In cooperation with the Vermont Agency of Natural Resources
Department of Environmental Conservation

SIMULATION OF THE EFFECTS OF STREAMBED-MANAGEMENT PRACTICES ON FLOOD LEVELS IN VERMONT

INTRODUCTION

On July 14, 1997, an intense rainstorm resulted in rapid runoff and severe flooding in parts of Vermont. During the storm, streambed and streambank erosion and deposition were significant at several locations in the State. Residents in flooded regions questioned whether deposited sediment constricted water flow and elevated the 1997 flood levels. Since 1986, the State of Vermont's policy on streambed management is to restrict the removal of sand and gravel from channels; however, the extent to which the policy affects stream conditions during severe flooding is unknown. To answer this question, a sediment-transport study by the U.S. Geological Survey (USGS), in cooperation with the Vermont Agency of Natural Resources, Department of Environmental Conservation, began in October 1997 to evaluate the potential effect of various streambed-management practices on future flood levels (Olson, 2000).

Three stream reaches that had been affected by the flood of July 1997, and which covered a wide range of basin characteristics common to Vermont, were selected for the study (fig. 1). The reaches selected were a 4.3-mile reach of the Trout River in Montgomery, Vt., a 6.5-mile reach of the Wild Branch in Wolcott, Vt., and the entire 15.4-mile reach of the Lamoille River within Cambridge, Vt.

The BRIdge Stream Tube Model for Alluvial River Simulation (BRI-STARS) (Molinas and Wu, 1997), calibrated with data for the flood of July 14-16, 1997, was used to simulate channel erosion and deposition of the streambed and the peak water-surface profile during a 10- and 100-year flood for three streambed-management practices. The three practices included (1) no removal of streambed material, (2) "scalping", or removing bars and other alluvial streambed materials to increase channel capacity, and (3) dredging the entire streambed channel by 2 feet.

DESCRIPTION OF INVESTIGATED REACHES

The Trout River (fig. 1) flows northwest through Montgomery, Vt., and is an upland stream in the north-central part of the State. Streambed material is primarily gravel and cobbles with some sand and exposed bedrock. Additional characteristics of Trout River and the other studied rivers are listed in table 1.

The Wild Branch (fig. 1) flows south through Wolcott, Vt., in the north-central part of the state, and drains into the Lamoille River. Streambed material ranges from sand to boulders with several areas of exposed bedrock.

The Lamoille River (fig. 1) flows west through Cambridge, Vt., in the northwestern part of the state. Streambed material ranges from silt to coarse gravel with several reaches having some cobbles or exposed bedrock.

SEDIMENT-TRANSPORT MODEL

BRI-STARS is a computer model that routes water through natural river channels and simulates streambed erosion and deposition. Because computer modeling of sediment transport is still in its developmental stages, the ability of models such as BRI-STARS to exactly simulate sediment-transport processes and effects is limited. For example,

Figure 1. Location of river reaches in the study.

computer-based models currently available (1999) do not adequately account for the removal of fine-grained particles by streamflow, which leaves erosion-resistant large-grained particles to protect or armour the stream channel (Richardson and others, 1990). Likewise, stream-bank erosion and the formation of meander bends and bed forms cannot be adequately simulated.

MODEL SIMULATIONS AND (SIMULATION) RESULTS

Streambed-management practices simulated in this study refer only to the removal of streambed-channel materials; bank protection and other channel improvements were not considered. Three streambed-management practices were selected for evaluation. The first practice evaluated was based on current (1999) State policy, which restricts the removal of streambed materials from channels. The second practice evaluated

Table 1. Characteristics of studied reaches of three rivers in Vermont

Characteristic	Trout River	Wild Branch	Lamoille River
Mean channel slope of study reach, in feet per mile	19	40	2.3
Approximate valley elevation at downstream end of study reach, in feet	470	670	460
Drainage area near downstream end of study reach, in square miles	71.6	39.5	520

was based on typical streambed-channel alterations and practices prior to 1986, when the current State policy took effect. Alterations under this practice included removing gravel bars and other features that may constrict flow. The third practice evaluated was based upon the frequent post-flooding argument that entire streambed channels need to be dredged periodically. The BRI-STARS model was used to determine the profile of the peak water surface and the final streambed elevation for a 10-year and a 100-year flood (table 2) in each river that would likely result from implementation of the three practices.

