# LEVEL II SCOUR ANALYSIS FOR BRIDGE 39 (TOPSTH00510039) on TOWN HIGHWAY 51, crossing the TABOR BRANCH WAITS RIVER, TOPSHAM, VERMONT

U.S. Geological Survey
Open-File Report 97-797

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior

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# LEVEL II SCOUR ANALYSIS FOR BRIDGE 39 (TOPSTH00510039) on TOWN HIGHWAY 51, crossing the TABOR BRANCH WAITS RIVER, TOPSHAM, VERMONT

By LORA K. STRIKER AND TIM SEVERANCE

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**Pembroke, New Hampshire**

**1997**

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

U.S. GEOLOGICAL SURVEY
Mark Schaefer, Acting Director

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## CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

| Multiply | By | To obtain |
|---|---|---|
| | **Length** | |
| inch (in.) | 25.4 | millimeter (mm) |
| foot (ft) | 0.3048 | meter (m) |
| mile (mi) | 1.609 | kilometer (km) |
| | **Slope** | |
| foot per mile (ft/mi) | 0.1894 | meter per kilometer (m/km) |
| | **Area** | |
| square mile ($mi^2$) | 2.590 | square kilometer ($km^2$) |
| | **Volume** | |
| cubic foot ($ft^3$) | 0.02832 | cubic meter ($m^3$) |
| | **Velocity and Flow** | |
| 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 ($m^3/s$) |
| cubic foot per second per square mile [$(ft^3/s)/mi^2$] | 0.01093 | cubic meter per second per square kilometer [$(m^3/s)/km^2$] |

## OTHER ABBREVIATIONS

| | | | |
|---|---|---|---|
| BF | bank full | LWW | left wingwall |
| cfs | cubic feet per second | MC | main channel |
| $D_{50}$ | median diameter of bed material | RAB | right abutment |
| DS | downstream | RABUT | face of right abutment |
| elev. | elevation | RB | right bank |
| f/p | flood plain | ROB | right overbank |
| $ft^2$ | square feet | RWW | right wingwall |
| ft/ft | feet per foot | TH | town highway |
| JCT | junction | UB | under bridge |
| LAB | left abutment | US | upstream |
| LABUT | face of left abutment | USGS | United States Geological Survey |
| LB | left bank | VTAOT | Vermont Agency of Transportation |
| LOB | left overbank | WSPRO | water-surface profile model |

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 (TOPSTH00510039) ON TOWN HIGHWAY 51, CROSSING THE TABOR BRANCH WAITS RIVER, TOPSHAM, VERMONT

*By* **Lora K. Striker and Tim Severance**

## INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure TOPSTH00510039 on Town Highway 51 crossing the Tabor Branch Waits River, Topsham, 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). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in east-central Vermont. The 17.4-$mi^2$ drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is predominantly pasture. However, beyond one bridge length on the right bank upstream the surface cover abruptly changes to forest.

In the study area, the Tabor Branch Waits River has a sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 53 ft and an average bank height of 6 ft. The predominant channel bed material is cobbles with a median grain size ($D_{50}$) of 86.4 mm (0.283 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 30, 1995, indicated that the reach was stable.

The Town Highway 51 crossing of the Tabor Branch Waits River is a 34-ft-long, one-lane bridge consisting of one 32-foot concrete slab span (Vermont Agency of Transportation, written communication, March 28, 1995). The opening length of the structure parallel to the bridge face is 31.0 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 5 degrees to the opening while the opening-skew-to-roadway is 10 degrees.

The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the left and right bank upstream, along the base of the upstream left wingwall, upstream right wingwall, left abutment, right abutment, downstream left wingwall, downstream right wingwall, and along the left and right bank downstream. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge is determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at 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 depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 0.4 ft. The worst-case contraction scour occurred at the maximum free surface flow discharge, which was less than the 100-year discharge. Abutment scour ranged from 4.8 to 8.0 ft. The worst-case abutment scour occurred at 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled "Scour Results". Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives "excessively conservative estimates of scour depths" (Richardson and others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

East Corinth, VT. Quadrangle, 1:24,000, 1973

NORTH

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.

