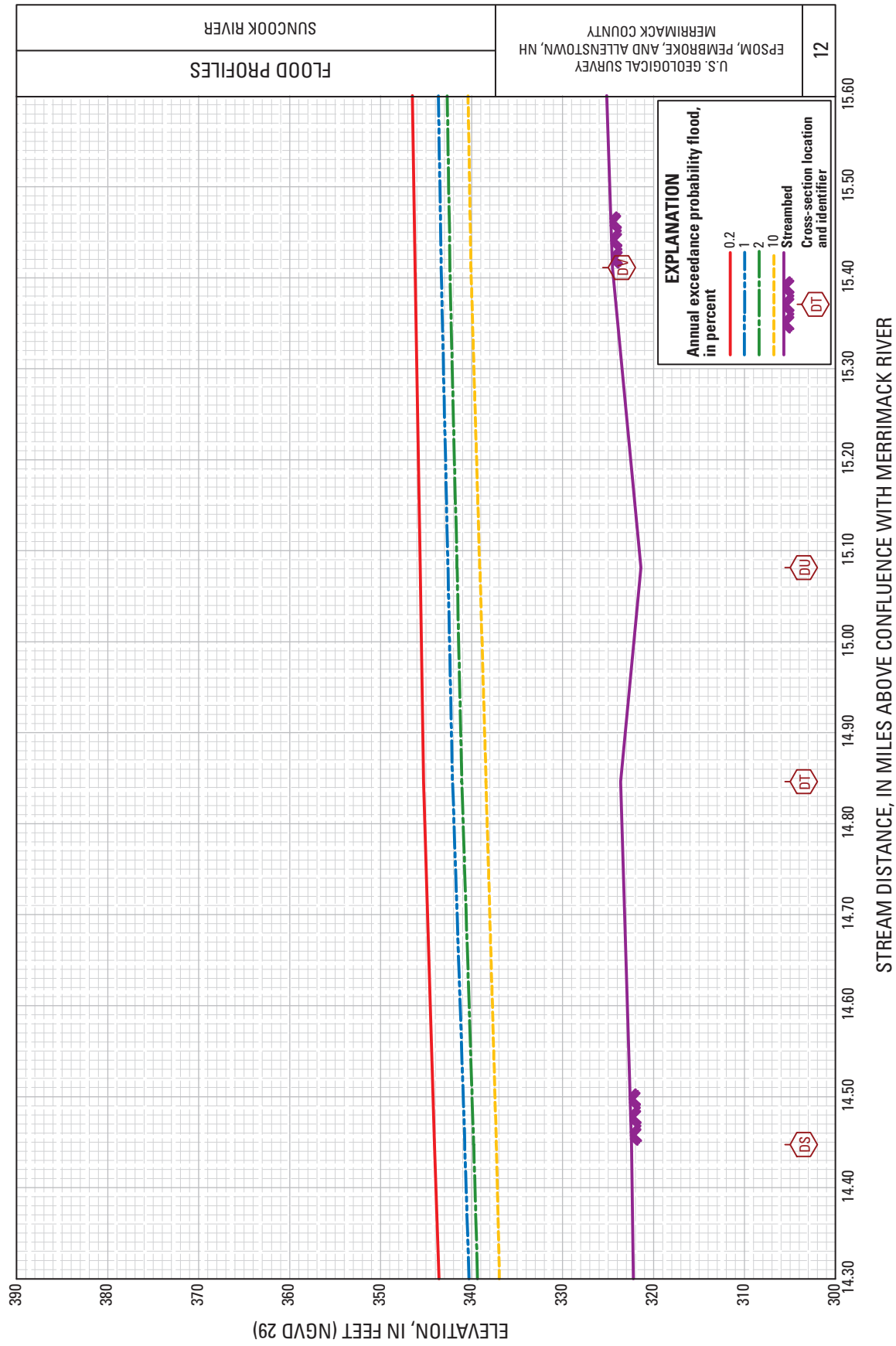
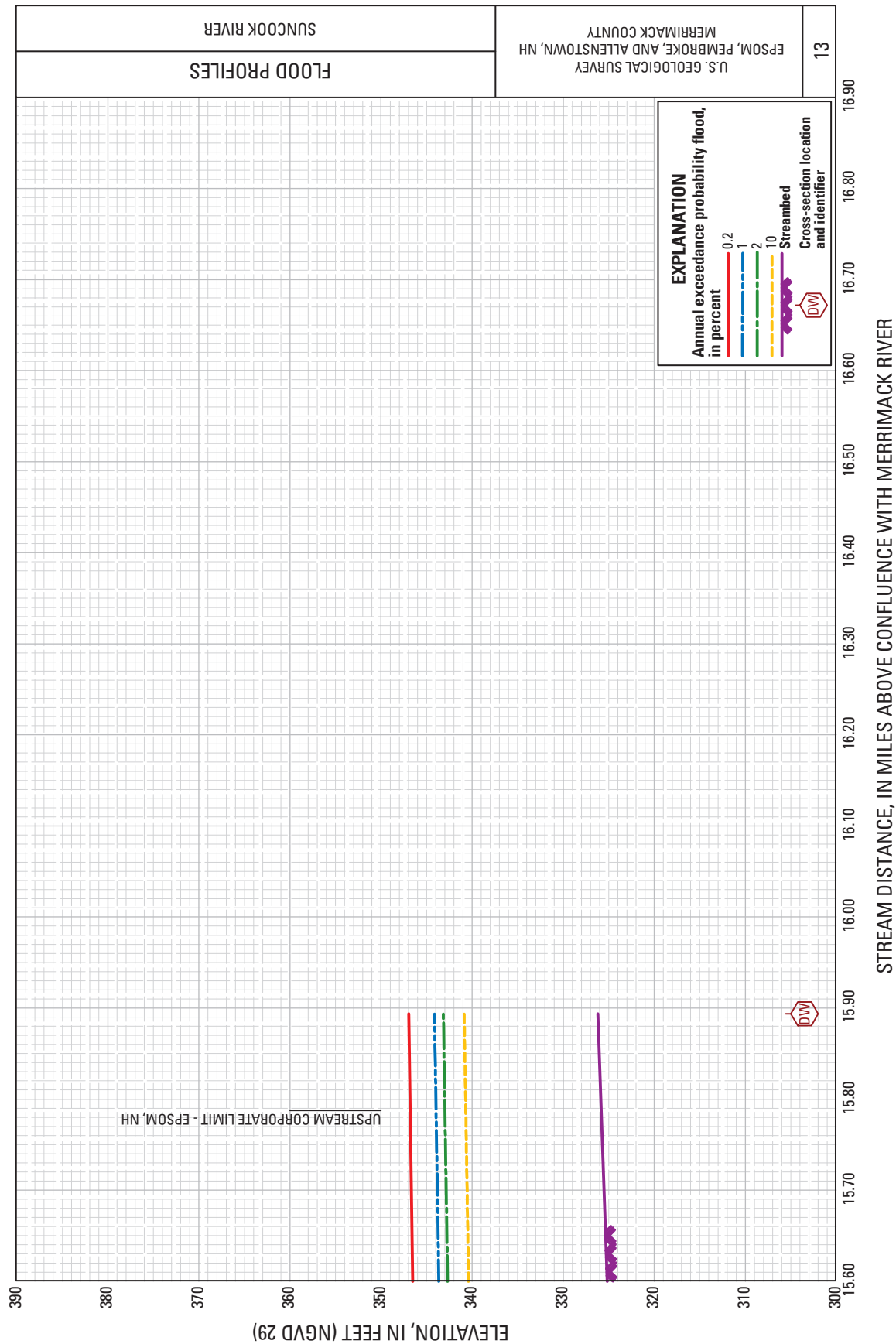


Figure 1-12. Suncook River 10-, 2-, 1-, and 0.2-percent annual chance flood profiles (10-, 50-, 100-, and 500-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figures 4-7 and 4-8. Detailed cross-section information shown in table 2.



**Appendix 2. Suncook River April 2007 Flood
and 50-, 20-, and 4-Percent Annual Exceedance
Probability Flood Profiles (2-, 5-, and 25-Year
Recurrence-Interval Floods, respectively)**

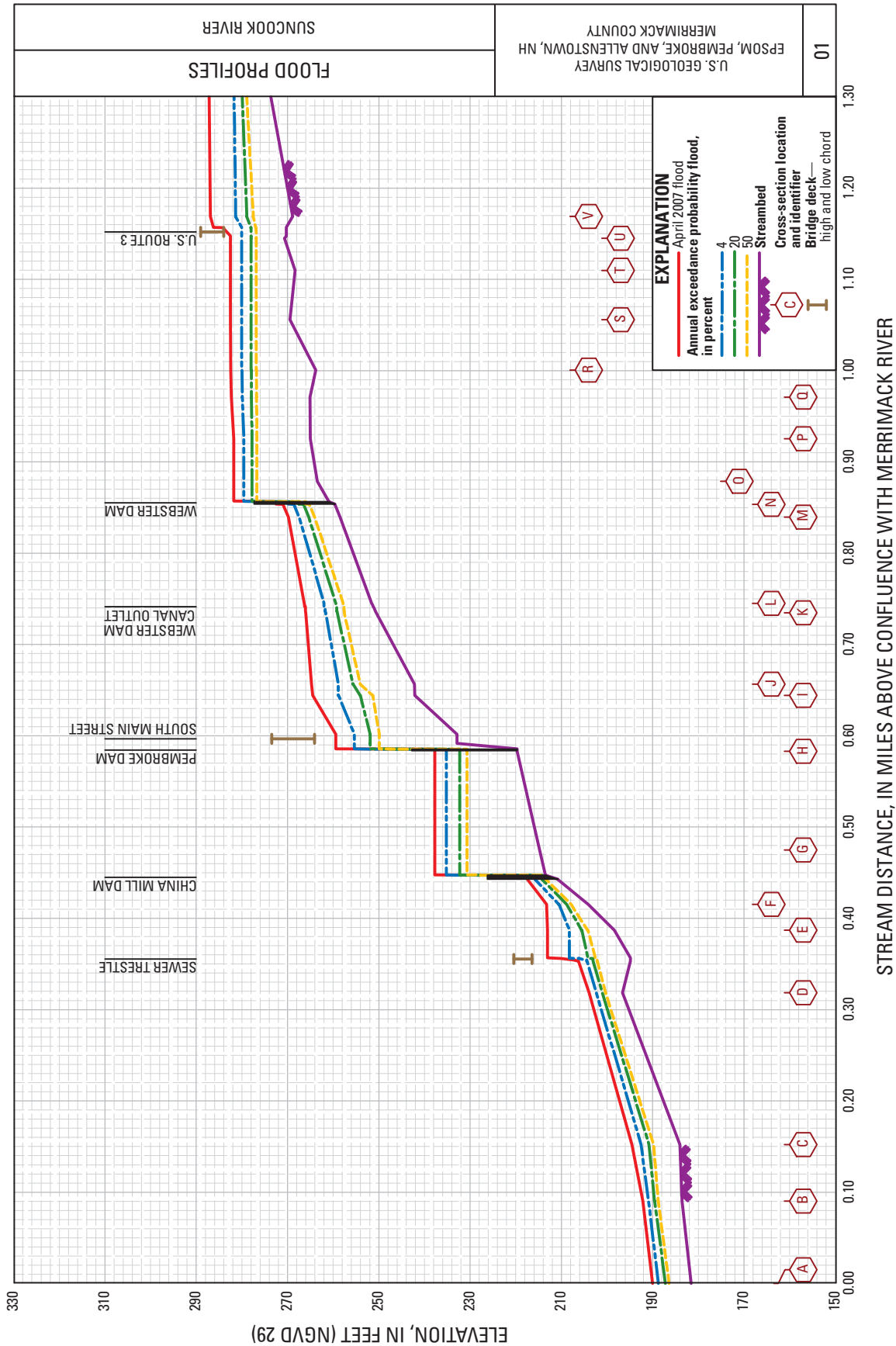


Figure 2-1. Suncook River April 2007 flood and 50-, 20-, and 4-percent chance flood profiles (2-, 5-, and 25-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figure 4-1. Detailed cross-section information shown in table 3.

