LEVEL II SCOUR ANALYSIS FOR BRIDGE 39 (RANDTH00730039) on TOWN HIGHWAY 73, crossing the SECOND BRANCH WHITE RIVER, RANDOLPH, VERMONT

By DONALD L. SONG and MICHAEL A. IVANOFF

U.S. Geological Survey
Open-File Report 96-234

Prepared in cooperation with
VERMONT AGENCY OF TRANSPORTATION
and
FEDERAL HIGHWAY ADMINISTRATION

Pembroke, New Hampshire
1996
CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

<table>
<thead>
<tr>
<th>Multiply</th>
<th>By</th>
<th>To obtain</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Length</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>inch (in.)</td>
<td>25.4</td>
<td>millimeter (mm)</td>
</tr>
<tr>
<td>foot (ft)</td>
<td>0.3048</td>
<td>meter (m)</td>
</tr>
<tr>
<td>mile (mi)</td>
<td>1.609</td>
<td>kilometer (km)</td>
</tr>
<tr>
<td><strong>Slope</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>foot per mile (ft/mi)</td>
<td>0.1894</td>
<td>meter per kilometer (m/km)</td>
</tr>
<tr>
<td><strong>Area</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>square mile (mi²)</td>
<td>2.590</td>
<td>square kilometer (km²)</td>
</tr>
<tr>
<td><strong>Volume</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cubic foot (ft³)</td>
<td>0.02832</td>
<td>cubic meter (m³)</td>
</tr>
<tr>
<td><strong>Velocity and Flow</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>foot per second (ft/s)</td>
<td>0.3048</td>
<td>meter per second (m/s)</td>
</tr>
<tr>
<td>cubic foot per second (ft³/s)</td>
<td>0.02832</td>
<td>cubic meter per second (m³/s)</td>
</tr>
<tr>
<td>cubic foot per second per square mile ([ft³/s]/mi²)</td>
<td>0.01093</td>
<td>cubic meter per second per square kilometer ([m³/s]/km²)</td>
</tr>
</tbody>
</table>

**OTHER ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF</td>
<td>bank full</td>
<td>LWW</td>
<td>left wingwall</td>
</tr>
<tr>
<td>cfs</td>
<td>cubic feet per second</td>
<td>MC</td>
<td>main channel</td>
</tr>
<tr>
<td>D₅₀</td>
<td>median diameter of bed material</td>
<td>RAB</td>
<td>right abutment</td>
</tr>
<tr>
<td>DS</td>
<td>downstream</td>
<td>RABUT</td>
<td>face of right abutment</td>
</tr>
<tr>
<td>elev.</td>
<td>elevation</td>
<td>RB</td>
<td>right bank</td>
</tr>
<tr>
<td>f/p</td>
<td>flood plain</td>
<td>ROB</td>
<td>right overbank</td>
</tr>
<tr>
<td>ft²</td>
<td>square feet</td>
<td>RWW</td>
<td>right wingwall</td>
</tr>
<tr>
<td>ft/ft</td>
<td>feet per foot</td>
<td>TH</td>
<td>town highway</td>
</tr>
<tr>
<td>JCT</td>
<td>junction</td>
<td>UB</td>
<td>under bridge</td>
</tr>
<tr>
<td>LAB</td>
<td>left abutment</td>
<td>US</td>
<td>upstream</td>
</tr>
<tr>
<td>LABUT</td>
<td>face of left abutment</td>
<td>USGS</td>
<td>United States Geological Survey</td>
</tr>
<tr>
<td>LB</td>
<td>left bank</td>
<td>VTAOT</td>
<td>Vermont Agency of Transportation</td>
</tr>
<tr>
<td>LOB</td>
<td>left overbank</td>
<td>WSPRO</td>
<td>water-surface profile model</td>
</tr>
</tbody>
</table>

In this report, the words “right” and “left” refer to directions that would be reported by an observer facing downstream.

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

In the appendices, the above abbreviations may be combined. For example, USLB would represent upstream left bank.
LEVEL II SCOUR ANALYSIS FOR BRIDGE 39 (RANDTH00730039) ON TOWN HIGHWAY 73, CROSSING THE SECOND BRANCH WHITE RIVER, RANDOLPH, VERMONT

By Donald L. Song and Michael A. Ivanoff

INTRODUCTION

This report provides the results of a detailed Level II analysis of scour potential at structure RANDTH00730039 on town highway 73 crossing the Second Branch White River, Randolph, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). A Level I study is included in Appendix E of this report. A Level I study provides a qualitative geomorphic characterization of the study site. Information on the bridge available from VTAOT files was compiled prior to conducting Level I and Level II analyses and can be found in Appendix D.

The site is in the Green Mountain physiographic province of central Vermont in the town of Randolph. The 53.7-mi² drainage area is in a predominantly rural basin. In the vicinity of the study site, the overbanks are covered by pasture except for the upstream right bank which is covered by brush.

In the study area, the Second Branch White River has a meandering channel with a slope of approximately 0.001 ft/ft, an average channel top width of 44 ft and an average channel depth of 6 ft. The predominant channel bed material is sand with median grain size ($D_{50}$) of 0.884 mm (0.0029 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 12, 1994, indicated that the reach was laterally unstable. This is because of severe cut-banks both upstream and downstream where mass wasting and block failure of bank material is evident. Furthermore, minimal erosion protection is provided by bank vegetation since woody vegetation cover is sparse.

The town highway 73 crossing of the Second Branch White River is a 42-ft-long, one-lane bridge consisting of one 40-foot span (Vermont Agency of Transportation, written communication, August 2, 1994). The bridge is supported by vertical, concrete abutments with wingwalls. The ends of the upstream left wingwall and the downstream right wingwall are protected by stone fill. However, this stone fill is slumping according to the Level I field inspection. The channel is skewed approximately 30 degrees to the opening while the opening-skew-to-roadway is 0 degrees. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.
Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1993). Total scour at a highway crossing is comprised of three components: 1) long-term aggradation or degradation; 2) contraction scour (due to reduction in flow area caused by a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute scour depths for contraction and local scour and a summary of the results follows.