Table 2. Magnitude of flood discharges used in the BRI-STAR simulations for three rivers in Vermont

River	10-year discharge, in cubic feet per second	100-year discharge, in cubic feet per second
Trout River	9,400	18,000
Wild Branch	3,100	6,340
Lamoille River	16,000	29,250

Channel bottoms from flood-insurance studies in effect prior to the 1997 flood are shown in figures 2-4 (Federal Emergency Management Agency, 1980, 1982a,b, and d). Also shown on these figures is the channel bottom after the 1997 flood (post-flood), and the 100-year water-surface profile from a fixed-bed model (Shearman, 1990).

Modeled water-surface and streambed-elevation profiles of the three study reaches for the 100-year flood are shown in figures 5-7. These profiles show the streambed profile as surveyed following the flood of 1997, and the corresponding 100-year water-surface elevation. Results from the BRI-STARS model simulations also are shown on these profiles and include the streambed elevation following a 100-year flood and the peak water-surface elevation during a 100-year flood for the three streambed-management practices.

For the Trout and Lamoille Rivers BRI-STARS model simulations, the average water-surface elevation decreased when streambed materials were removed; however, simulations did not show the same average decrease in water-surface elevations for the Wild Branch (table 3). Furthermore, flooding actually increased in some reaches of the maintained or dredged channels. This is because the dredged channel has a greater capacity to convey water and, in turn, transport sediment. The increase in sediment-transport capacity results in greater potential for erosion and deposition. Respective changes to the water-surface profile occur as the channel adjusts to re-establish equilibrium (Richardson and others, 1990). Simulations also showed increased streambed erosion beneath bridges following dredging.

Resulting water-surface elevations from BRI-STARS simulations also indicated that channel configuration has a greater effect on the water-surface elevation of a small flood such as a 10-year event than on a large flood such as a 100-year event or the 1997 flood. This result was expected because a large portion of the flood waters flow on the flood plains during a high flood regardless of the condition of the stream channel.

The model used in this study provides information on the short-term effect of streambed-management practices on the water-surface profile during a flood and on the streambed-elevation profile following a flood. The management practices evaluated in this study may have local effects on flooding, erosion, and deposition that are beyond the scope of this study. Investigations of streambed-channel stability by the Center for Watershed Protection (1999) and Rosgen (1996) have documented that containment of high flows within the channel increased erosion rates, generated large volumes of sediment, and ultimately reduced channel capacity.

—By Scott A. Olson

Table 3. Model-simulated changes in peak water-surface elevations resulting from alterations to channels of three rivers in Vermont

[All measurements are in feet; - indicates a decrease; and + indicates an increase in water-surface elevation compared to that in simulation of unaltered channel]

Channel alteration	Trout River			Lamoille River			Wild Branch		
	Minimum	Mean	Maximum	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Bars and obstructions removed, 10-year flood	-1.0	-0.1	+0.2	-0.2	-0.1	0	-2.0	+0.1	+3.8
Bars and obstructions removed, 100-year flood	-2.7	-0.2	+0.4	-0.1	-0.1	0	-3.8	0	+2.1
Channel dredged, 10-year flood	-4.7	-1.5	+1.1	-2.6	-1.4	0	-3.6	0	+4.2
Channel dredged, 100-year flood	-4.8	-1.1	+0.1	-1.7	-1.0	0	-3.1	-0.5	+2.2