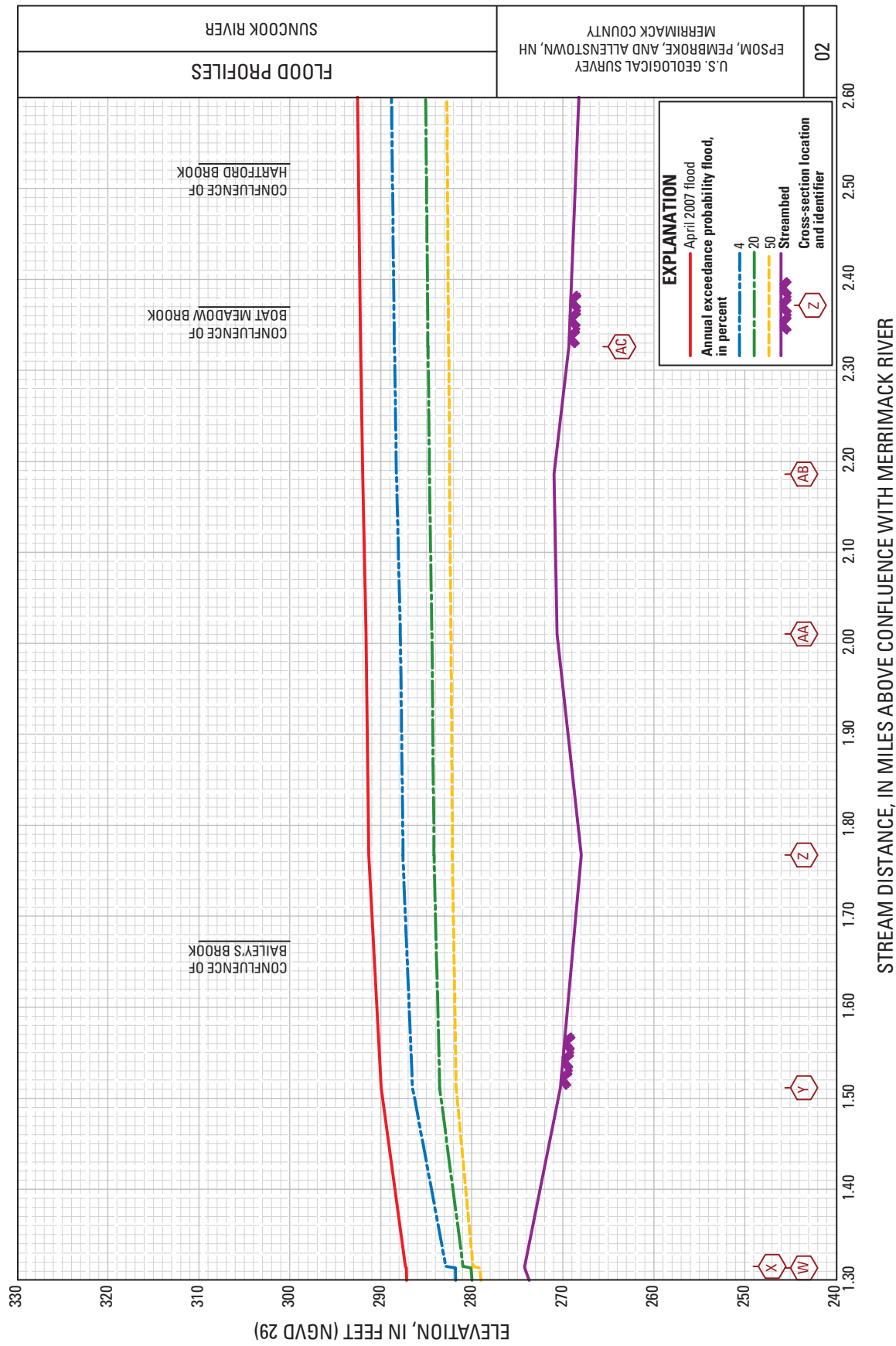


Figure 2-2. Suncook River April 2007 flood and 50-, 20-, and 4-percent chance flood profiles (2-, 5-, and 25-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figure 4-1. Detailed cross-section information shown in table 3.

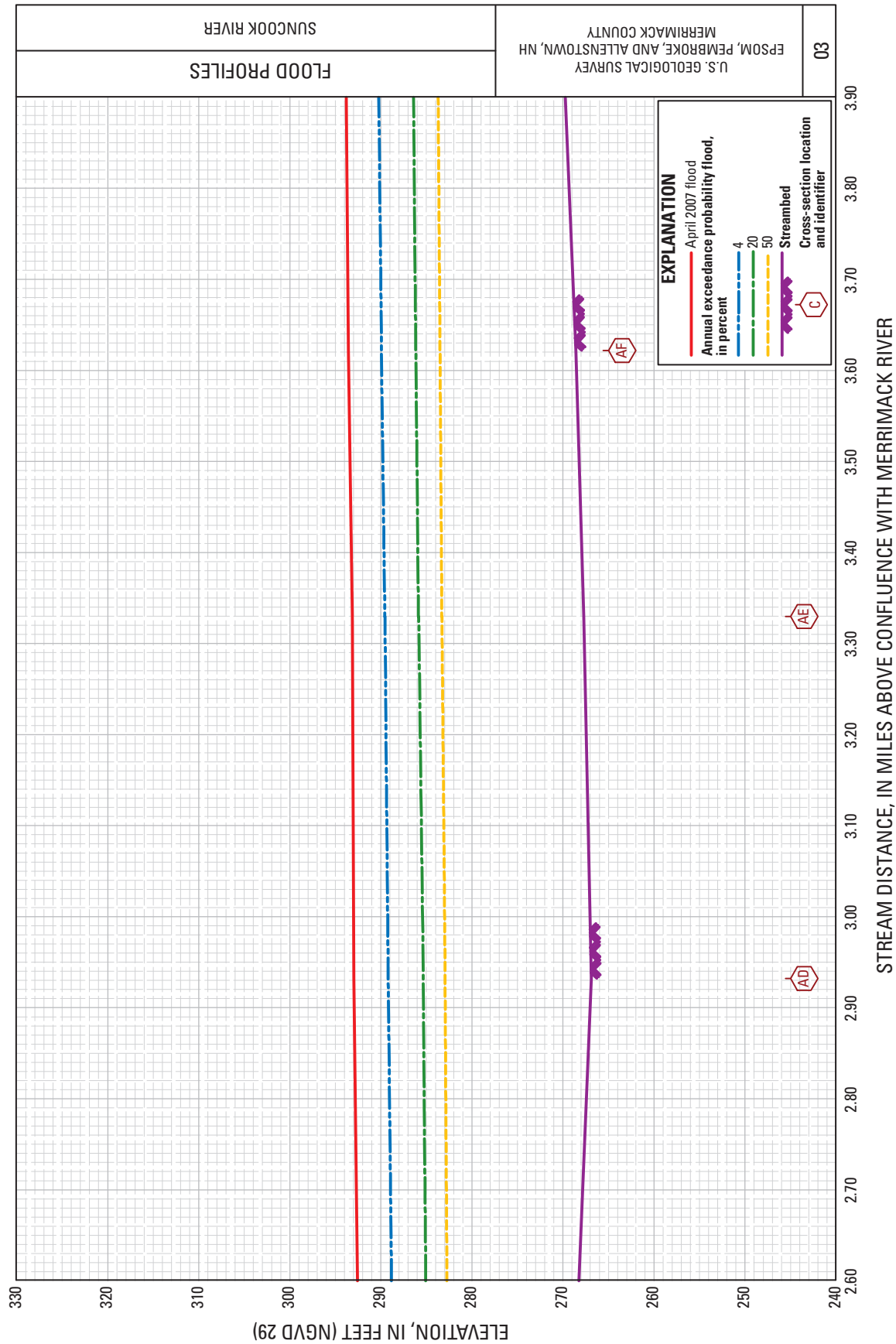


Figure 2-3. Suncook River April 2007 flood and 50-, 20-, and 4-percent chance flood profiles (2-, 5-, and 25-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figure 4-2. Detailed cross-section information shown in table 3.

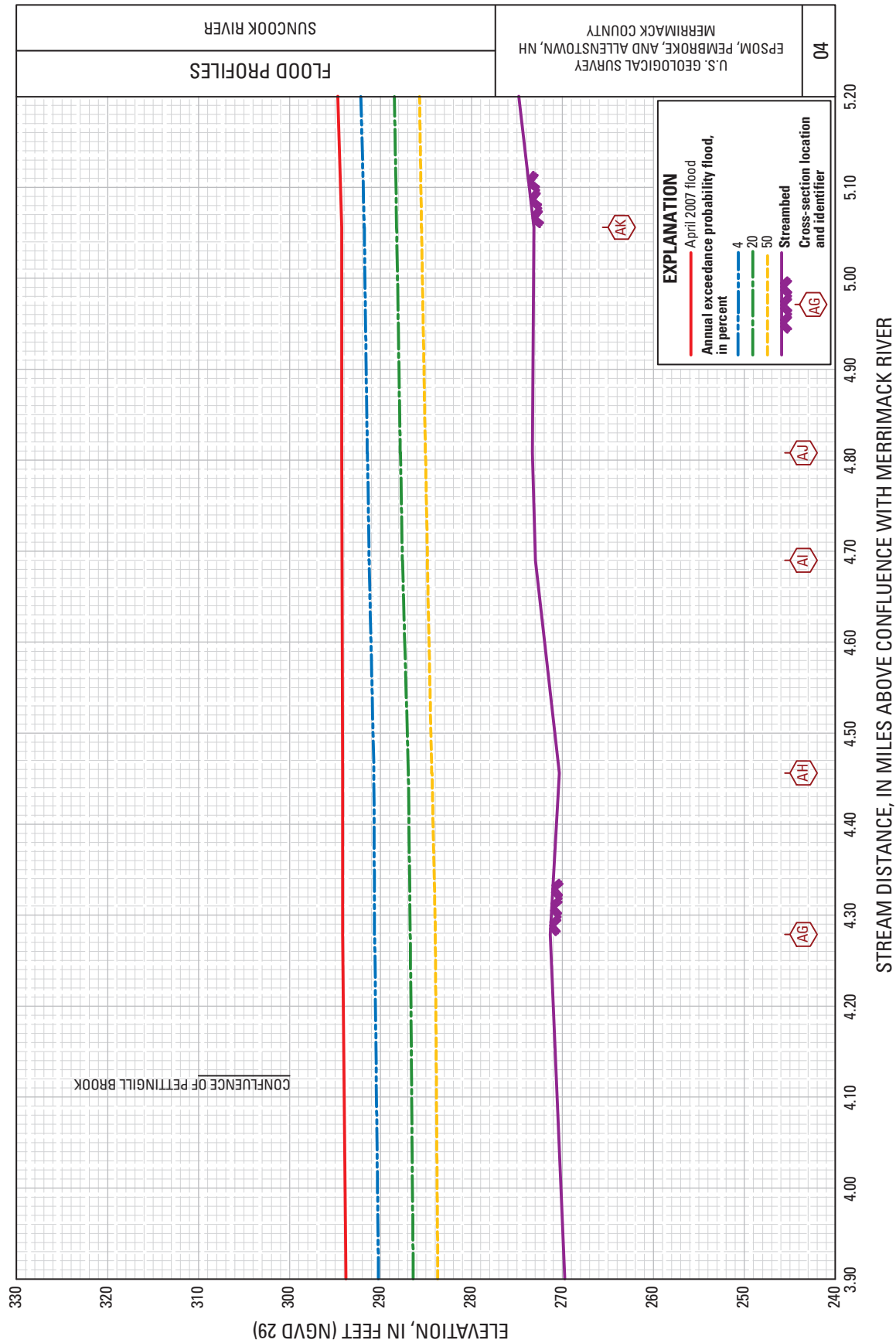


Figure 2-4. Suncook River April 2007 flood and 50-, 20-, and 4-percent chance flood profiles (2-, 5-, and 25-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figure 4-2. Detailed cross-section information shown in table 3.