Contraction scour for all modelled flows ranged from 1.9 ft to 4.6 ft and the worst-case contraction scour occurred at the incipient overtopping discharge. Abutment scour ranged from 4.0 ft to 22.5 ft and the worst-case abutment scour occurred at the 500-year discharge. Scour depths and depths to armoring are summarized on p. 14 in the section titled “Scour Results”. Scour elevations, based on the calculated depths are presented in tables 1 and 2; a graph of the scour elevations is presented in figure 8 Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

For all scour presented in this report, “the scour depths adopted [by VTAOT] may differ from the equation values based on engineering judgement” (Richardson and others, 1993, p. 21, 27). It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and others, 1993, p. 48). Many factors, including historical performance during flood events, the geomorphic assessment, and the results of the hydraulic analyses, must be considered to properly assess the validity of abutment scour results.
Figure 1. Location of study area on USGS 1:24,000 scale map.
Figure 2. Location of study area on Vermont Agency of Transportation town highway map.
## Structure Number
RANDTH00730039

## Stream
Second Branch White River

### County
Orange

### Road
TH073

### District
04

### Description of Bridge

<table>
<thead>
<tr>
<th>Bridge length</th>
<th>ft</th>
<th>Bridge width</th>
<th>ft</th>
<th>Max span length</th>
<th>ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
<td></td>
<td>12.8</td>
<td></td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

### Alignment of bridge to road (on curve or straight)
straight

### Abutment type
cement

### Embankment type
vertical

### Stone fill on abutment?
no

### Date of inspection
08/12/94

### Description of stone fill
type II stone fill (less than 36 inches diameter) at ends of the upstream
left wingwall and downstream right wingwall. This stone fill was reported as slumped.

Abutments are concrete with wingwalls.

<table>
<thead>
<tr>
<th>Is bridge skewed to flood flow according to Mode' survey?</th>
<th>Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>30</td>
</tr>
</tbody>
</table>

### Debris accumulation on bridge at time of Level I or Level II site visit:

<table>
<thead>
<tr>
<th>Date of inspection</th>
<th>Percent of channel blocked horizontally</th>
<th>Percent of channel blocked vertically</th>
</tr>
</thead>
<tbody>
<tr>
<td>08/12/94</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Level I**

same

**Level II**

Moderate, due to trees on the unstable banks.

### Potential for debris

August 12, 1994: The left abutment protrudes into the low-water channel. The floodplain at this
Description of the Geomorphic Setting

General topography: The bridge is in an approximately 200-300 ft-wide, flat valley over a meandering stream.

Geomorphic conditions at bridge site: downstream (DS), upstream (US)

Date of inspection: 08/12/94

| DS left: | wide flood plain to steep valley wall |
| DS right: | narrow flood plain to moderately steep valley wall |
| US left: | wide flood plain to steep valley wall |
| US right: | steep valley wall |

Description of the Channel

| Average top width | 44 | ft |
| Predominant bed material | sand |
| Average depth | 6.0 | ft |
| Predominant bed material | silty sand |
| Bank material | meandering, with |

wide flood plains. It is alluvial and laterally unstable

Vegetative cover on channel banks near bridge:

| DS left: | pasture |
| DS right: | pasture |
| US left: | scattered brush and some trees |
| US right: | N |

Do banks appear stable? 08/12/94--Heavy fluvial erosion has occurred on the banks both upstream and downstream. Several bank “block failures” were observed.

Do banks appear stable? 08/12/94--Heavy fluvial erosion has occurred on the banks both upstream and downstream. Several bank “block failures” were observed.

On 08/12/94, there were several scattered logs in the channel within the reach. This debris was not obstructing flow at the time of the inspection.

Describe any obstructions in channel and date of observation.
Drainage area 53.7 mi²

Percentage of drainage area in physiographic provinces: (approximate)

<table>
<thead>
<tr>
<th>Physiographic province</th>
<th>Percent of drainage area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Green Mountain</td>
<td>100</td>
</tr>
</tbody>
</table>

Is drainage area considered rural or urban? Rural

Describe any significant urbanization:

Is there a USGS gage on the stream of interest? No

USGS gage description --

USGS gage number --

Gage drainage area -- mi²

Is there a lake/pond that will significantly affect hydrology/hydraulics? No

Calculated Discharges

<table>
<thead>
<tr>
<th>Q100</th>
<th>ft³/s</th>
<th>Q500</th>
<th>ft³/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>7,910</td>
<td></td>
<td>11,100</td>
<td></td>
</tr>
</tbody>
</table>

The 100-yr discharge was determined from a drainage area relationship \([(53.7/46.0)^{0.7}] \) with an upstream site. The upstream site had a drainage area of 46 square miles and a 100-yr discharge, determined from a previous study, of 7100 cfs. (Landry, D., oral communication, March 1995). The 500-yr discharge was determined in the same manner after the 500-yr discharge from the upstream site was found by extrapolating available flood frequency estimates graphically. Incipient road overflow discharge was determined to be 1,880 cfs.
Description of the Water-Surface Profile Model (WSPRO) Analysis

Datum for WSPRO analysis (USGS survey, sea level, VTAOT plans)  USGS survey

Datum tie between USGS survey and VTAOT plans  N/A

Description of reference marks used to determine USGS datum.  RM1 is the center of a chiseled “L” in the top of the downstream end of the left abutment; the arbitrary survey elevation is 497.79 feet.

Cross-Sections Used in WSPRO Analysis

<table>
<thead>
<tr>
<th>Cross-section</th>
<th>Section Reference Distance (SRD) in feet</th>
<th>2Cross-section development</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXITX</td>
<td>0</td>
<td>1</td>
<td>Exit section</td>
</tr>
<tr>
<td>FULLV</td>
<td>23</td>
<td>2</td>
<td>Downstream Full-valley section (Templated from EXITX)</td>
</tr>
<tr>
<td>BRIDG</td>
<td>23</td>
<td>1</td>
<td>Bridge section</td>
</tr>
<tr>
<td>RDWAY</td>
<td>29.5</td>
<td>1</td>
<td>Road Grade section</td>
</tr>
<tr>
<td>APPRO</td>
<td>81</td>
<td>1</td>
<td>Approach section</td>
</tr>
</tbody>
</table>

1 For location of cross-sections see plan-view sketch included with Level I field form, Appendix E. For more detail on how cross-sections were developed see WSPRO input file.
Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration’s WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analysis reported herein reflects conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, Appendix B, and figure 7.