## LEVEL II SUMMARY

***Structure Number*** TOPSTH00510039 ***Stream*** Tabor Branch Waits River

***County*** Orange ***Road*** TH 51 ***District*** 7

### Description of Bridge

***Bridge length*** 34 ***ft*** ***Bridge width*** 17.4 ***ft*** ***Max span length*** 32 ***ft***

***Alignment of bridge to road (on curve or straight)*** Straight

***Abutment type*** Vertical, concrete ***Embankment type*** Sloping

***Stone fill on abutment?*** Yes ***Date of inspection*** 08/30/95

***Description of stone fill*** Type-2, along the entire base length of the left and right abutments, upstream right wingwall, upstream left wingwall, downstream right wingwall, and downstream left wingwall.

***Brief description of piers/abutments*** Abutments and wingwalls are concrete.

***Is bridge skewed to flood flow according to*** N ***survey?*** Yes ***Angle*** 10

***Is bridge located on a bend in channel? If so, describe (mild, moderate, severe)***

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

| | ***Date of inspection*** | ***Percent of channel blocked horizontally*** | ***Percent of channel blocked vertically*** |
|---|---|---|---|
| ***Level I*** | 08/30/95 | 0 | 0 |
| ***Level II*** | 08/30/95 | 0 | 0 |

***Potential for debris*** Low.

***Describe any features near or at the bridge that may affect flow (include observation date)*** None, 08/30/95

## Description of the Geomorphic Setting

***General topography*** The channel is located in a moderate relief valley with a narrow flood plain and moderately sloping to steep valley walls.

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

***Date of inspection*** 08/30/95

***DS left:*** Narrow flood plain to steep valley wall

***DS right:*** Moderately sloping channel bank and overbank

***US left:*** Narrow flood plain to steep valley wall

***US right:*** Moderately sloping channel bank and overbank

## Description of the Channel

***Average top width*** 53 *ft* ***Average depth*** 6 *ft*

***Predominant bed material*** Cobbles ***Bank material*** Sand

Sinuous but stable with semi-alluvial channel boundaries and a narrow flood plain.

08/30/95

***Vegetative co*** Brush, shrubs, and small trees with pasture on the overbank

***DS left:*** Brush, shrubs, and small trees with pasture on the overbank

***DS right:*** Tall grass, shrubs, and a few trees with pasture on the overbank

***US left:*** Tall grass and trees with pasture and forest on the overbank.

***US right:***

***Do banks appear stable?*** Yes ***If not, describe location and type of instability and date of observation.***

There is significant undercutting of trees along the right bank upstream. The trees have been removed and only the trunks remain.

None, 08/30/95.

***Describe any obstructions in channel and date of observation.***

## Hydrology

***Drainage area*** 17.4 ***mi²***

***Percentage of drainage area in physiographic provinces: (approximate)***

| ***Physiographic province/section*** | ***Percent of drainage area*** |
| --- | --- |
| New England/New England Upland | 100 |

***Is drainage area considered rural or urban?*** Rural ***Describe any significant urbanization***: None.

***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/p*** No

### Calculated Discharges

***Q100*** 2,600 ***ft³/s*** ***Q500*** 3,300 ***ft³/s***

The 100- year discharge was taken from the VTAOT database and extrapolated to the 500-year discharge. The VTAOT discharges are within range of several empirical equations (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

## Description of the Water-Surface Profile Model (WSPRO) Analysis

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

***Datum tie between USGS survey and VTAOT plans*** -

***Description of reference marks used to determine USGS datum.*** RM1 is a VT AOT survey mark at center point of triangle on brass tablet at the upstream end of the right abutment (elev. 502.45 ft, arbitrary survey datum). RM2 is a chiseled X on the left abutment concrete at the downstream end (elev. 502.48 ft, arbitrary survey datum).