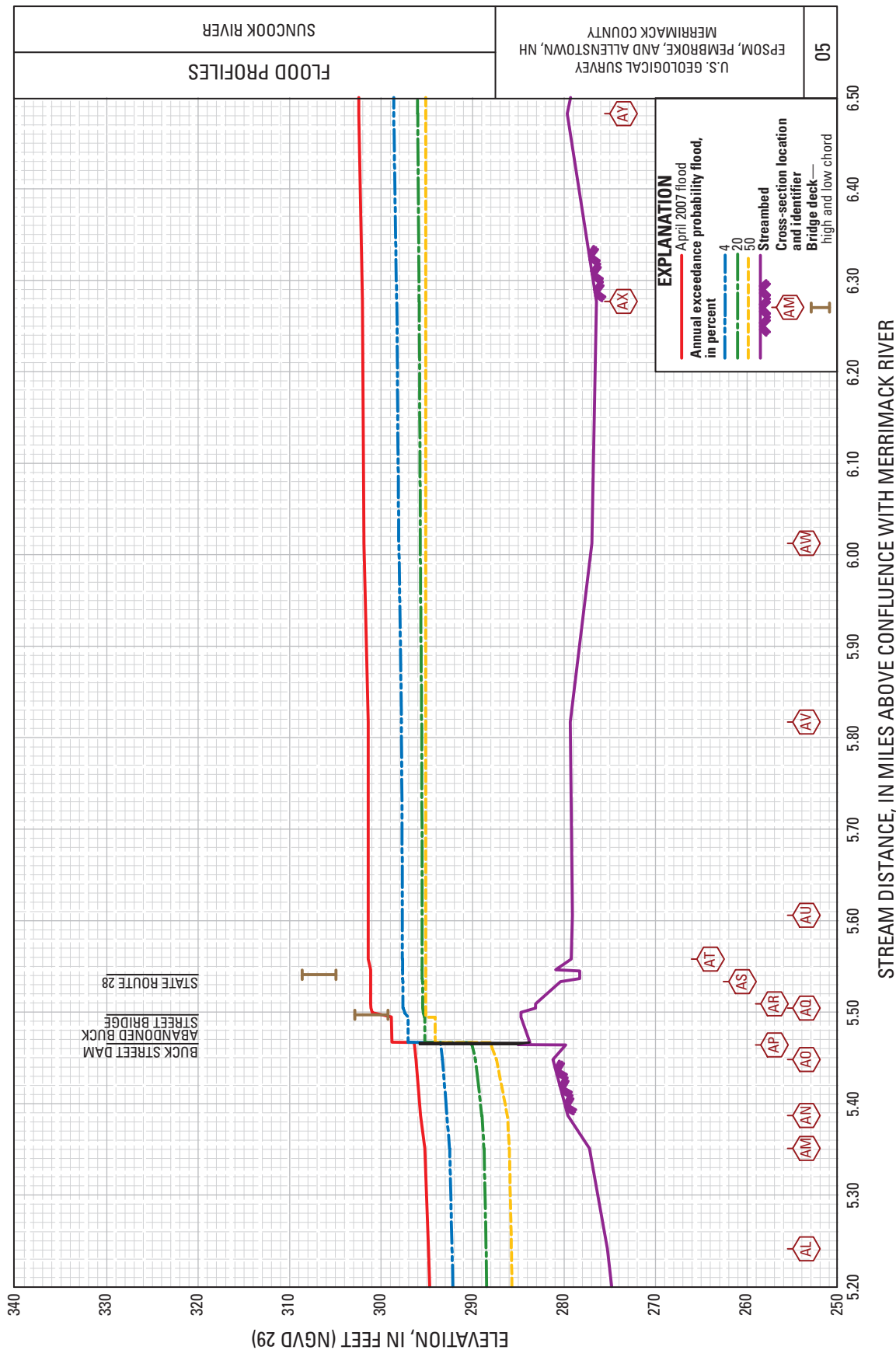
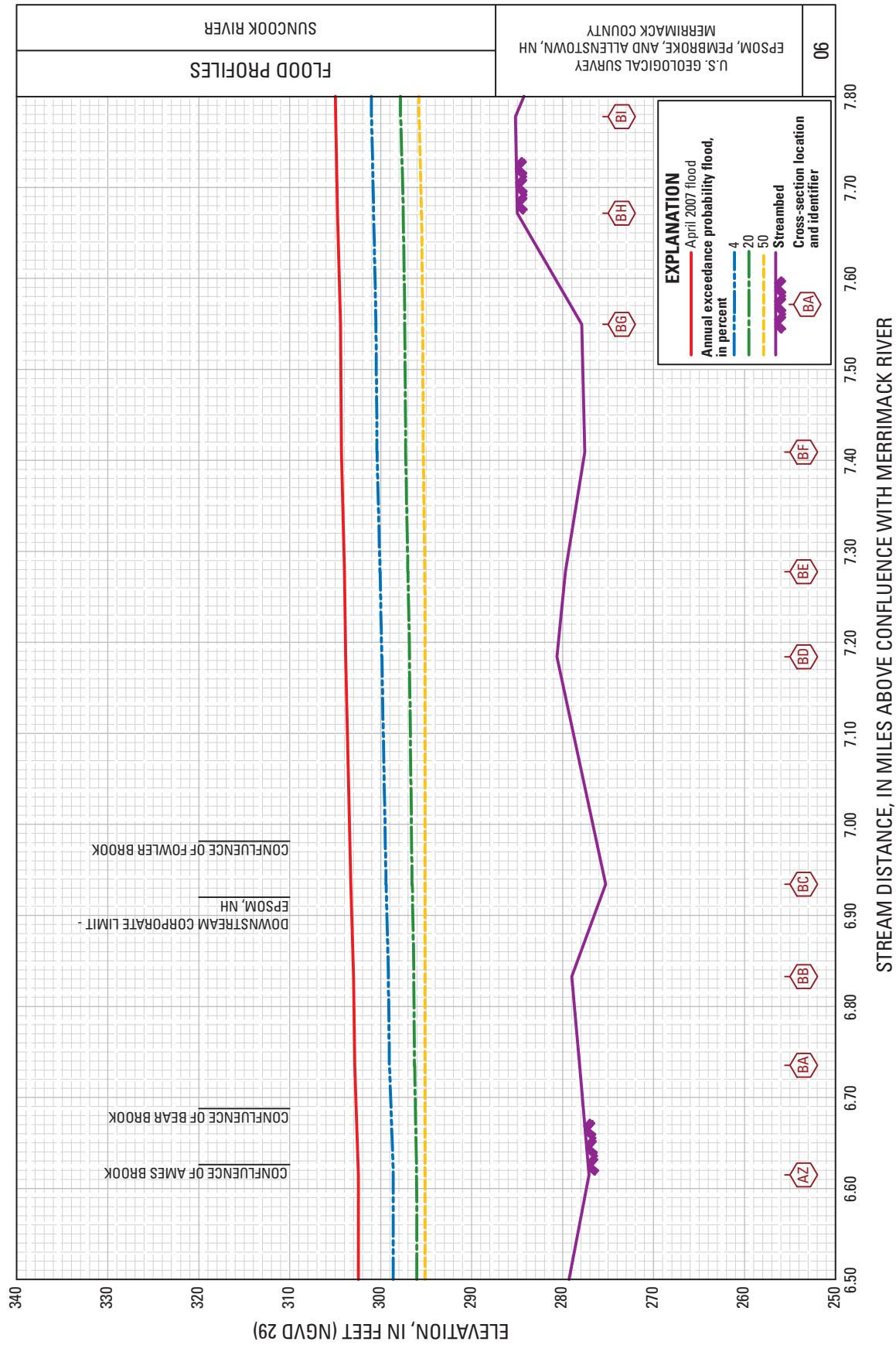


Figure 2-5. Suncook River April 2007 flood and 50-, 20-, and 4-percent chance flood profiles (2-, 5-, and 25-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figure 4-3. Detailed cross-section information shown in table 3.



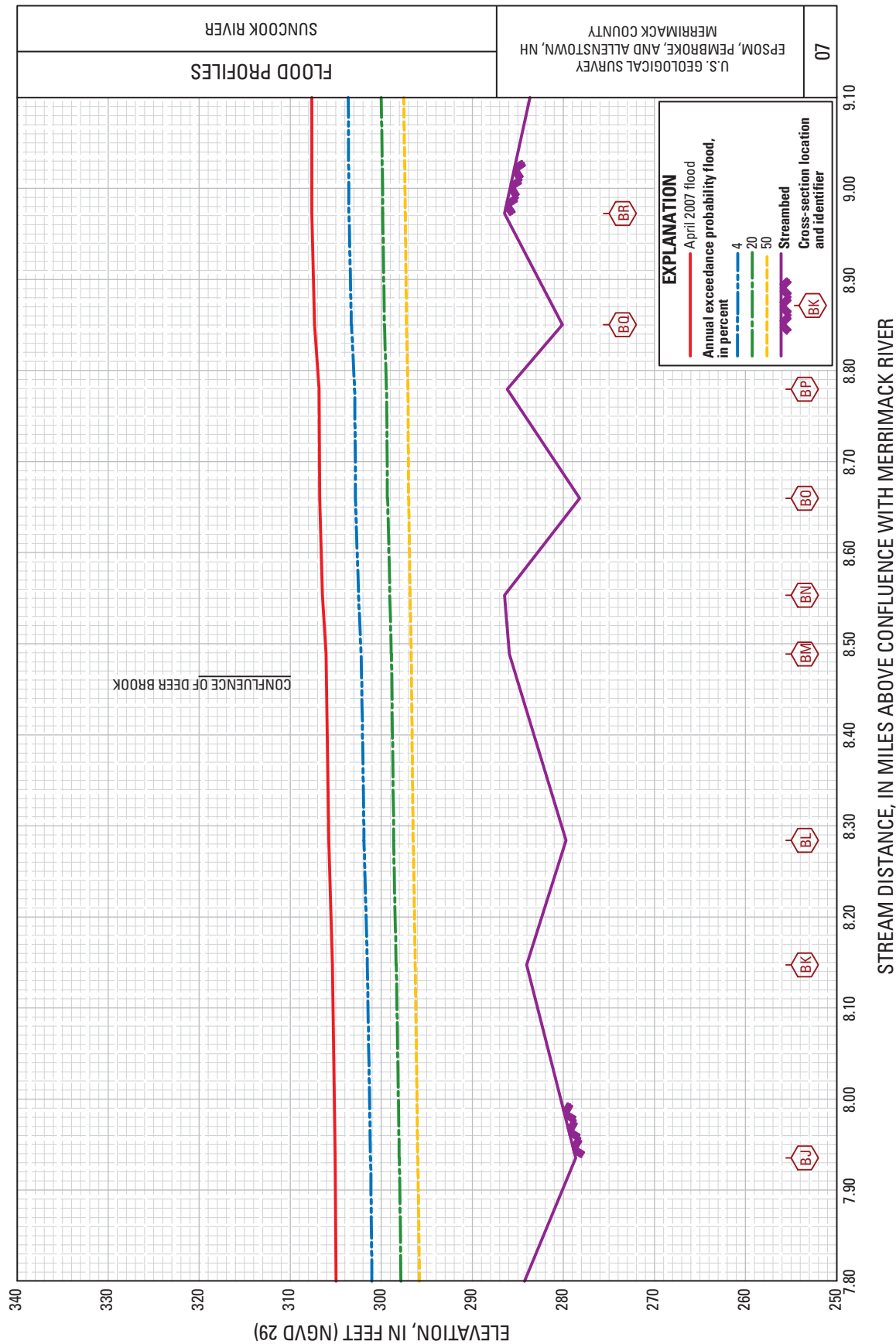


Figure 2-7. Suncook River April 2007 flood and 50-, 20-, and 4-percent chance flood profiles (2-, 5-, and 25-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figures 4-4 and 4-5. Detailed cross-section information shown in table 3.