Channel roughness factors (Manning’s “n”) used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement, Jr. and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel “n” values for the reach ranged from 0.035 to 0.043, and overbank “n” values ranged from 0.035 to 0.046.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the User’s manual for WSPRO (Shearman, 1990). The slope used was 0.0008 ft/ft which was measured from water-surface profiles for the Second Branch White River in the Flood Insurance Study for the Town of Randolph (Federal Emergency Management Agency, 1991).
### Bridge Hydraulics Summary

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average bridge embankment elevation</td>
<td>497.5 ft</td>
</tr>
<tr>
<td>Average low steel elevation</td>
<td>494.9 ft</td>
</tr>
<tr>
<td>100-year discharge</td>
<td>7,910 ft³/s</td>
</tr>
<tr>
<td>Water-surface elevation in bridge opening</td>
<td>495.0 ft</td>
</tr>
<tr>
<td>Road overtopping? Y</td>
<td>Discharge over road 5,506 ft³/s</td>
</tr>
<tr>
<td>Area of flow in bridge opening</td>
<td>296 ft²</td>
</tr>
<tr>
<td>Average velocity in bridge opening</td>
<td>8.1 ft/s</td>
</tr>
<tr>
<td>Maximum WSPRO tube velocity at bridge</td>
<td>9.4 ft/s</td>
</tr>
<tr>
<td>Water-surface elevation at Approach section with bridge</td>
<td>498.6 ft</td>
</tr>
<tr>
<td>Water-surface elevation at Approach section without bridge</td>
<td>497.3 ft</td>
</tr>
<tr>
<td>Amount of backwater caused by bridge</td>
<td>1.5 ft</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>500-year discharge</td>
<td>11,100 ft³/s</td>
</tr>
<tr>
<td>Water-surface elevation in bridge opening</td>
<td>495.0 ft</td>
</tr>
<tr>
<td>Road overtopping? Y</td>
<td>Discharge over road 8,950 ft³/s</td>
</tr>
<tr>
<td>Area of flow in bridge opening</td>
<td>296 ft²</td>
</tr>
<tr>
<td>Average velocity in bridge opening</td>
<td>7.8 ft/s</td>
</tr>
<tr>
<td>Maximum WSPRO tube velocity at bridge</td>
<td>9.1 ft/s</td>
</tr>
<tr>
<td>Water-surface elevation at Approach section with bridge</td>
<td>499.6 ft</td>
</tr>
<tr>
<td>Water-surface elevation at Approach section without bridge</td>
<td>498.3 ft</td>
</tr>
<tr>
<td>Amount of backwater caused by bridge</td>
<td>1.3 ft</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incipient overtopping discharge</td>
<td>1,876 ft³/s</td>
</tr>
<tr>
<td>Water-surface elevation in bridge opening</td>
<td>493.4 ft</td>
</tr>
<tr>
<td>Area of flow in bridge opening</td>
<td>248 ft²</td>
</tr>
<tr>
<td>Average velocity in bridge opening</td>
<td>7.6 ft/s</td>
</tr>
<tr>
<td>Maximum WSPRO tube velocity at bridge</td>
<td>9.2 ft/s</td>
</tr>
<tr>
<td>Water-surface elevation at Approach section with bridge</td>
<td>494.3 ft</td>
</tr>
<tr>
<td>Water-surface elevation at Approach section without bridge</td>
<td>493.8 ft</td>
</tr>
<tr>
<td>Amount of backwater caused by bridge</td>
<td>0.5 ft</td>
</tr>
</tbody>
</table>
Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1993). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour was computed by use of the live-bed contraction scour equation (Richardson and others, 1993, p. 33, equation 16). For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour. The 100-year and 500-year discharges resulted in submerged orifice flow. The results of Chang’s contraction scour (Richardson and others, 1995, p. 145-146) for these two events were also computed and can be found in appendix F. Because the Chang equation for pressure flow scour was derived solely with data for clear-water scour, it is not currently understood how well it would predict in live-bed conditions. Therefore, although pressure flow conditions exist for the 100-year and 500-year flows, the reported scour depths were computed using Laursen’s live-bed contraction scour equation.

Abutment scour for the right abutment was computed by use of the Froehlich equation (Richardson and others, 1993, p. 49, equation 24). The Froehlich equation gives “excessively conservative estimates of scour depths” (Richardson and others, 1993, p. 48). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour at the left abutment was computed by use of the HIRE equation (Richardson and others, 1993, p. 50, equation 25) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.
### Scour Results

<table>
<thead>
<tr>
<th>Contraction scour:</th>
<th>100-yr discharge</th>
<th>500-yr discharge</th>
<th>Incipient overtopping discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(Scour depths in feet)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Main channel</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Live-bed scour</td>
<td>3.3</td>
<td>1.9</td>
<td>4.6</td>
</tr>
<tr>
<td>Clear-water scour</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Depth to armoring</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Left overbank</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Right overbank</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Local scour:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abutment scour</td>
<td>5.9</td>
<td>6.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Left abutment</td>
<td>19.7-</td>
<td>22.5-</td>
<td>10.3-</td>
</tr>
<tr>
<td>Right abutment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pier scour</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Pier 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pier 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pier 3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Rock Riprap Sizing

<table>
<thead>
<tr>
<th>Rock Riprap Sizing</th>
<th>Incipient overtopping discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100-yr discharge</td>
</tr>
<tr>
<td></td>
<td>(D_{50} in feet)</td>
</tr>
<tr>
<td><strong>Abutments:</strong></td>
<td></td>
</tr>
<tr>
<td>Left abutment</td>
<td>1.4</td>
</tr>
<tr>
<td>Right abutment</td>
<td>--</td>
</tr>
<tr>
<td><strong>Piers:</strong></td>
<td></td>
</tr>
<tr>
<td>Pier 1</td>
<td>--</td>
</tr>
<tr>
<td>Pier 2</td>
<td></td>
</tr>
</tbody>
</table>
Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure RANDTH00730039 on town highway 73, crossing the Second Branch White River, Randolph, Vermont.
Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure RANDTH00730039 on town highway 73, crossing the Second Branch White River, Randolph, Vermont.
Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure RANDTH00730039 on Town Highway 73, crossing the Second Branch White River, Randolph, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

<table>
<thead>
<tr>
<th>Description</th>
<th>Station</th>
<th>VTAOT minimum low-chord elevation (feet)</th>
<th>Surveyed minimum low-chord elevation (feet)</th>
<th>Bottom of footing elevation (feet)</th>
<th>Channel elevation at abutment/ pier (feet)</th>
<th>Contraction scour depth (feet)</th>
<th>Abutment scour depth (feet)</th>
<th>Pier scour depth (feet)</th>
<th>Depth of total scour (feet)</th>
<th>Elevation of scour (feet)</th>
<th>Remaining footing/pile depth (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left abutment</td>
<td>-3</td>
<td>--</td>
<td>495.0</td>
<td>--</td>
<td>486.9</td>
<td>3.3</td>
<td>5.9</td>
<td>--</td>
<td>9.2</td>
<td>477.7</td>
<td>--</td>
</tr>
<tr>
<td>Right abutment</td>
<td>35</td>
<td>--</td>
<td>494.8</td>
<td>--</td>
<td>486.8</td>
<td>3.3</td>
<td>19.7</td>
<td>--</td>
<td>23.0</td>
<td>463.8</td>
<td>--</td>
</tr>
</tbody>
</table>