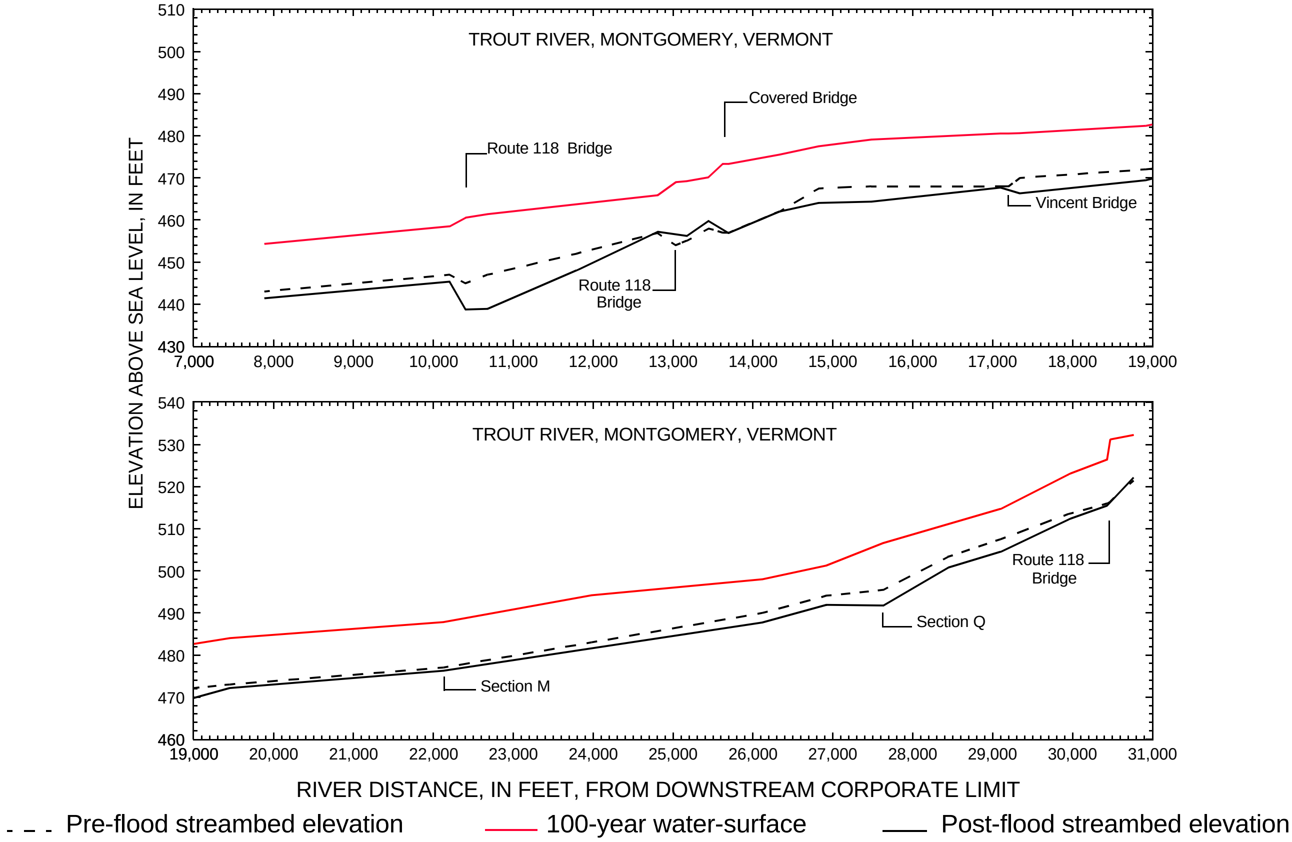


Figure 2. Pre-flood 1997 streambed and 100-year water-surface profiles from flood-insurance study and post-flood 1997 streambed profiles of the Trout River.