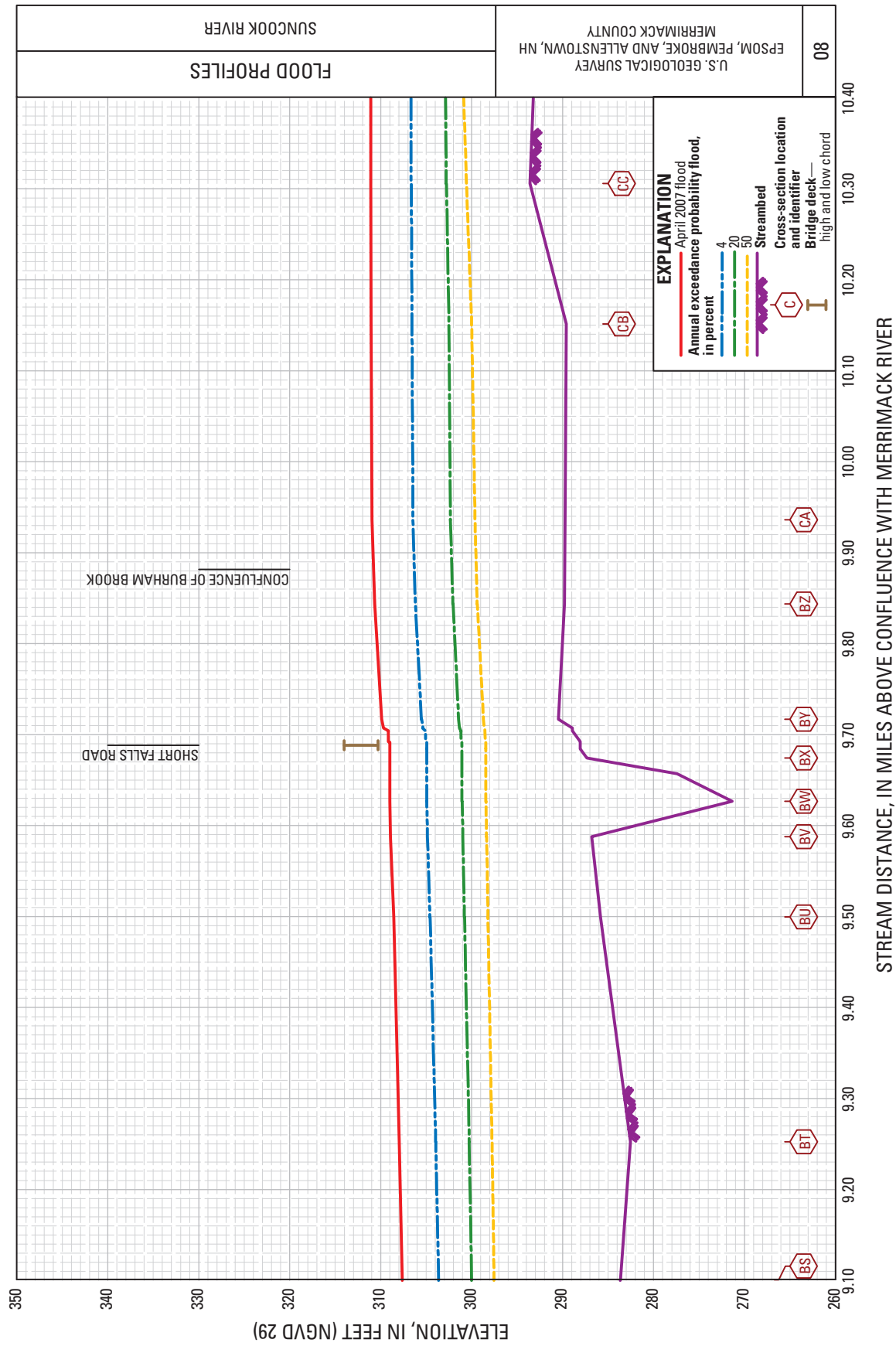


Figure 2-8. Suncook River April 2007 flood and 50-, 20-, and 4-percent chance flood profiles (2-, 5-, and 25-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figure 4-5. Detailed cross-section information shown in table 3.

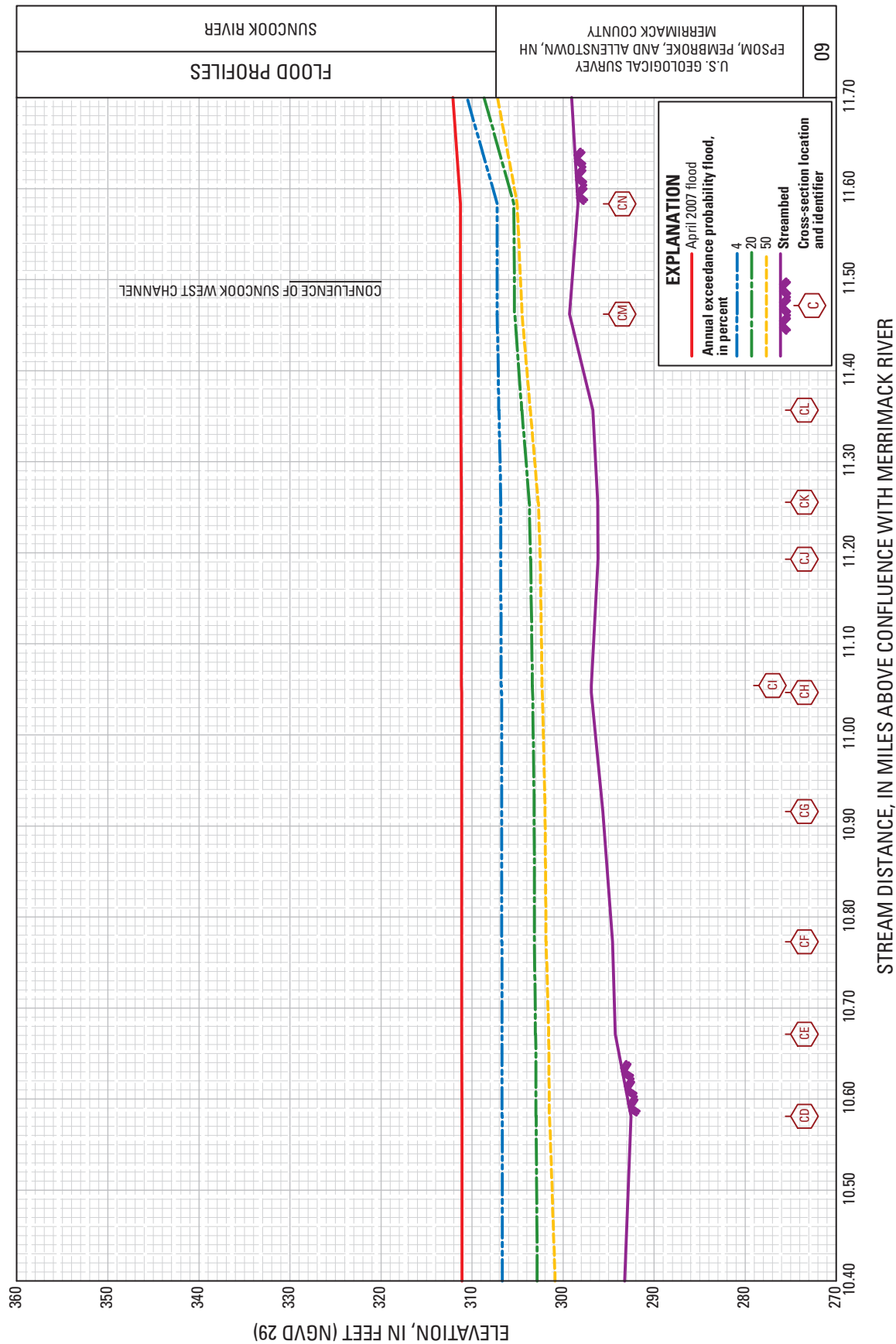


Figure 2-9. Suncook River April 2007 flood and 50-, 20-, and 4-percent chance flood profiles (2-, 5-, and 25-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figure 4-5. Detailed cross-section information shown in table 3.



Figure 2-10. Suncook River April 2007 flood and 50-, 20-, and 4-percent chance flood profiles (2-, 5-, and 25-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figure 4-6. Detailed cross-section information shown in table 3.

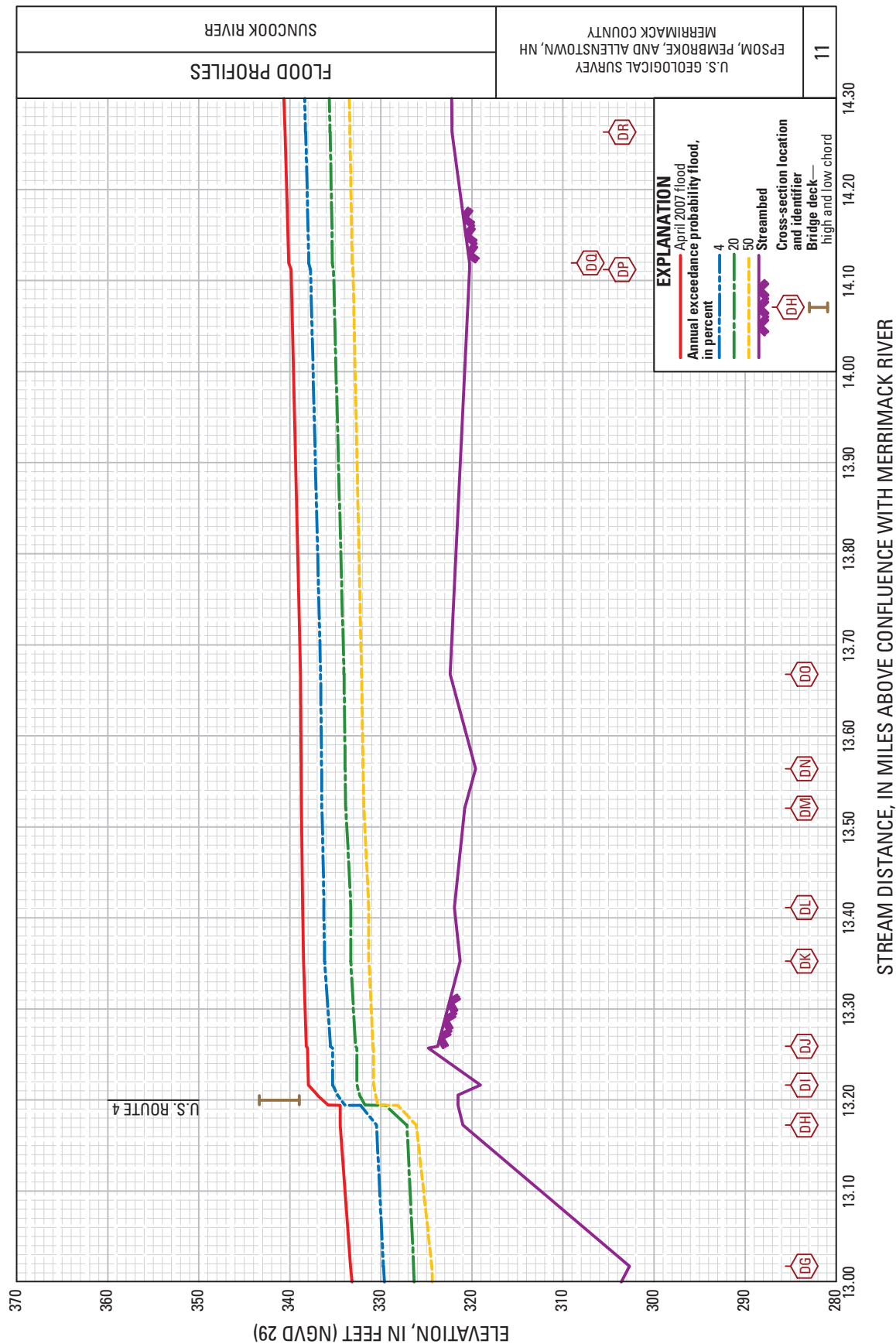


Figure 2-11. Suncook River April 2007 flood and 50-, 20-, and 4-percent chance flood profiles (2-, 5-, and 25-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figures 4–6 and 4–7. Detailed cross-section information shown in table 3.