1. Measured along the face of the most constricting side of the bridge.
2. Arbitrary datum for this study.

100-yr. discharge is 7,910 cubic-feet per second

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure RANDTH00730039 on Town Highway 73, crossing the Second Branch White River, Randolph, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

<table>
<thead>
<tr>
<th>Description</th>
<th>Station</th>
<th>VTAOT minimum low-chord elevation (feet)</th>
<th>Surveyed minimum low-chord elevation (feet)</th>
<th>Bottom of footing elevation (feet)</th>
<th>Channel elevation at abutment/ pier (feet)</th>
<th>Contraction scour depth (feet)</th>
<th>Abutment scour depth (feet)</th>
<th>Pier scour depth (feet)</th>
<th>Depth of total scour (feet)</th>
<th>Elevation of scour (feet)</th>
<th>Remaining footing/pile depth (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left abutment</td>
<td>-3</td>
<td>--</td>
<td>495.0</td>
<td>--</td>
<td>486.9</td>
<td>1.9</td>
<td>6.0</td>
<td>--</td>
<td>7.9</td>
<td>479.0</td>
<td>--</td>
</tr>
<tr>
<td>Right abutment</td>
<td>35</td>
<td>--</td>
<td>494.8</td>
<td>--</td>
<td>486.8</td>
<td>1.9</td>
<td>22.5</td>
<td>--</td>
<td>24.4</td>
<td>462.4</td>
<td>--</td>
</tr>
</tbody>
</table>

1. Measured along the face of the most constricting side of the bridge.
2. Arbitrary datum for this study.

500-yr. discharge is 11,100 cubic-feet per second


APPENDIX A:

WS PRO INPUT FILE
WSPRO INPUT FILE

T1 U.S. GEOLOGICAL SURVEY WS PRO INPUT FILE rand039.wsp
T2 CREATED ON 27-MAR-95 FOR BRIDGE RANDTH00730039 USING FILE rand039.dca
T3 SECOND BRANCH WHITE RIVER, TOWN of RANDOLPH, ORANGE COUNTY, TH 73
*
J3 6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
J1 * * 0.001
*
Q 7910 11100 1876
SK 0.0008 0.0008 0.0008
*
XS EXITX 0
GR -402. , 502.81 -375. , 494.11 -363. , 492.17 -338. , 492.06
GR -292. , 490.91 -259. , 492.73 -199. , 492.83 -128. , 492.55
GR -51. , 492.49 -7. , 492.49 0. , 486.56 13. , 486.97
GR 28. , 483.54 36. , 485.68 39. , 491.93 60. , 493.71
GR 75. , 496.88 89. , 497.90 105. , 503.71
N 0.036 0.001 0.002
SA -7. 39.
*
XS FULLV 23 * 0.8 * 0.014
*
BR BRIDG 23 494.9 30
GR -3. , 495.01 -3. , 486.88 0. , 486.70 29. , 484.92
GR 34. , 486.59 35. , 486.85 35. , 494.80 -3. , 495.01
CD 1 20.6 * * 42.5 6.6
N 0.035
*
XR RDWAY 29.5 12.8 2 2.8
GR -346. , 504.08 -328. , 499.69 -296. , 497.85 -226. , 495.52
GR -156. , 494.80 -98. , 494.24 -41. , 494.84 0. , 497.39
GR 43. , 497.73 73. , 500.28 96. , 503.02 117. , 504.53
BP 0
*
AS APPRO 81
GR -315. , 504.91 -295. , 500.27 -262. , 497.41 -187. , 495.31
GR -148. , 493.63 -82. , 493.21 -51. , 493.11 -34. , 492.89
GR -21. , 492.98 -7. , 492.29 -4. , 486.52 0. , 484.99
GR 6. , 484.70 30. , 486.81 34. , 490.70 63. , 491.36
GR 92. , 495.10 106. , 496.65 118. , 498.41 126. , 501.31
GR 136. , 503.62
N 0.035 0.041 0.046
SA -7 34
BP -4 34 32 53
*
HP 1 APPRO 498.56 1 498.56
HP 2 APPRO 498.56 * * 7910
HP 2 RDWAY 498.04 * * 5506
HP 1 BRIDG 495.01 1 495.01
HP 2 BRIDG 495.01 * * 2407
HP 1 APPRO 499.63 1 499.63
HP 2 APPRO 499.63 * * 2407
HP 2 RDWAY 499.00 * * 8950
HP 1 BRIDG 495.01 1 495.01
HP 2 BRIDG 495.01 * * 2314
HP 1 APPRO 494.34 1 494.34
HP 2 APPRO 494.34 * * 1876
HP 1 BRIDG 493.43 1 493.43
APPENDIX B:

WSPRO OUTPUT FILE
SECOND BRANCH WHITE RIVER, TOWN of RANDOLPH, ORANGE COUNTY, TH 73

CROSS-SECTION PROPERTIES: ISEQ = 5; SECID = APPRO; SRD = 81.

<table>
<thead>
<tr>
<th>WSSEL</th>
<th>SA#</th>
<th>AREA</th>
<th>K</th>
<th>TOPW</th>
<th>WETP</th>
<th>ALPH</th>
<th>LEW</th>
<th>REW</th>
<th>QCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1089</td>
<td>118002.0</td>
<td>268.0</td>
<td>116.0</td>
<td>110.9</td>
<td>102.7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>508.0</td>
<td>90796.0</td>
<td>41.4</td>
<td>46.0</td>
<td>10132.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>423.0</td>
<td>39956.0</td>
<td>84.85</td>
<td>5472.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

VELOCITY DISTRIBUTION: ISEQ = 5; SECID = APPRO; SRD = 81.

<table>
<thead>
<tr>
<th>WSSEL</th>
<th>LEW</th>
<th>REW</th>
<th>K</th>
<th>Q</th>
<th>VEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>498.56</td>
<td>-275.3</td>
<td>118.4</td>
<td>118.4</td>
<td>120.9</td>
<td>118.4</td>
</tr>
<tr>
<td>90796.0</td>
<td>118.4</td>
<td>118.4</td>
<td>118.4</td>
<td>118.4</td>
<td>118.4</td>
</tr>
</tbody>
</table>

VELOCITY DISTRIBUTION: ISEQ = 4; SECID = RDWAY; SRD = 30.