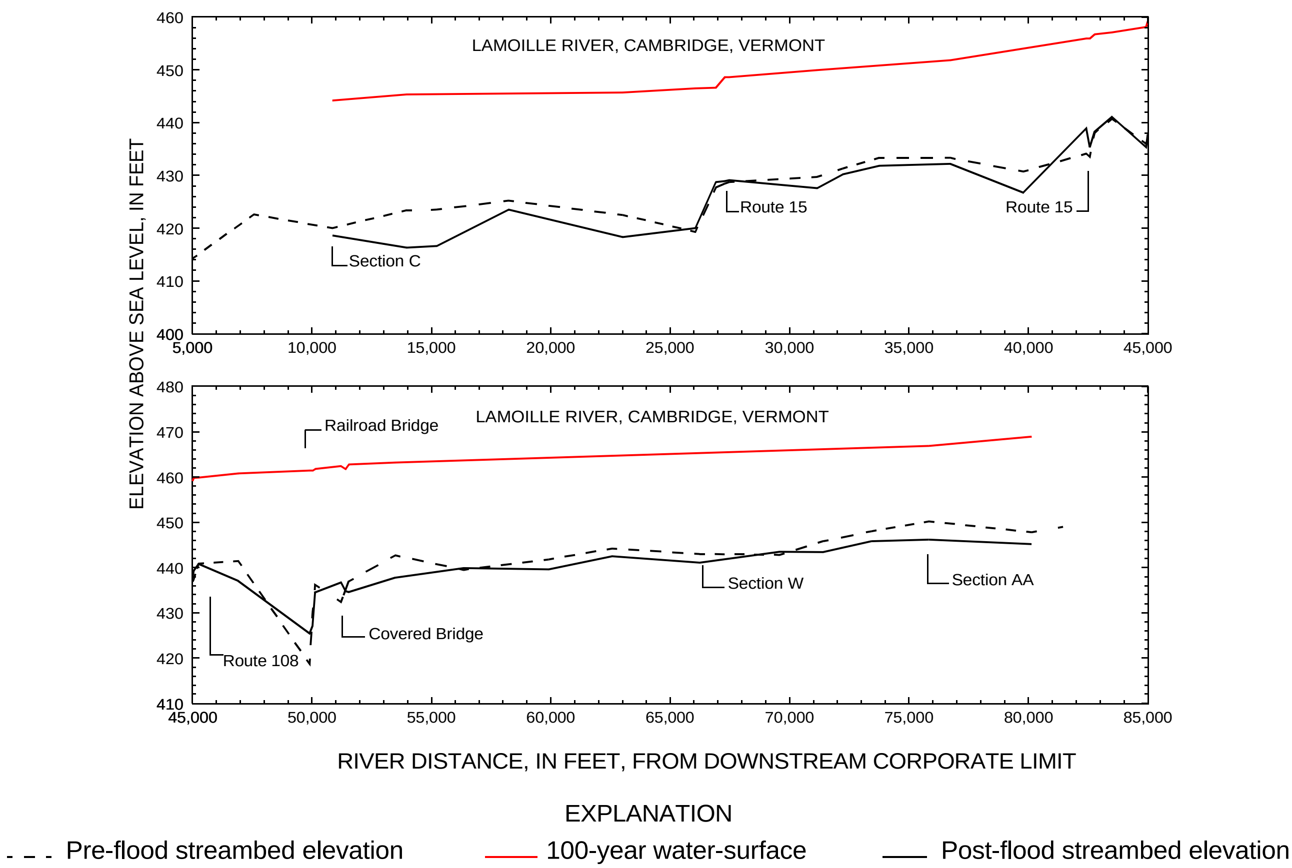


Figure 3. Pre-flood 1997 streambed and 100-year water-surface profiles from flood-insurance study and post-flood 1997 streambed profiles of the Lamoille River.