### Cross-Sections Used in WSPRO Analysis

| *[1]Cross-section* | *Section Reference Distance (SRD) in feet* | *[2]Cross-section development* | *Comments* |
|---|---|---|---|
| EXITX | -24 | 1 | Exit section |
| FULLV | 0 | 2 | Downstream Full-valley section (Templated from EXITX) |
| BRIDG | 0 | 1 | Bridge section |
| RDWAY | 12 | 1 | Road Grade section |
| APTEM | 49 | 1 | Approach section as surveyed (Used as a template) |
| APPRO | 54 | 2 | Modelled Approach section (Templated from APTEM) |

[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 analyses reported herein reflect 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 and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.045, and overbank "n" values ranged from 0.040 to 0.060.

Normal depth at the exit section (EXITX) was assumed as the starting water surface for the incipient roadway overtopping discharge. The depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0076 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1973). Critical depth at the exit section (EXITX) was assumed as the starting water surface elevation for the 100-year and 500-year discharge. The computed normal depth was within 0.2 ft of critical depth for the 100-year and 500-year discharges by use of the slope conveyance method. Therefore, the critical water surface was assumed to be a satisfactory starting water surface for the 100- and 500-year discharge models.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0182 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

## Bridge Hydraulics Summary

***Average bridge embankment elevation*** 502.5 ***ft***
***Average low steel elevation*** 501.0 ***ft***

***100-year discharge*** 2600 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 501.1 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 787 ***$ft^3/s$***
***Area of flow in bridge opening*** 257 ***$ft^2$***
***Average velocity in bridge opening*** 7.1 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 8.4 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 502.1
***Water-surface elevation at Approach section without bridge*** 499.6
***Amount of backwater caused by bridge*** 2.5 ***ft***

***500-year discharge*** 3300 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 501.1 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 1230 ***$ft^3/s$***
***Area of flow in bridge opening*** 257 ***$ft^2$***
***Average velocity in bridge opening*** 8.1 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 9.5 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 502.4
***Water-surface elevation at Approach section without bridge*** 500.4
***Amount of backwater caused by bridge*** 2.0 ***ft***

***Incipient overtopping discharge*** 1890 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 497.9 ***ft***
***Area of flow in bridge opening*** 161 ***$ft^2$***
***Average velocity in bridge opening*** 11.8 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 14.4 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 500.5
***Water-surface elevation at Approach section without bridge*** 499.2
***Amount of backwater caused by bridge*** 1.3 ***ft***

## 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, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution, although bedrock outcrops were noted at a few locations in the channel at the site.

Contraction scour for the incipient overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 100- and 500-year discharges resulted in unsubmerged orifice flow with road overflow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for the 100- and 500-year discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). 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. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the 100- and 500-year discharges were computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144), and the results are presented in Appendix F. Furthermore, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations for the 100- and 500-year discharge. Results with respect to these substitutions are provided in Appendix F.

Abutment scour for the right abutment was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). 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, 1995, p. 49, equation 29) 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.

Because the influence of scour processes on the extensive stone-fill abutment protection is uncertain, the scour depth at the vertical abutment walls was computed at the toe of the stone-fill. The computed total scour depth was applied to the elevation at the toe of the stone fill in front of the abutments and is shown in Tables 1 and 2 and Figure 8.