<table>
<thead>
<tr>
<th>WSSEL</th>
<th>LEW</th>
<th>REW</th>
<th>K</th>
<th>Q</th>
<th>VEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>498.04</td>
<td>-299.3</td>
<td>46.6</td>
<td>46.6</td>
<td>46.6</td>
<td>46.6</td>
</tr>
<tr>
<td>61825.0</td>
<td>46.6</td>
<td>46.6</td>
<td>46.6</td>
<td>46.6</td>
<td>46.6</td>
</tr>
</tbody>
</table>

VELOCITY DISTRIBUTION: ISEQ = 3; SECID = BRIDG; SRD = 23.

<table>
<thead>
<tr>
<th>WSSEL</th>
<th>LEW</th>
<th>REW</th>
<th>K</th>
<th>Q</th>
<th>VEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>495.01</td>
<td>-0.4</td>
<td>2.7</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
</tr>
<tr>
<td>296.2</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
</tr>
</tbody>
</table>

VELOCITY DISTRIBUTION: ISEQ = 3; SECID = BRIDG; SRD = 23.

<table>
<thead>
<tr>
<th>WSSEL</th>
<th>LEW</th>
<th>REW</th>
<th>K</th>
<th>Q</th>
<th>VEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>495.01</td>
<td>-3.0</td>
<td>0.4</td>
<td>2.7</td>
<td>4.8</td>
<td>4.8</td>
</tr>
<tr>
<td>296.2</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
</tr>
</tbody>
</table>

VELOCITY DISTRIBUTION: ISEQ = 3; SECID = BRIDG; SRD = 23.

<table>
<thead>
<tr>
<th>WSSEL</th>
<th>LEW</th>
<th>REW</th>
<th>K</th>
<th>Q</th>
<th>VEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>495.01</td>
<td>-3.0</td>
<td>0.4</td>
<td>2.7</td>
<td>4.8</td>
<td>4.8</td>
</tr>
<tr>
<td>296.2</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
<td>4.8</td>
</tr>
</tbody>
</table>
U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE rand039.wsp
CREATED ON 27-MAR-95 FOR BRIDGE RANDTH00730039 USING FILE rand039.dca
SECOND BRANCH WHITE RIVER, TOWN of RANDOLPH, ORANGE COUNTY, TH 73

*** RUN DATE & TIME: 07-11-95 14:24

CROSS-SECTION PROPERTIES: ISEQ = 5; SECID = APPRO; SRD = 81.

<table>
<thead>
<tr>
<th>WSEL</th>
<th>SA#</th>
<th>AREA</th>
<th>K</th>
<th>TOPW</th>
<th>WETP</th>
<th>ALPH</th>
<th>LEW</th>
<th>REW</th>
<th>QCR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1383</td>
<td>170442.</td>
<td>281</td>
<td>281</td>
<td></td>
<td></td>
<td></td>
<td>17423.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>551</td>
<td>104250.</td>
<td>41</td>
<td>46</td>
<td>87, 88</td>
<td></td>
<td></td>
<td>11474.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>515</td>
<td>54125.</td>
<td>87</td>
<td>88</td>
<td></td>
<td></td>
<td></td>
<td>7092.</td>
</tr>
</tbody>
</table>

499.63 | 2449. | 328818. | 409 | 415 | 1.17 | -288. | 121 | 31490. |

VELOCITY DISTRIBUTION: ISEQ = 5; SECID = APPRO; SRD = 81.

<table>
<thead>
<tr>
<th>WSEL</th>
<th>LEW</th>
<th>REW</th>
<th>AREA</th>
<th>K</th>
<th>Q</th>
<th>VEL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-287.6</td>
<td>-200.5</td>
<td>-165.3</td>
<td>-141.4</td>
<td>-120.2</td>
<td>-100.9</td>
</tr>
<tr>
<td></td>
<td>217.7</td>
<td>160.0</td>
<td>137.0</td>
<td>129.3</td>
<td>120.8</td>
<td>120.8</td>
</tr>
<tr>
<td></td>
<td>2.55</td>
<td>3.47</td>
<td>4.05</td>
<td>4.29</td>
<td>4.59</td>
<td></td>
</tr>
</tbody>
</table>

X STA. | -287.6 | -250.1 | -227.1 | -209.5 | -194.1 | -179.6 |
A(I)   | 99.5   | 70.1   | 62.7   | 57.6   | 56.4   | 56.4 |
V(I)   | 4.50   | 6.38   | 7.14   | 7.77   | 7.93   |

X STA. | -179.6 | -166.0 | -153.7 | -141.8 | -130.4 | -119.7 |
A(I)   | 54.6   | 51.1   | 51.1   | 49.9   | 48.0   | 48.0 |
V(I)   | 8.20   | 8.75   | 8.75   | 8.96   | 9.32   |

X STA. | -119.7 | -109.5 | -99.5  | -89.6  | -79.6  | -69.4  |
A(I)   | 47.2   | 46.7   | 46.6   | 46.3   | 46.1   | 46.1 |
V(I)   | 9.48   | 9.58   | 9.60   | 9.66   | 9.70   |

X STA. | -69.4 | -58.4 | -47.0  | -34.3  | -15.6  | 57.9  |
A(I)   | 48.5   | 48.7   | 51.5   | 59.2   | 104.1  | 104.1 |
V(I)   | 9.22   | 9.20   | 8.68   | 7.56   | 4.30   |

CROSS-SECTION PROPERTIES: ISEQ = 4; SECID = RDWAY; SRD = 30.

<table>
<thead>
<tr>
<th>WSEL</th>
<th>LEW</th>
<th>REW</th>
<th>AREA</th>
<th>K</th>
<th>Q</th>
<th>VEL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>296.2</td>
<td>29612.</td>
<td>2314.</td>
<td>296.2</td>
<td>29612.</td>
<td>2314.</td>
</tr>
</tbody>
</table>

X STA. | -3.0 | 0.4  | 2.7   | 4.8   | 6.7   | 8.5   |
A(I)   | 24.5   | 16.4   | 15.2   | 14.3   | 14.0   | 14.0 |
V(I)   | 4.73   | 7.04   | 7.60   | 8.12   | 8.26   |

X STA. | 8.5   | 10.3  | 12.0  | 13.7  | 15.4  | 17.0  |
A(I)   | 13.6   | 13.3   | 13.0   | 13.2   | 12.9   | 12.9 |
V(I)   | 6.48   | 8.70   | 8.90   | 8.77   | 8.96   |