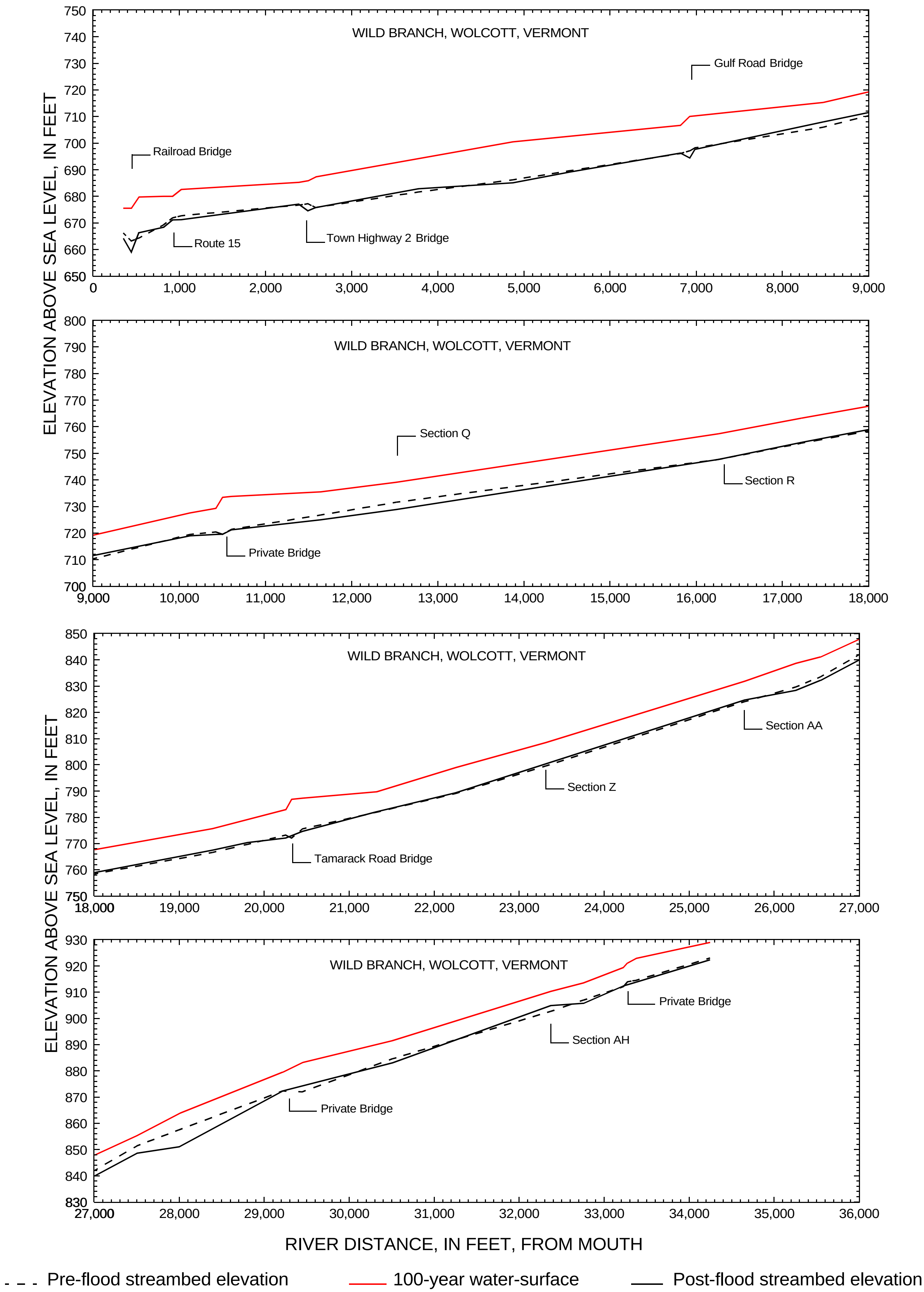
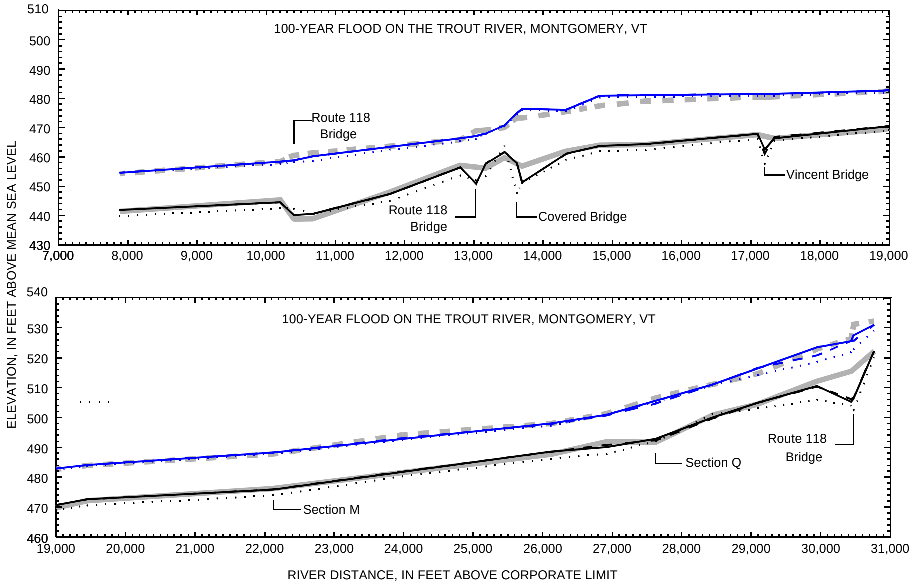