## Scour Results

| *Contraction scour:* | *100-yr discharge* | *500-yr discharge* | *Incipient overtopping discharge* |
|---|---|---|---|
| | | *(Scour depths in feet)* | |
| *Main channel* | | | |
| *Live-bed scour* | -- | -- | -- |
| *Clear-water scour* | 0.0 | 0.0 | 0.4 |
| *Depth to armoring* | 0.9 | 1.9 | 24.8 |
| *Left overbank* | -- | -- | -- |
| *Right overbank* | -- | -- | -- |

| *Local scour:* | | | |
|---|---|---|---|
| *Abutment scour* | | | |
| *Left abutment* | 7.5 | 8.0 | 4.8 |
| *Right abutment* | 8.0 | 7.6 | 7.5 |
| *Pier scour* | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |
| *Pier 3* | -- | -- | -- |

## Riprap Sizing

| | *100-yr discharge* | *500-yr discharge* | *Incipient overtopping discharge* |
|---|---|---|---|
| | | *($D_{50}$ in feet)* | |
| *Abutments:* | | | |
| *Left abutment* | 2.1 | 1.3 | 2.1 |
| *Right abutment* | 2.1 | 1.3 | 2.1 |
| *Piers:* | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |

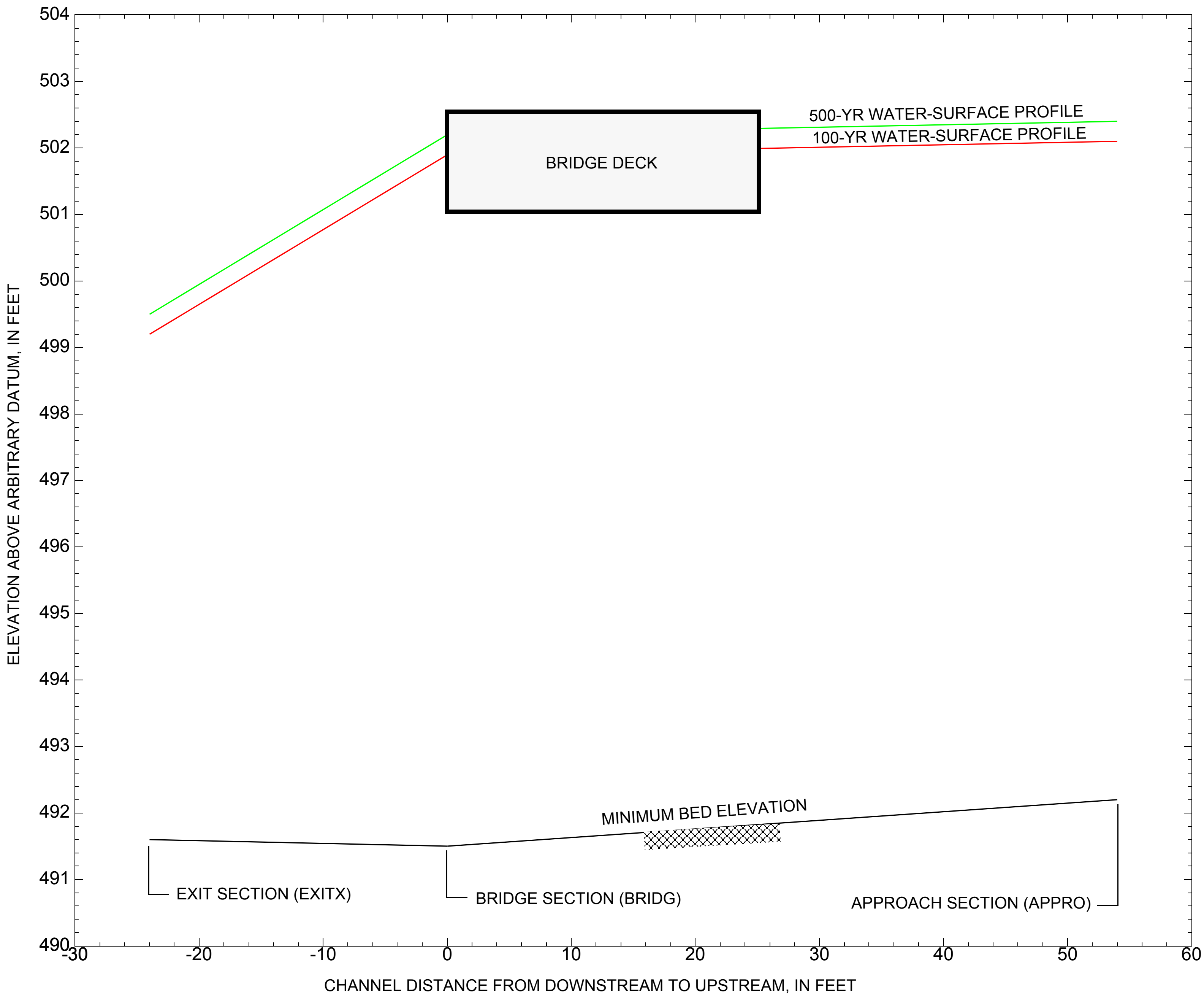


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure TOPSTH00510039 on Town Highway 51, crossing Tabor Branch Waits River, Topsham, Vermont.