X STA. | 17.0  | 18.6  | 20.2  | 21.7  | 23.3  | 24.9  |
A(I)   | 12.8   | 12.9   | 12.8   | 13.1   | 12.8   | 12.8 |
V(I)   | 9.02   | 8.94   | 9.06   | 8.84   | 9.02   |

X STA. | 24.9  | 26.4  | 28.0  | 29.7  | 31.6  | 35.0  |
A(I)   | 13.0   | 13.5   | 14.4   | 15.7   | 24.7   | 24.7 |
V(I)   | 8.90   | 8.57   | 8.05   | 7.36   | 4.68   |
### Second Branch White River, Town of Randolph, Orange County, TH 73

**Cross-Section Properties:**

<table>
<thead>
<tr>
<th>ISEQ</th>
<th>SECID</th>
<th>SRC</th>
<th>WSEL</th>
<th>SA#</th>
<th>AREA</th>
<th>K</th>
<th>TOPW</th>
<th>WETP</th>
<th>ALPH</th>
<th>LEW</th>
<th>REW</th>
<th>QCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>81</td>
<td>1</td>
<td>168</td>
<td>7471</td>
<td>157</td>
<td>158</td>
<td>985</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>81</td>
<td>2</td>
<td>334</td>
<td>4532</td>
<td>41</td>
<td>46</td>
<td>5422</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>5</td>
<td>81</td>
<td>3</td>
<td>130</td>
<td>7768</td>
<td>52</td>
<td>52</td>
<td>1171</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Velocity Distribution:**

<table>
<thead>
<tr>
<th>ISEQ</th>
<th>SECID</th>
<th>SRC</th>
<th>WSEL</th>
<th>LEW</th>
<th>REW</th>
<th>AREA</th>
<th>K</th>
<th>Q</th>
<th>VEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>81</td>
<td>494.34</td>
<td>-164.5</td>
<td>-70.4</td>
<td>-22.3</td>
<td>2.8</td>
<td>-0.1</td>
<td>2.2</td>
</tr>
</tbody>
</table>

X STA. | A(I) | V(I) |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-164.5</td>
<td>79.9</td>
<td>1.17</td>
</tr>
<tr>
<td>-70.4</td>
<td>62.4</td>
<td>1.50</td>
</tr>
</tbody>
</table>

### bridge RANDTH00730039

**Cross-Section Properties:**

<table>
<thead>
<tr>
<th>ISEQ</th>
<th>SECID</th>
<th>SRC</th>
<th>WSEL</th>
<th>SA#</th>
<th>AREA</th>
<th>K</th>
<th>TOPW</th>
<th>WETP</th>
<th>ALPH</th>
<th>LEW</th>
<th>REW</th>
<th>QCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>81</td>
<td>1</td>
<td>248</td>
<td>32176</td>
<td>33</td>
<td>46</td>
<td>3856</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Velocity Distribution:**

<table>
<thead>
<tr>
<th>ISEQ</th>
<th>SECID</th>
<th>SRC</th>
<th>WSEL</th>
<th>LEW</th>
<th>REW</th>
<th>AREA</th>
<th>K</th>
<th>Q</th>
<th>VEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>81</td>
<td>493.43</td>
<td>-3.0</td>
<td>1.0</td>
<td>3.4</td>
<td>5.4</td>
<td>7.4</td>
<td>9.2</td>
</tr>
</tbody>
</table>

X STA. | A(I) | V(I) |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-3.0</td>
<td>22.9</td>
<td>4.10</td>
</tr>
<tr>
<td>1.0</td>
<td>14.4</td>
<td>6.52</td>
</tr>
</tbody>
</table>

### bridge RANDTH00730039

**Cross-Section Properties:**

<table>
<thead>
<tr>
<th>ISEQ</th>
<th>SECID</th>
<th>SRC</th>
<th>WSEL</th>
<th>SA#</th>
<th>AREA</th>
<th>K</th>
<th>TOPW</th>
<th>WETP</th>
<th>ALPH</th>
<th>LEW</th>
<th>REW</th>
<th>QCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>81</td>
<td>1</td>
<td>248</td>
<td>32176</td>
<td>33</td>
<td>46</td>
<td>3856</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Velocity Distribution:**

<table>
<thead>
<tr>
<th>ISEQ</th>
<th>SECID</th>
<th>SRC</th>
<th>WSEL</th>
<th>LEW</th>
<th>REW</th>
<th>AREA</th>
<th>K</th>
<th>Q</th>
<th>VEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>81</td>
<td>493.43</td>
<td>-3.0</td>
<td>35.0</td>
<td>247.7</td>
<td>32176</td>
<td>1876</td>
<td>7.57</td>
</tr>
</tbody>
</table>

X STA. | A(I) | V(I) |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-3.0</td>
<td>22.9</td>
<td>4.10</td>
</tr>
<tr>
<td>35.0</td>
<td>14.4</td>
<td>6.52</td>
</tr>
</tbody>
</table>

### bridge RANDTH00730039

**Cross-Section Properties:**

<table>
<thead>
<tr>
<th>ISEQ</th>
<th>SECID</th>
<th>SRC</th>
<th>WSEL</th>
<th>SA#</th>
<th>AREA</th>
<th>K</th>
<th>TOPW</th>
<th>WETP</th>
<th>ALPH</th>
<th>LEW</th>
<th>REW</th>
<th>QCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>81</td>
<td>1</td>
<td>248</td>
<td>32176</td>
<td>33</td>
<td>46</td>
<td>3856</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Velocity Distribution:**

<table>
<thead>
<tr>
<th>ISEQ</th>
<th>SECID</th>
<th>SRC</th>
<th>WSEL</th>
<th>LEW</th>
<th>REW</th>
<th>AREA</th>
<th>K</th>
<th>Q</th>
<th>VEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>81</td>
<td>493.43</td>
<td>-3.0</td>
<td>35.0</td>
<td>247.7</td>
<td>32176</td>
<td>1876</td>
<td>7.57</td>
</tr>
</tbody>
</table>

X STA. | A(I) | V(I) |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-3.0</td>
<td>22.9</td>
<td>4.10</td>
</tr>
<tr>
<td>35.0</td>
<td>14.4</td>
<td>6.52</td>
</tr>
</tbody>
</table>

---

**WSPRO OUTPUT FILE (continued)**
WSPRO OUTPUT FILE (continued)

U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE rand039.wsp
CREATED ON 27-MAR-95 FOR BRIDGE RANDTH00730039 USING FILE rand039.dca
SECOND BRANCH WHITE RIVER, TOWN of RANDOLPH, ORANGE COUNTY, TH 73
*** RUN DATE & TIME: 07-11-95 14:24