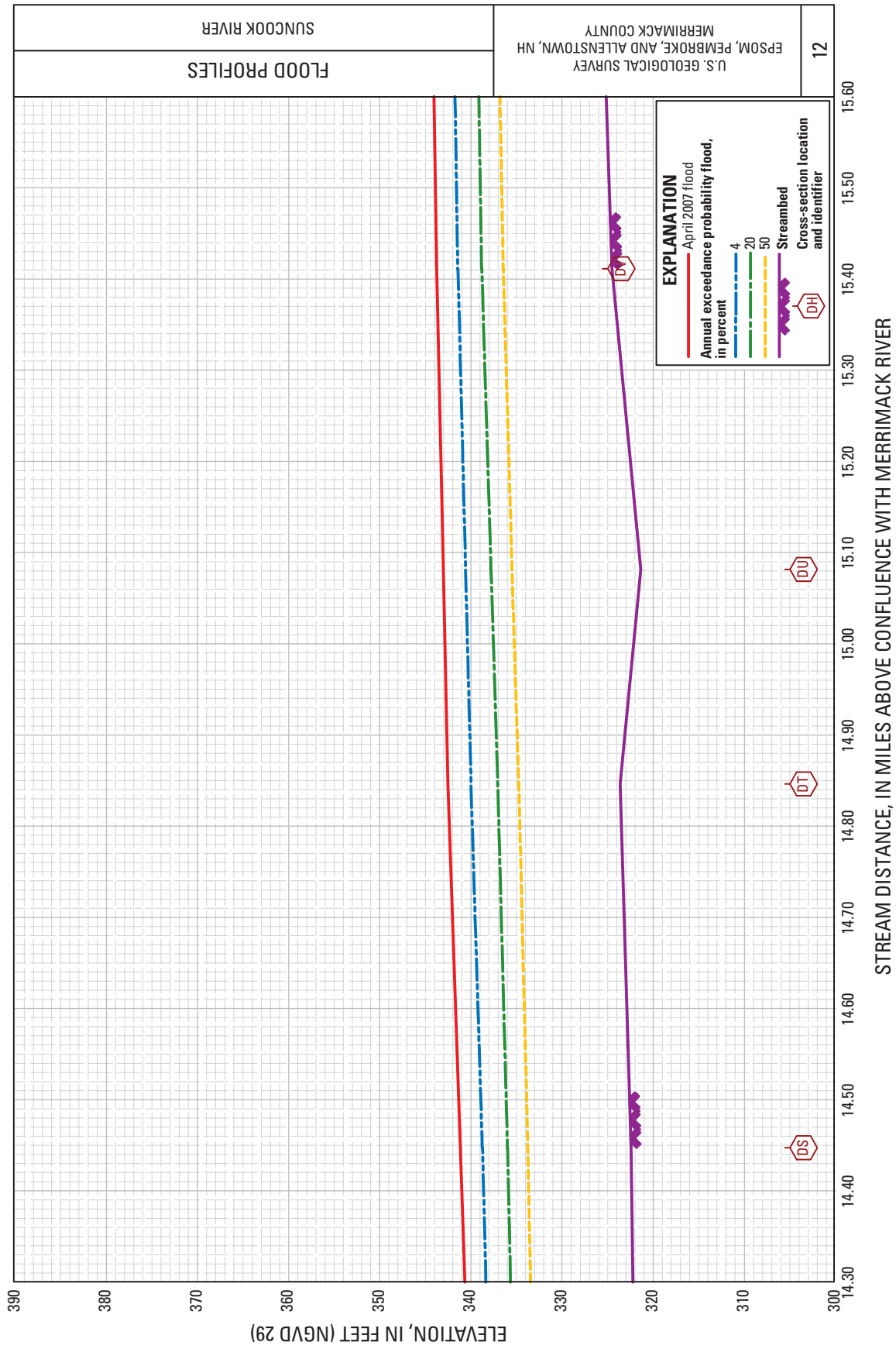


Figure 2-12. Suncook River April 2007 flood and 50-, 20-, and 4-percent chance flood profiles (2-, 5-, and 25-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figures 4-7 and 4-8. Detailed cross-section information shown in table 3.

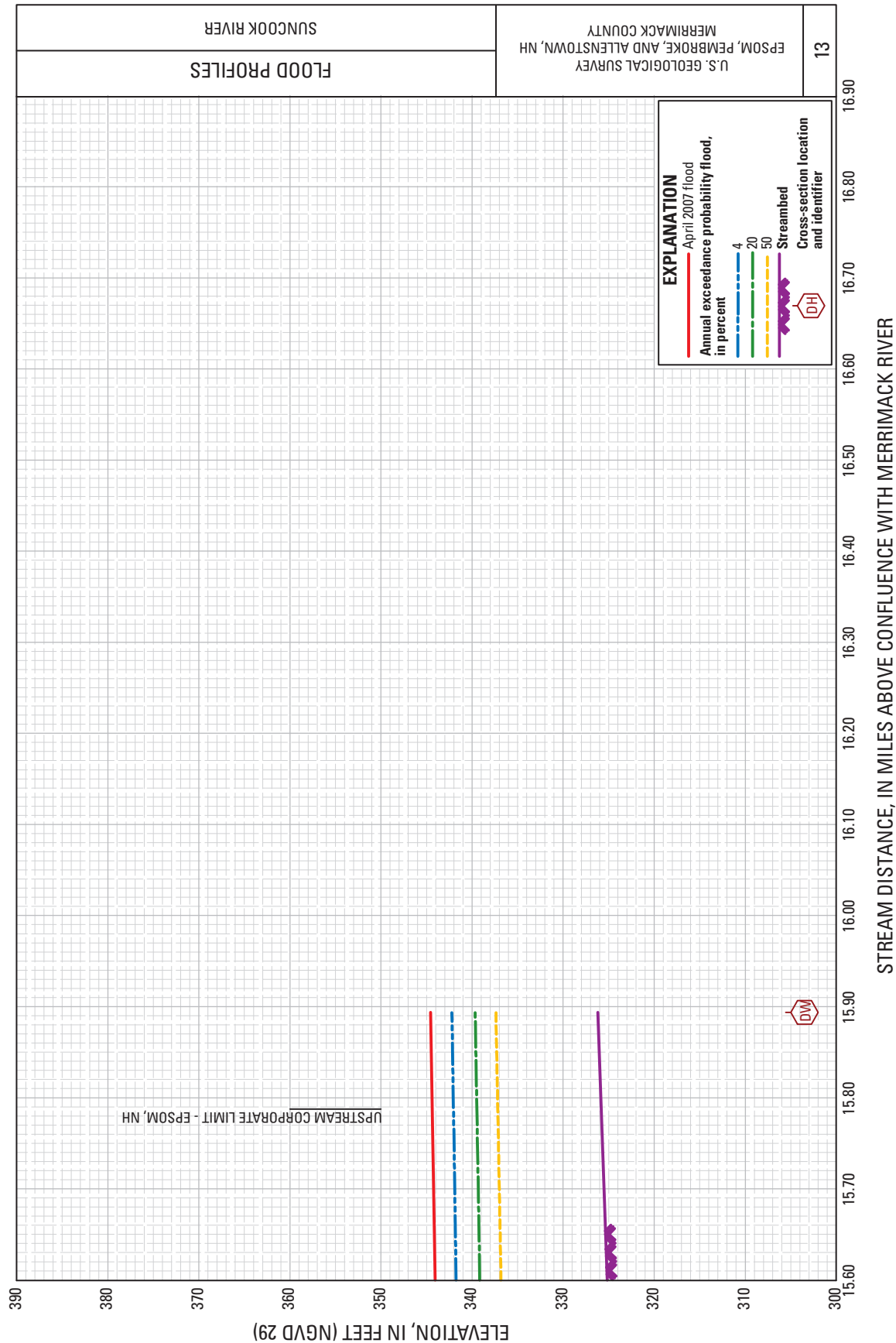


Figure 2-13. Suncook River April 2007 flood and 50-, 20-, and 4-percent chance flood profiles (2-, 5-, and 25-year recurrence-interval floods, respectively) in Epsom, Pembroke, and Allenstown, NH. Most, but not all, locations of cross sections are shown in appendix figure 4-8. Detailed cross-section information shown in table 3.

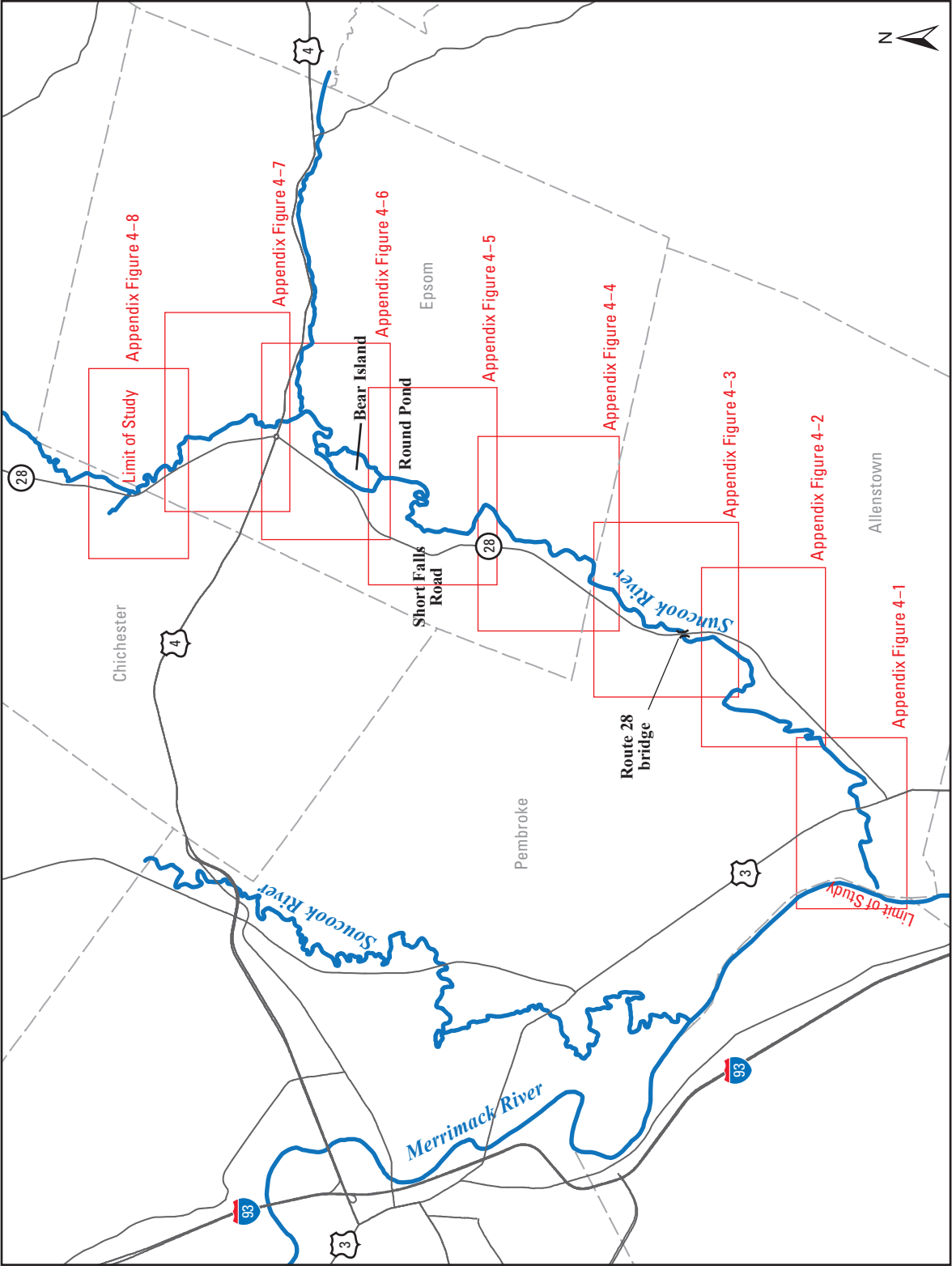
Appendix 3. Elevation Reference Marks

Appendix 3. Elevation reference marks.