Figure 4. Pre-flood 1997 streambed and 100-year water-surface profile from flood-insurance study and post-flood 1997 streambed profile of the Wild Branch.



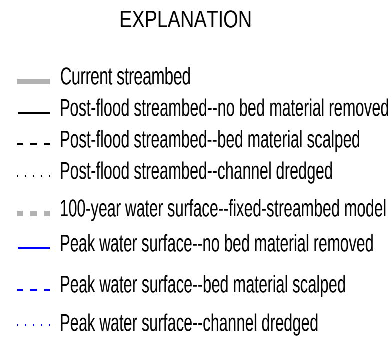
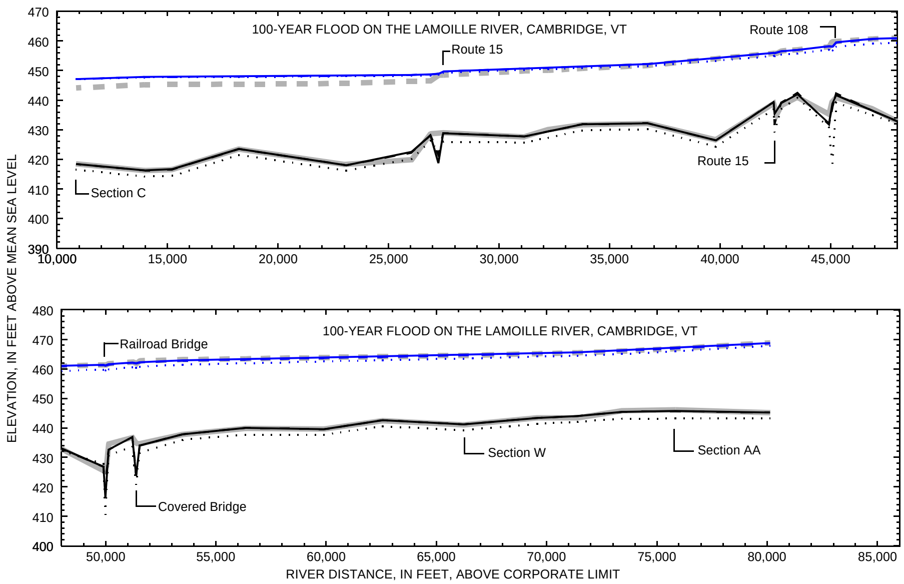


Figure 5. Simulated results of water-surface and streambed-elevation profiles of the modeled reach of the Trout River.



Figures 6. Simulated results of water-surface and streambed-elevation profiles of the modeled reach of the Lamoille River.