XSID:CODE  SRDL  LEW  AREA  VHD  HF  EGL  CRWS  Q  WSEL
SRD  FLEN  REW  K  ALPH  HO  ERR  FR#  VEL
EXITX:XS    23.  -384.  2323.  0.19 497.23 494.40 7910. 497.03
0. 497.23  77.  279554. 1.07  0.28  3.41
FULLY:FV 23.  -383.  2184.  0.22  0.02  497.27  7910. 497.05
23.  7910. 497.05
<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>

===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
"APPRO" KRATIO = 0.62
APPRO:AS 58.  -249.  1449.  0.63  0.09  497.69  7910. 497.06
81.  58. 109. 158475. 1.37  0.33  0.00  0.56  5.46
<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>

===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
WSLN,LESL = 497.05 494.90

<<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>
XSID:CODE  SRDL  LEW  AREA  VHD  HF  EGL  CRWS  Q  WSEL
SRD  FLEN  REW  K  ALPH  HO  ERR  FR#  VEL
BRIDG:BR 23.  -3.  296.  1.03 496.04 491.41 2407. 495.01
23.  35.  29612.  1.00  0.51  8.13
TYPE PPCD FLOW
C  P/A  LSEL  BLEN  XLAB  XRAB
1.  6. 0.800  0.000  494.90  494.90
XSID:CODE  SRDL  LEW  AREA  VHD  HF  EGL  CRWS  Q  WSEL
SRD  FLEN  REW  K  ALPH  HO  ERR  FR#  VEL
RDWAY:RS  30.  45.  0.05  0.29  498.85  7910. 498.56
Q  WLEN  LEW  REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
LT:  5416.  319.  -299.  20.  3.8  2.5  7.8  6.8  3.2  2.9
RT:   90.  27.  20.  47.  0.5  0.4  4.5  9.1  1.1  2.8
XSID:CODE  SRDL  LEW  AREA  VHD  HF  EGL  CRWS  Q  WSEL
SRD  FLEN  REW  K  ALPH  HO  ERR  FR#  VEL
APPRO:AS 37.  -275.  2018.  0.30  498.85  7910. 498.56
81.  54.  118.  248511. 1.23  0.00  0.00  0.34  3.92
FIRST USER DEFINED TABLE.
XSID:CODE  SRDL  LEW  AREA  VHD  HF  EGL  CRWS  Q  WSEL
SRD  FLEN  REW  K  ALPH  HO  ERR  FR#  VEL
EXITX:XS    0.  -384.  77.  7910. 279554. 2323.  3.41 497.03
FULLY:FV 23.  -383.  74.  7910. 254146. 2184.  3.62 497.05
BRIDG:BR 23.  -3.  35.  2407.  29612.  296.  8.13 495.01
RDWAY:RS 30.  5416.  319.  -299.  20.  3.8  2.5  7.8  6.8  3.2  2.9
APPRO:AS 81.  -275.  2018.  0.30  498.85  7910. 498.56
SECOND USER DEFINED TABLE.
XSID:CODE  CRWS  FR#  YMIN  YMAX  HF  HO  VHD  EGL  WSEL
EXITX:XS    494.40  0.28  483.54  503.71  497.23  497.03
FULLY:FV 494.40  0.28  483.54  503.71  497.23  497.03
BRIDG:BR 491.41  0.51  484.92  495.01  1.03  496.04  495.01
RDWAY:RS 495.59  0.34  484.70  504.91  0.20  0.00  0.29  498.85  498.56
SECOND BRANCH WHITE RIVER, TOWN of RANDOLPH, ORANGE COUNTY, TH 73

--- 135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.

"APPRO" K RATIO = 0.63

APPRO:AS 58. -272. 1905. 0.66 0.09 498.93 ****** 11100. 498.27
39. 23. 0.28 498.26 3.84

<<<<< THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW >>>>>

--- 255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.

WSNL, LSEL = 498.26 494.90

<<<<< RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW >>>>>
### WSPRO Output File (continued)

**U.S. Geological Survey WSPRO Input File rand039.wsp**
**CREATED ON 27-MAR-95 FOR BRIDGE RANDTH00730039 USING FILE rand039.dca**
**SECOND BRANCH WHITE RIVER, TOWN of RANDOLPH, ORANGE COUNTY, TH 73**

#### Run Date & Time: 07-11-95 14:24

<table>
<thead>
<tr>
<th>XSID</th>
<th>CODE</th>
<th>SRDL</th>
<th>LEW</th>
<th>AREA</th>
<th>VHD</th>
<th>HF</th>
<th>EGL</th>
<th>CRWS</th>
<th>Q</th>
<th>WSEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRDL</td>
<td>FLEN</td>
<td>REW</td>
<td>K</td>
<td>ALPH</td>
<td>HO</td>
<td>ERR</td>
<td>FR#</td>
<td>VEL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**EXITX:**

| ****** | -373 | 856 | 0.12 | ****** | 493.87 | 489.97 | 1876. | 493.75 |
| ****** | 60 | 66280 | 1.60 | ****** | 0.35 | 2.19 |

**FULLV:**

| 23 | -371 | 722 | 0.18 | 0.02 | 493.94 | ****** | 1876. | 493.76 |

<<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>

**APPRO:**

| 58 | -152 | 504. | 0.33 | 0.08 | 494.14 | ****** | 1876. | 493.81 |

<<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>

---215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.

WS1, WSSD, W3, ROMIN = 494.34 0.00 493.43 494.24

---260 ATTEMPTING FLOW CLASS 4 SOLUTION.

<<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>

### First User Defined Table.

<table>
<thead>
<tr>
<th>XSID</th>
<th>CODE</th>
<th>SRDL</th>
<th>LEW</th>
<th>AREA</th>
<th>VHD</th>
<th>HF</th>
<th>EGL</th>
<th>CRWS</th>
<th>Q</th>
<th>WSEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRDL</td>
<td>FLEN</td>
<td>REW</td>
<td>K</td>
<td>ALPH</td>
<td>HO</td>
<td>ERR</td>
<td>FR#</td>
<td>VEL</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| BRIDG:BR | 23 | -3 | 248 | 0.96 | 0.04 | 494.39 | 490.56 | 1876. | 493.43 |
| 23 | 35 | 32189 | 1.08 | 0.48 | 0.00 | 0.51 | 7.57 |