[ft, feet; NGVD 29, National Geodetic Vertical Datum of 1929; °, degrees; USCGS, U.S. Coast and Geodetic Survey; USGS, U.S. Geological Survey; NHDPWH, N.H. Department of Public Works and Highways]

Reference mark	Elevation (ft above NGVD 29)	Description of location
D 17 1934 (43° 07' 48" N, 71° 26' 48" W)	283.49	Standard USCGS disk stamped "D 17 1934" and set in the northeast corner of the U.S. Route 3 bridge, 19.0 ft northeast from the center of the road, 4.0 ft northeast from the face of the bridge, and 1.5 ft southeast from the wingwall.
D 18 1934 (43° 08' 30" N, 71° 25' 05" W)	335.42	Standard USCGS disk stamped "D 18 1934" and set into a large outcrop, 10.0 ft below the top of the outcrop and 4.0 ft above the ground, 15.0 ft above River Road. Located 84.0 ft south from a stone wall, 270 ft southeast from the center of River Road, 280 ft southeast from power pole 1½ NYNEX/PSNH/66/96.
D 19 1934 (44° 11' 49" N, 71° 22' 17" W)	354.28	Standard USGS disk stamped "D 19 1934" and set in a 25 × 25 ft partially exposed ledge, 10.0 ft above the road. Located 84.0 ft east-southeast from the center of River Road, 45.0 ft south-southwest from a stonewall, and 103 ft east-northeast from the northeast corner of a white house.
1149-0160 (43° 13' 31.77" N, 71° 21' 44.97" W)	368.09	Standard NHDPWH disk stamped "1149-0160" and set into the top of a 5-ft rock ledge 1.5 ft above the ground, 32.0 ft east from the center of the Rte. 28, 121 ft southwest from power pole CE/3A/CO, 112 ft south-southwest from the center of an iron-covered sewer manhole, 23.0 ft west from the woods line.
TBM 364 364.567 (43° 14' 25" N, 71° 21' 40" W)	364.57	Standard rivet set in an embedded boulder 15.0 ft above an abandoned railroad bed and 3.0 ft above the ground. Located 36.0 ft east from the abandoned railroad bed, approximately 500 ft west of Goboro Road and much lower in a wooded area behind a small field.

Appendix 4. Suncook River Flood Map of the Floodway, and the 100- and 500-Year Flood from the Confluence with the Merrimack River to the Upstream Corporate Limit of Epsom, New Hampshire



Index map to figures in Appendix 4.

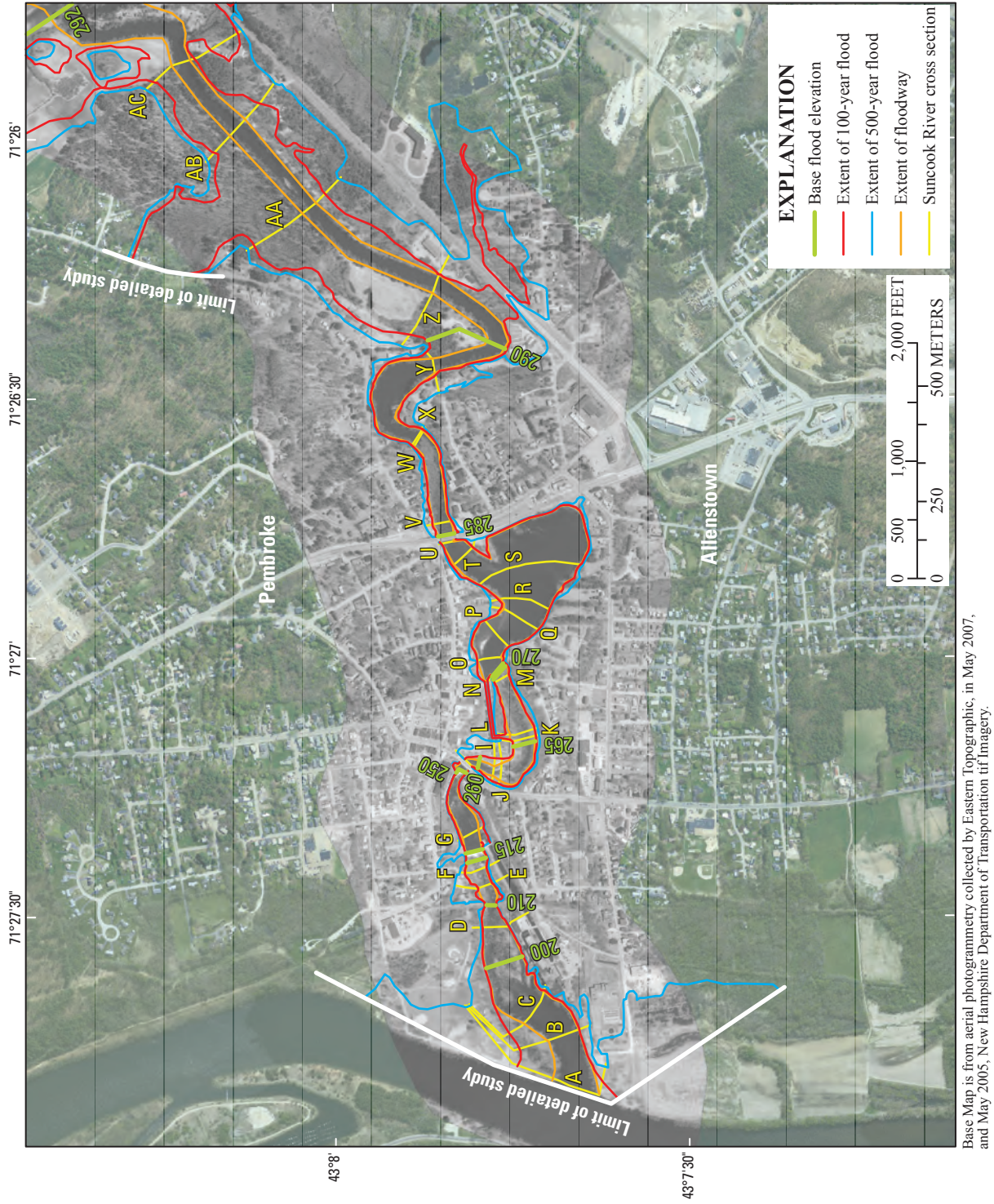


Figure 4-1. Location of base, 500- and 100-year flood elevations and cross sections along the Suncook River in Epsom, Pembroke, and Allenstown, NH. Detailed cross-section information shown in appendix 1 and in tables 2 and 5.

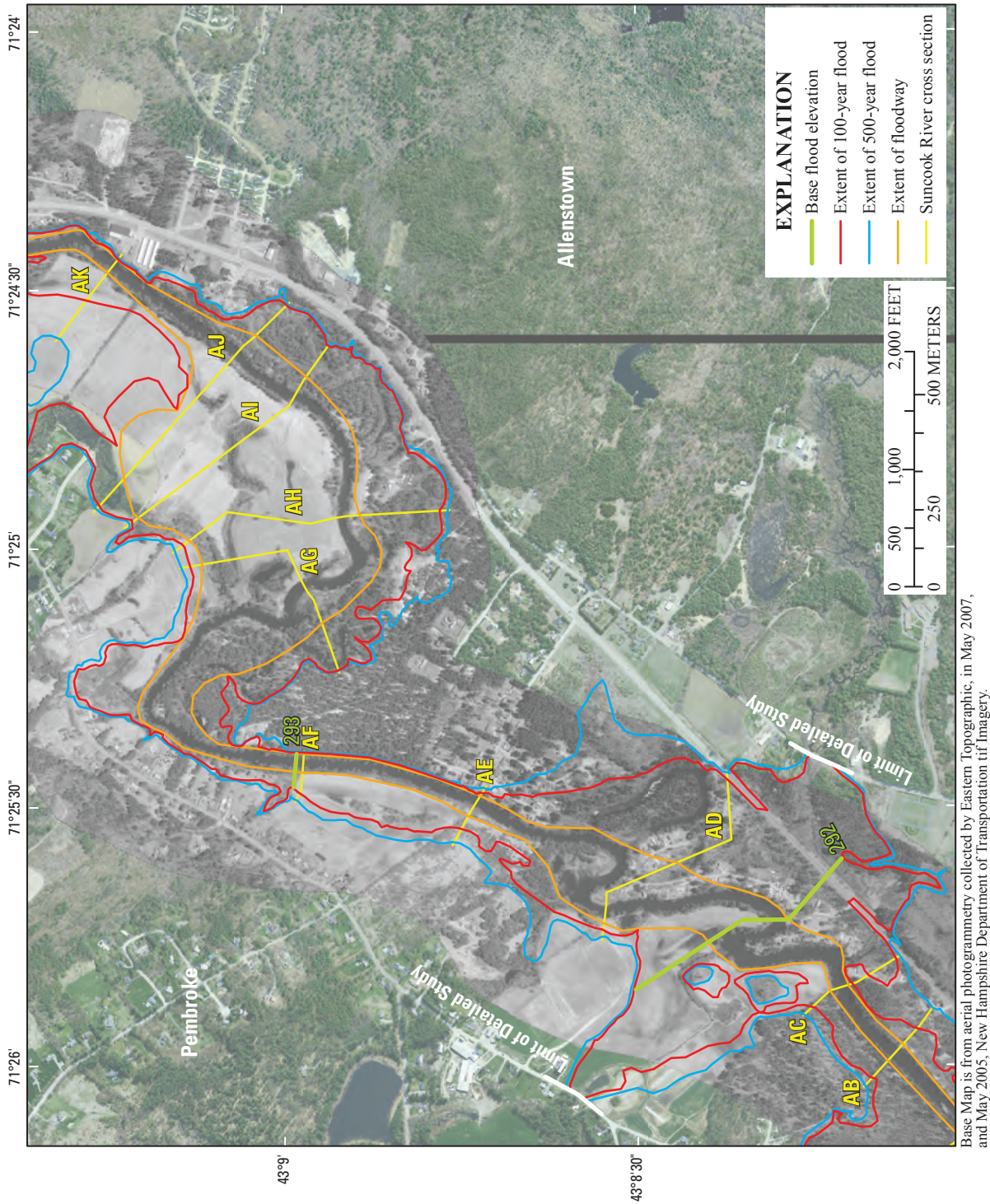


Figure 4-2. Location of base, 500- and 100-year flood elevations and cross sections along the Suncook River in Epsom, Pembroke, and Allenstown, NH. Detailed cross-section information shown in appendix 1 and in tables 2 and 5.