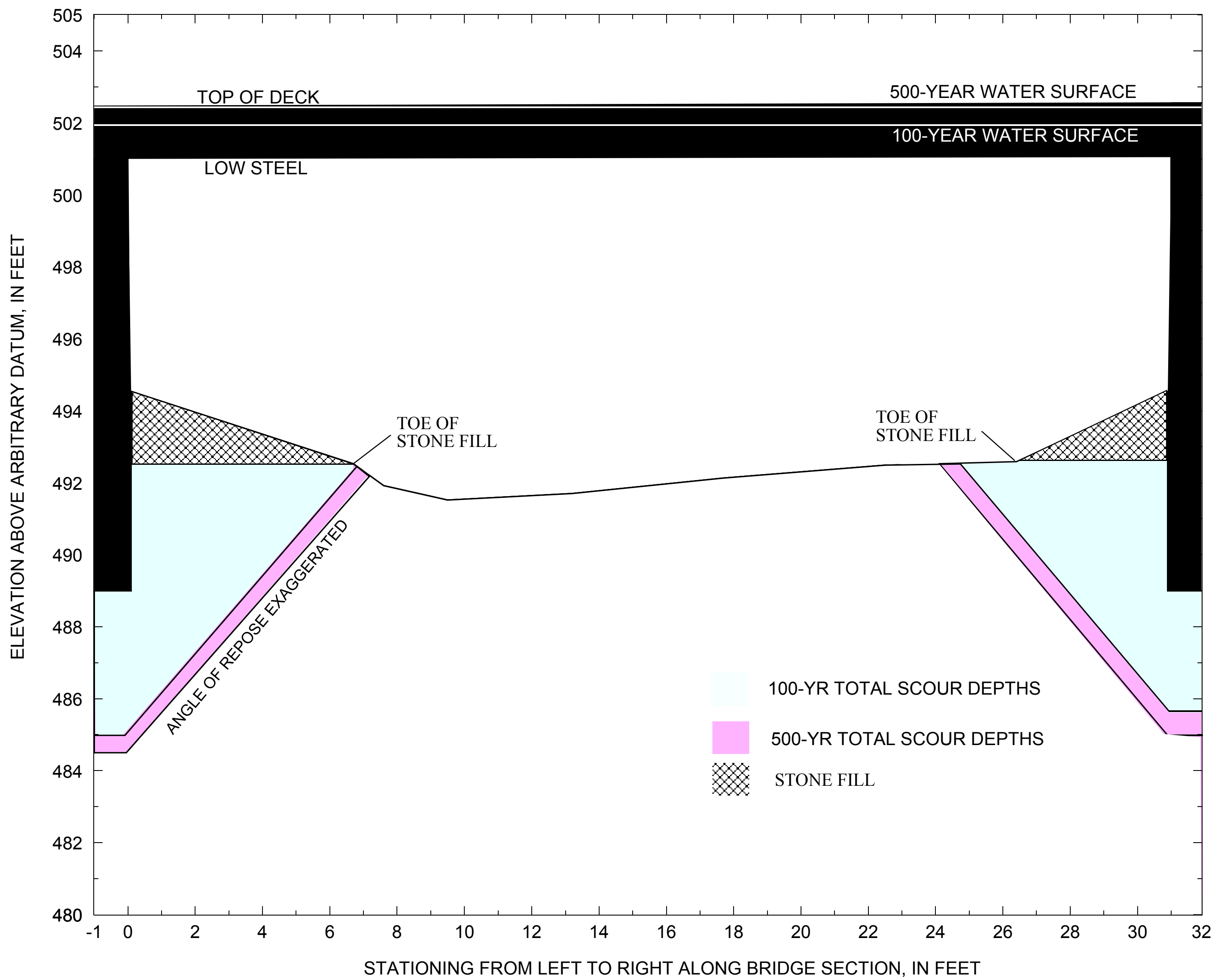


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure TOPSTH00510039 on Town Highway 51, crossing the Tabor Branch Waits River, Topsham, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure TOPSTH00510039 on Town Highway 51, crossing the Tabor Branch Waits River, Topsham, Vermont.

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

| Description | Station[1] | VTAOT minimum low-chord elevation (feet) | Surveyed minimum low-chord elevation[2] (feet) | Bottom of footing/pile elevation[2] (feet) | Channel elevation at abutment/ pier[2] (feet) | Contraction scour depth (feet) | Abutment scour depth (feet) | Pier scour depth (feet) | Depth of total scour (feet) | Elevation of scour[2] (feet) | Remaining footing/pile depth (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 100-yr. discharge is 1,700 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | 501.0 | 501.0 | 489.0 | 492.5 | 0.0 | 7.5 | -- | 7.5 | 485.0 | -4.0 |
| Right abutment | 30.9 | 501.1 | 501.1 | 489.0 | 492.6 | 0.0 | 7.0 | -- | 7.0 | 485.6 | -3.4 |

1.Measured along the face of the most constricting side of the bridge.

2.Arbitrary datum for this study.



**Table 2.** Remaining footing/pile depth at abutments for the 500-year discharge at structure TOPSTH00510039 on Town Highway 51, crossing the Tabor Branch Waits River, Topsham, Vermont.

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

| Description | Station[1] | VTAOT minimum low-chord elevation (feet) | Surveyed minimum low-chord elevation[2] (feet) | Bottom of footing/pile elevation[2] (feet) | Channel elevation at abutment/ pier[2] (feet) | Contraction scour depth (feet) | Abutment scour depth (feet) | Pier scour depth (feet) | Depth of total scour (feet) | Elevation of scour[2] (feet) | Remaining footing/pile depth (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 500-yr. discharge is 2,410 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | 501.0 | 501.0 | 489.0 | 492.5 | 0.0 | 8.0 | -- | 8.0 | 484.5 | -4.5 |
| Right abutment | 30.9 | 501.1 | 501.1 | 489.0 | 492.6 | 0.0 | 7.6 | -- | 7.6 | 485.0 | -4.0 |

1.Measured along the face of the most constricting side of the bridge.

2.Arbitrary datum for this study.

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U.S. Geological Survey, 1973, East Corinth, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