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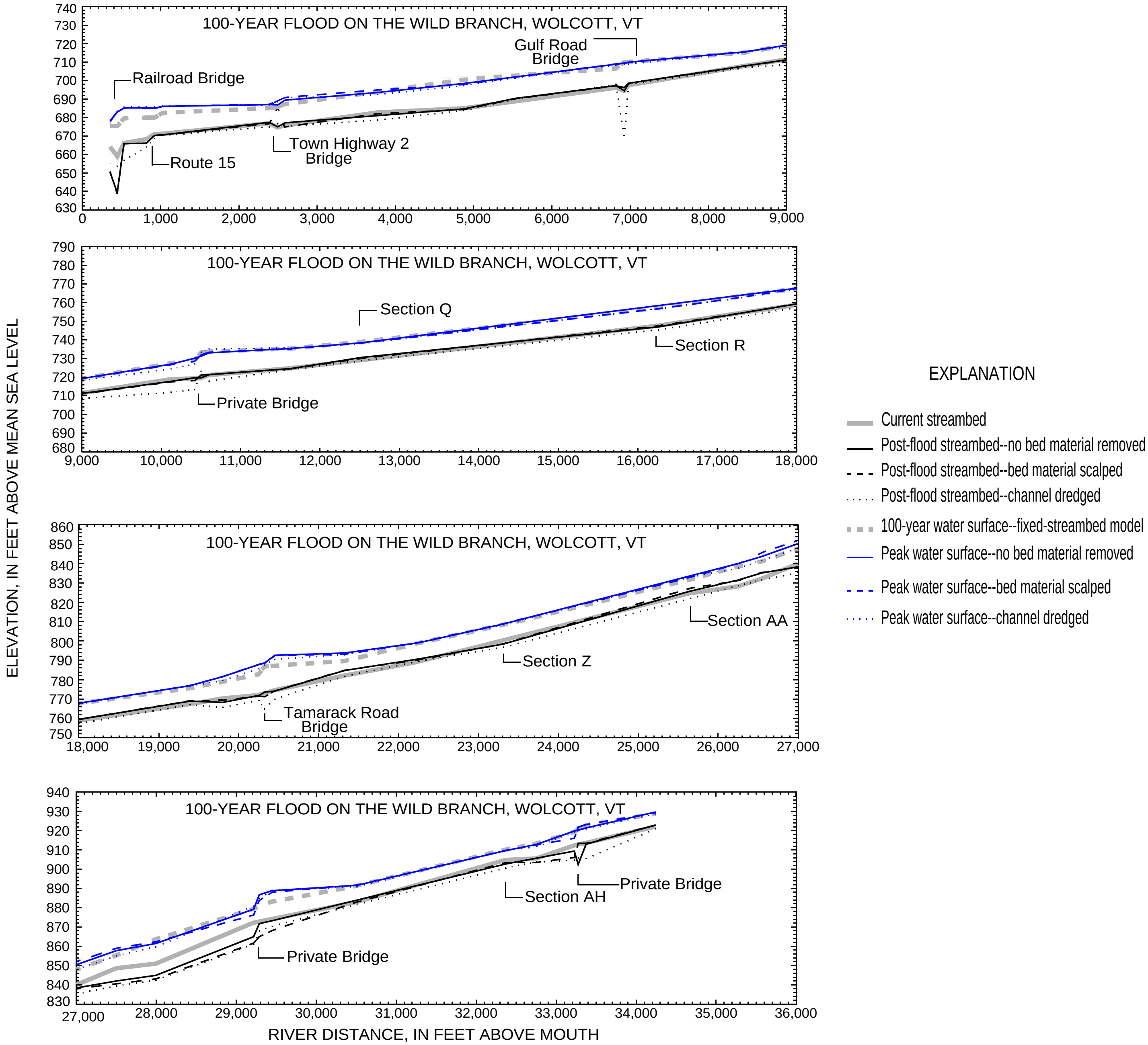

Figure 7. Simulated results of water-surface and streambed-elevation profiles of the modeled reach of the Wild Branch.

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