**TYPE PPCD FLOW**

C P/A LSEL BLEN XLAB XRAB

| 1 | **** | 4 | 0.963 | ****** | 494.90 | ****** | ****** | ****** |

**SECOND USER DEFINED TABLE:**

<table>
<thead>
<tr>
<th>XSID</th>
<th>CODE</th>
<th>CRWS</th>
<th>FR#</th>
<th>YMIN</th>
<th>YMAX</th>
<th>HF</th>
<th>HO</th>
<th>VHD</th>
<th>EGL</th>
<th>WSEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXITX:XS</td>
<td>0.373</td>
<td>60.</td>
<td>1876.</td>
<td>66280.</td>
<td>856.</td>
<td>2.19</td>
<td>493.75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FULLV:FV</td>
<td>23</td>
<td>-371</td>
<td>57.</td>
<td>1876.</td>
<td>54316.</td>
<td>722.</td>
<td>2.60</td>
<td>493.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRIDG:BR</td>
<td>23</td>
<td>-3</td>
<td>35.</td>
<td>1876.</td>
<td>32189</td>
<td>248.</td>
<td>7.57</td>
<td>493.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDWAY:RG</td>
<td>30</td>
<td>86.</td>
<td>60609</td>
<td>1.58</td>
<td>0.07</td>
<td>0.01</td>
<td>0.41</td>
<td>2.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>APPRO:AS</td>
<td>37.</td>
<td>-165</td>
<td>633</td>
<td>0.22</td>
<td>0.09</td>
<td>494.56</td>
<td>490.12</td>
<td>1876.</td>
<td>494.34</td>
<td></td>
</tr>
<tr>
<td>APPRO:AS</td>
<td>81</td>
<td>52.</td>
<td>60609</td>
<td>1.58</td>
<td>0.07</td>
<td>0.01</td>
<td>0.41</td>
<td>2.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDWAY:RG</td>
<td>30</td>
<td>86.</td>
<td>60609</td>
<td>1.58</td>
<td>0.07</td>
<td>0.01</td>
<td>0.41</td>
<td>2.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>APPRO:AS</td>
<td>490.12</td>
<td>0.41</td>
<td>484.70</td>
<td>504.91</td>
<td>0.09</td>
<td>0.07</td>
<td>0.22</td>
<td>494.56</td>
<td>494.34</td>
<td></td>
</tr>
</tbody>
</table>

**SECOND USER DEFINED TABLE:**

<table>
<thead>
<tr>
<th>XSID</th>
<th>CODE</th>
<th>CRWS</th>
<th>FR#</th>
<th>YMIN</th>
<th>YMAX</th>
<th>HF</th>
<th>HO</th>
<th>VHD</th>
<th>EGL</th>
<th>WSEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXITX:XS</td>
<td>0.373</td>
<td>60.</td>
<td>1876.</td>
<td>66280.</td>
<td>856.</td>
<td>2.19</td>
<td>493.75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FULLV:FV</td>
<td>23</td>
<td>-371</td>
<td>57.</td>
<td>1876.</td>
<td>54316.</td>
<td>722.</td>
<td>2.60</td>
<td>493.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRIDG:BR</td>
<td>23</td>
<td>-3</td>
<td>35.</td>
<td>1876.</td>
<td>32189</td>
<td>248.</td>
<td>7.57</td>
<td>493.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDWAY:RG</td>
<td>30</td>
<td>86.</td>
<td>60609</td>
<td>1.58</td>
<td>0.07</td>
<td>0.01</td>
<td>0.41</td>
<td>2.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>APPRO:AS</td>
<td>490.12</td>
<td>0.41</td>
<td>484.70</td>
<td>504.91</td>
<td>0.09</td>
<td>0.07</td>
<td>0.22</td>
<td>494.56</td>
<td>494.34</td>
<td></td>
</tr>
</tbody>
</table>

**SECOND USER DEFINED TABLE:**

<table>
<thead>
<tr>
<th>XSID</th>
<th>CODE</th>
<th>CRWS</th>
<th>FR#</th>
<th>YMIN</th>
<th>YMAX</th>
<th>HF</th>
<th>HO</th>
<th>VHD</th>
<th>EGL</th>
<th>WSEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXITX:XS</td>
<td>0.373</td>
<td>60.</td>
<td>1876.</td>
<td>66280.</td>
<td>856.</td>
<td>2.19</td>
<td>493.75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FULLV:FV</td>
<td>23</td>
<td>-371</td>
<td>57.</td>
<td>1876.</td>
<td>54316.</td>
<td>722.</td>
<td>2.60</td>
<td>493.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRIDG:BR</td>
<td>23</td>
<td>-3</td>
<td>35.</td>
<td>1876.</td>
<td>32189</td>
<td>248.</td>
<td>7.57</td>
<td>493.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDWAY:RG</td>
<td>30</td>
<td>86.</td>
<td>60609</td>
<td>1.58</td>
<td>0.07</td>
<td>0.01</td>
<td>0.41</td>
<td>2.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>APPRO:AS</td>
<td>490.12</td>
<td>0.41</td>
<td>484.70</td>
<td>504.91</td>
<td>0.09</td>
<td>0.07</td>
<td>0.22</td>
<td>494.56</td>
<td>494.34</td>
<td></td>
</tr>
</tbody>
</table>

**SECOND USER DEFINED TABLE:**

<table>
<thead>
<tr>
<th>XSID</th>
<th>CODE</th>
<th>CRWS</th>
<th>FR#</th>
<th>YMIN</th>
<th>YMAX</th>
<th>HF</th>
<th>HO</th>
<th>VHD</th>
<th>EGL</th>
<th>WSEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXITX:XS</td>
<td>0.373</td>
<td>60.</td>
<td>1876.</td>
<td>66280.</td>
<td>856.</td>
<td>2.19</td>
<td>493.75</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FULLV:FV</td>
<td>23</td>
<td>-371</td>
<td>57.</td>
<td>1876.</td>
<td>54316.</td>
<td>722.</td>
<td>2.60</td>
<td>493.76</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BRIDG:BR</td>
<td>23</td>
<td>-3</td>
<td>35.</td>
<td>1876.</td>
<td>32189</td>
<td>248.</td>
<td>7.57</td>
<td>493.43</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RDWAY:RG</td>
<td>30</td>
<td>86.</td>
<td>60609</td>
<td>1.58</td>
<td>0.07</td>
<td>0.01</td>
<td>0.41</td>
<td>2.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>APPRO:AS</td>
<td>490.12</td>
<td>0.41</td>
<td>484.70</td>
<td>504.91</td>
<td>0.09</td>
<td>0.07</td>
<td>0.22</td>
<td>494.56</td>
<td>494.34</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION
Bed material particle-size distributions for five samples taken at the approach cross-section and combined for structure RANDTH00730039, in Randolph, Vermont
APPENDIX D:
HISTORICAL DATA FORM