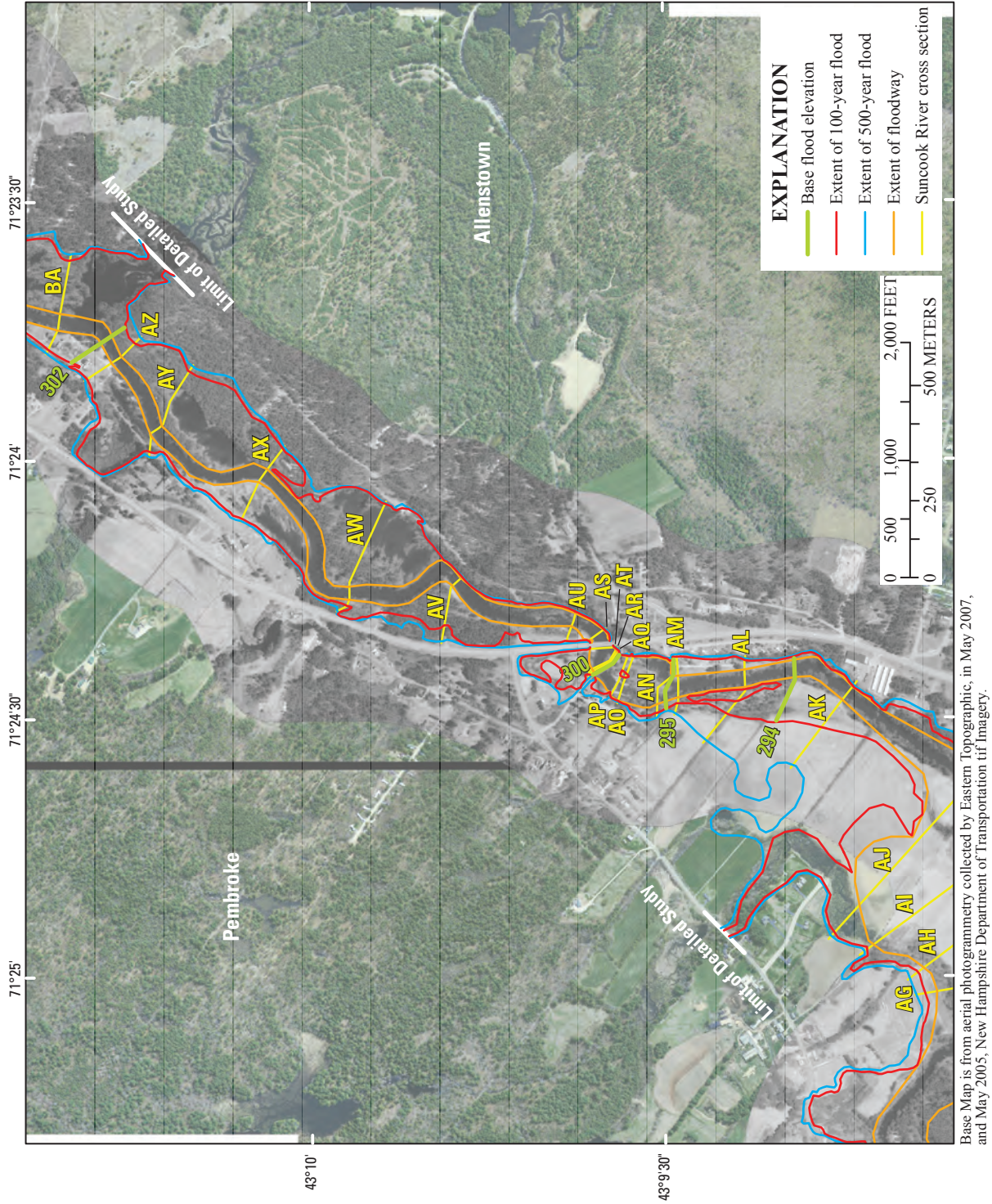


Figure 4-3. Location of base, 500- and 100-year flood elevations and cross sections along the Suncook River in Epsom, Pembroke, and Allenstown, NH. Detailed cross-section information shown in appendix 1 and in tables 2 and 5.

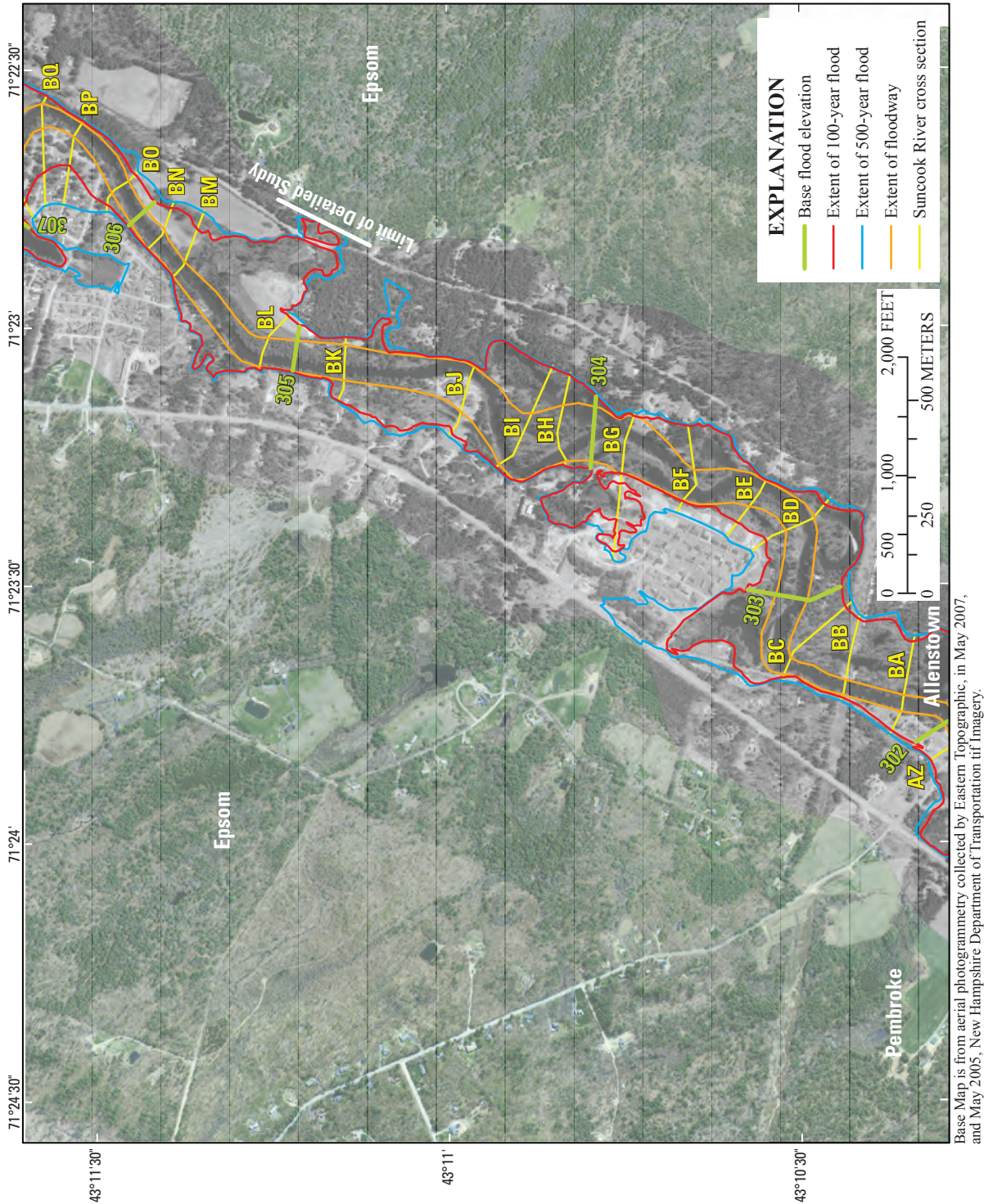
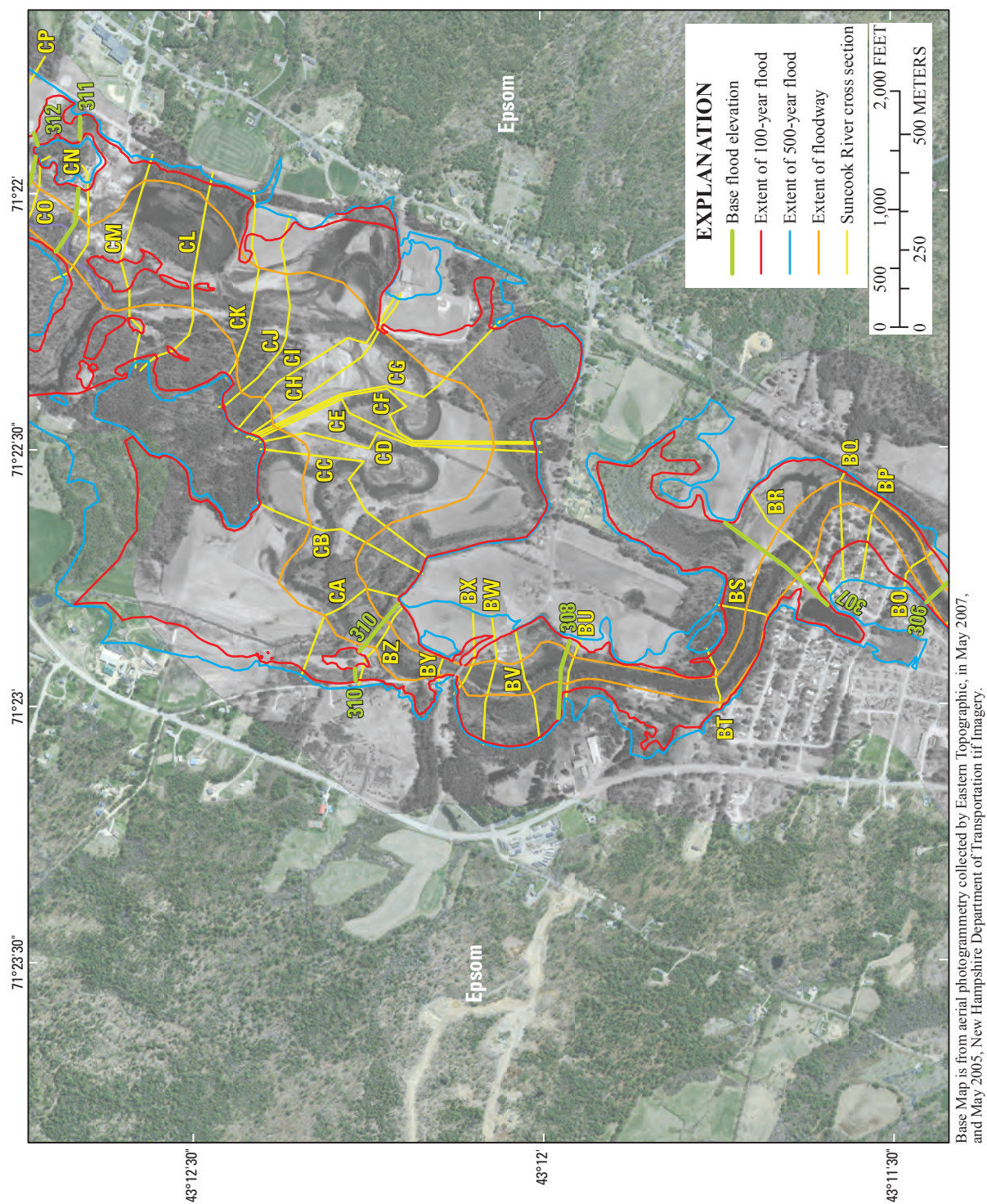


Figure 4-4. Location of base, 500- and 100-year flood elevations and cross sections along the Suncook River in Epsom, Pembroke, and Allenstown, NH. Detailed cross-section information shown in appendix 1 and in tables 2 and 5.



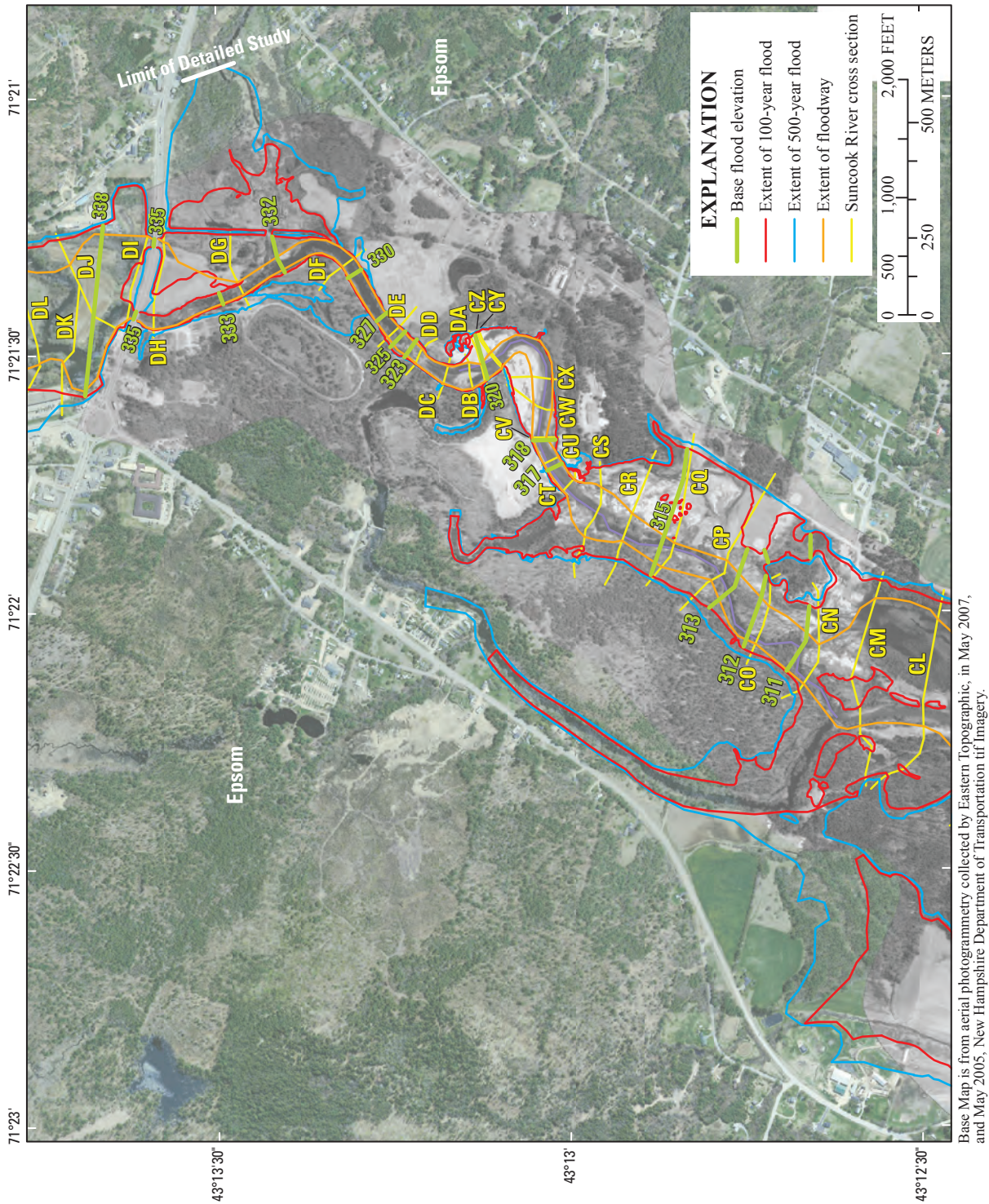


Figure 4-6. Location of base, 500- and 100-year flood elevations and cross sections along the Suncook River in Epsom, Pembroke, and Allenstown, NH. Detailed cross-section information shown in appendix 1 and in tables 2 and 5.

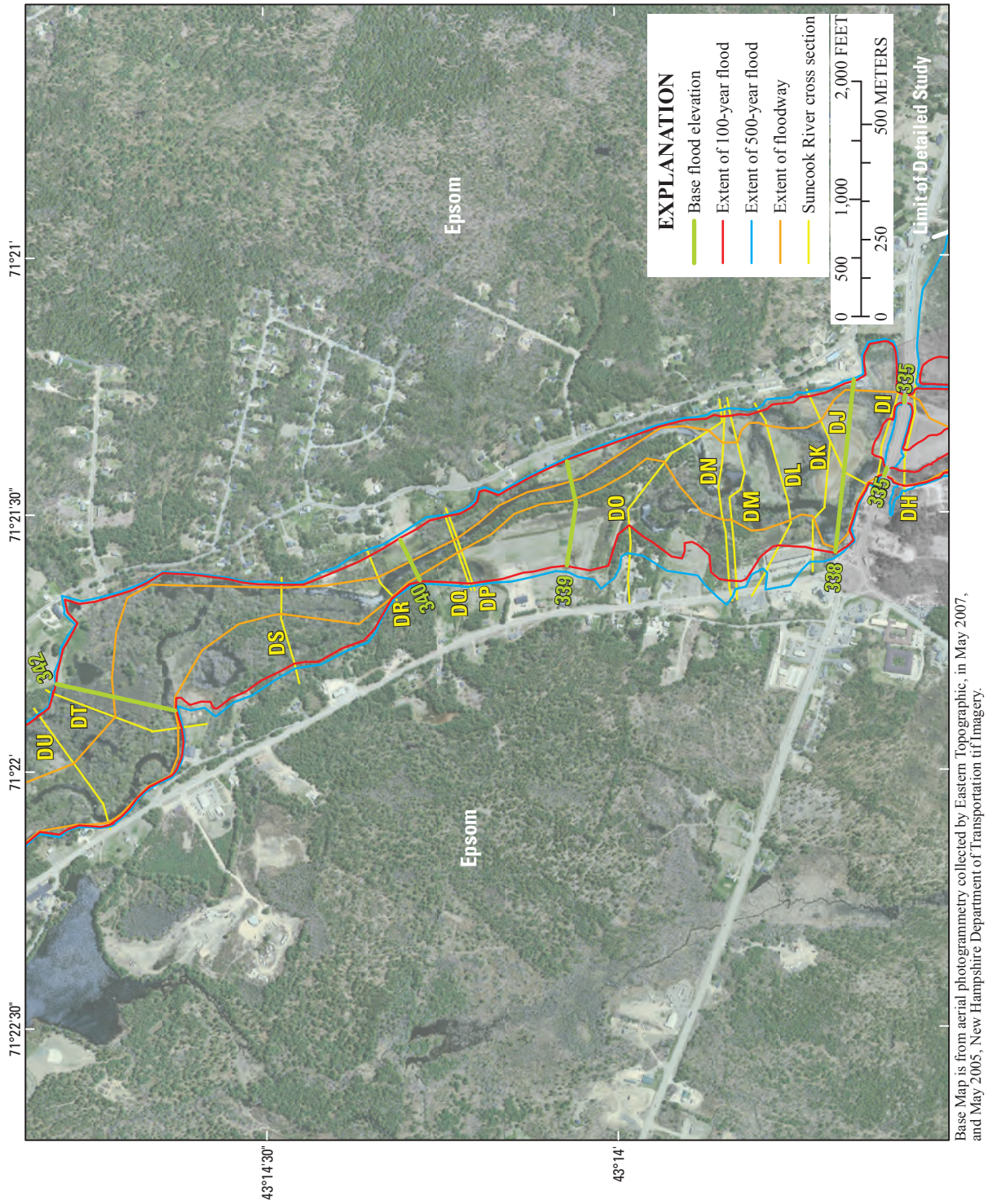


Figure 4-7. Location of base, 500- and 100-year flood elevations and cross sections along the Suncook River in Epsom, Pembroke, and Allenstown, NH. Detailed cross-section information shown in appendix 1 and in tables 2 and 5.

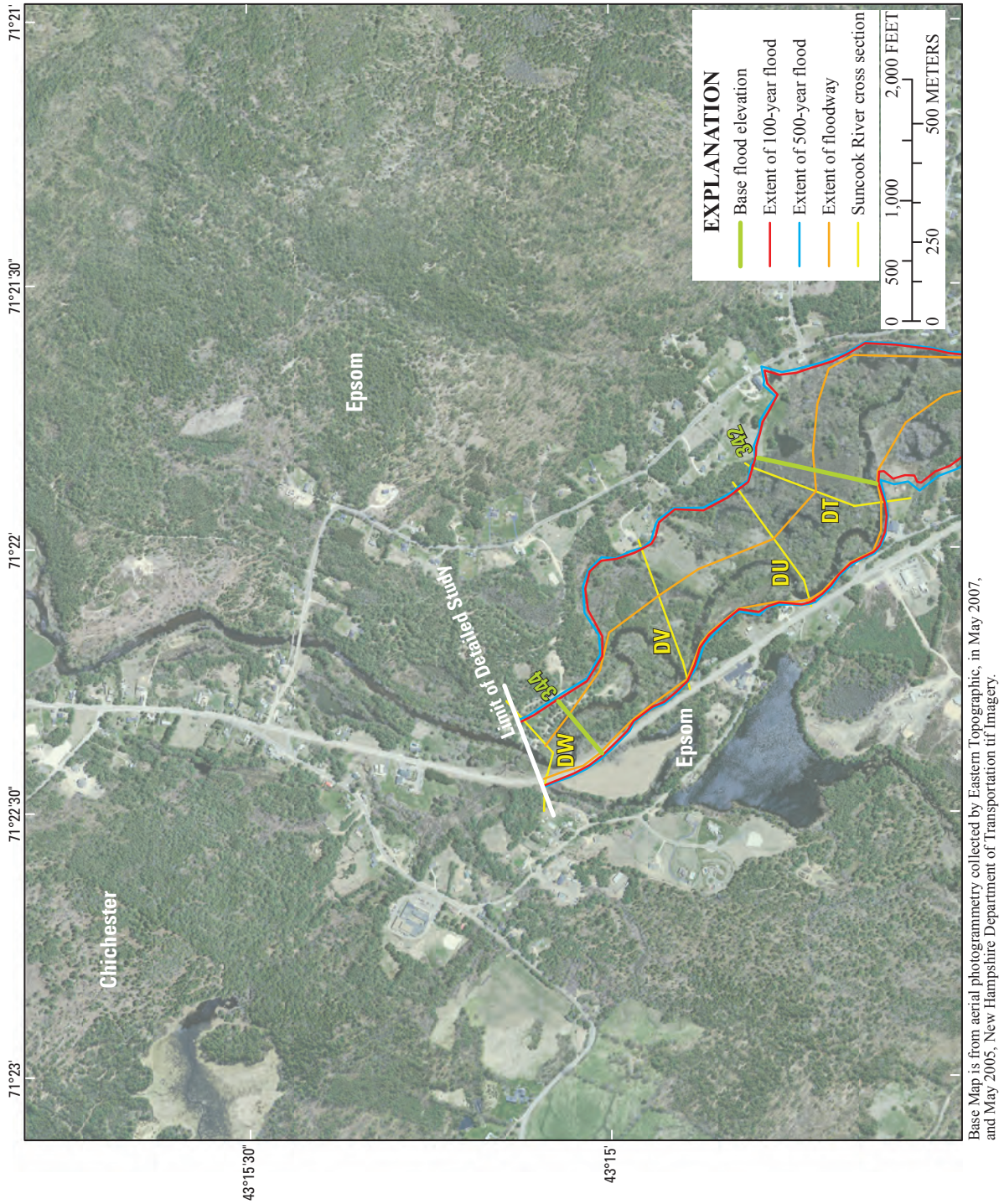


Figure 4-8. Location of base, 500- and 100-year flood elevations and cross sections along the Suncook River in Epsom, Pembroke, and Allenstown, NH. Detailed cross-section information shown in appendix 1 and in tables 2 and 5.

Prepared by the Pembroke Publishing Service Center.

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