# WSPRO INPUT FILE

# WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File tops039.wsp
T2        Hydraulic analysis for structure  TOPSTH00510039  Date: 12-JUN-97
T3        TH 51 crossing Tabor Branch Waits River, 0.1 miles to juntion TH 1
*
J1         * * 0.002
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2600.0   3300.0   1890.0
SK          0.0076   0.0076   0.0076
*
XS   EXITX    -24
GR         -333.3, 518.34   -312.5, 510.61   -229.2, 498.39   -131.8, 498.71
GR         -113.1, 497.41    -69.6, 497.65     -5.4, 498.27      0.0, 496.32
GR            6.6, 492.53     11.1, 492.11     19.7, 491.59     24.0, 491.82
GR           27.9, 492.53     35.1, 496.60     43.3, 498.63     96.7, 500.18
GR          128.1, 501.15    165.5, 501.86    217.8, 504.57    284.9, 509.89
*
N           0.040        0.040        0.045
SA                  -5.4         43.3
*
*
XS   FULLV      0  * * *   0.0000
*
*    Highest of low steel elevationsi was used. This allowed computation of the
*    flow tubes for the Q500 which was not possible using the average low steel
*    elevation.
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    501.07      10.0
GR            0.0, 501.02      0.1, 494.54      6.7, 492.53      7.6, 491.92
GR            9.5, 491.52     13.2, 491.70     17.7, 492.13     22.5, 492.49
GR           26.4, 492.59     30.9, 494.54     31.0, 501.07      0.0, 501.02
*
*         BRTYPE  BRWDTH   EMBSS    EMBELV   WWANGL
CD          4      32.2     2.9     502.5     52.7
N           0.040
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     12      17.4     2
GR         -343.2, 518.26   -270.3, 506.00   -217.3, 502.55   -164.9, 500.96
GR         -127.8, 500.26    -76.8, 500.66    -24.7, 502.13      0.0, 502.46
GR           31.4, 502.55     85.8, 501.70    119.6, 501.11    142.9, 503.26
GR          218.6, 507.05    260.4, 508.33
*
XT   APTEM     49
GR         -349.4, 518.12   -335.4, 513.40   -229.8, 500.19   -169.3, 499.77
GR         -110.4, 499.64    -41.6, 498.10    -10.8, 498.05     -3.9, 497.05
GR            0.0, 494.92      4.6, 492.91      8.4, 492.41     11.2, 492.65
GR           13.8, 492.63     15.9, 492.06     17.3, 492.27     17.9, 492.59
GR           20.3, 492.56     22.9, 492.92     28.6, 493.13     37.0, 497.49
GR           45.9, 499.99     72.1, 501.06    113.1, 502.73    180.6, 509.53
GR          242.2, 511.92
*
AS   APPRO     54 * * * 0.0182
GT
N           0.040        0.045        0.060
SA                 -10.8         45.9
*
HP 1 BRIDG 501.07 1 501.07
HP 2 BRIDG 501.07 * * 1813
HP 1 BRIDG 499.59 1 499.59
HP 2 RDWAY 501.85 * *  787
HP 1 APPRO 502.08 1 502.08
HP 2 APPRO 502.08 * * 2600
*
HP 1 BRIDG 501.07 1 501.07
HP 2 BRIDG 501.07 * * 2069
```

APPENDIX B:

# WSPRO OUTPUT FILE

# WSPRO OUTPUT FILE

```
         U.S. Geological Survey WSPRO Input File tops039.wsp
         Hydraulic analysis for structure  TOPSTH00510039  Date: 12-JUN-97
         TH 51 crossing Tabor Branch Waits River, 0.1 miles to juntion TH 1
            *** RUN DATE & TIME: 10-17-97  13:14
     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#    AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1     257     21739      0     75                     16895088
    501.07          257     21739      0     75  1.00      0     31 16895088
1
   HP 2 BRIDG 501.07 * * 1813

     VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

           WSEL     LEW     REW    AREA        K        Q    VEL
         501.07     0.0    31.0   256.7   21739.    1813.   7.06

 X STA.         0.0        3.2        5.1        6.7        8.1        9.3
   A(I)            21.3       14.4       13.0       12.5       11.4
   V(I)            4.25       6.29       6.97       7.27       7.93

 X STA.         9.3       10.5       11.7       12.9       14.1       15.3
   A(I)            11.4       11.1       10.8       11.0       10.9
   V(I)            7.98       8.18       8.36       8.23       8.33

 X STA.        15.3       16.6       17.8       19.1       20.4       21.8
   A(I)            11.1       11.0       11.4       11.4       11.4
   V(I)            8.14       8.24       7.96       7.96       7.95

 X STA.        21.8       23.2       24.6       26.2       27.9       31.0
   A(I)            11.9       12.2       12.8       14.3       21.2
   V(I)            7.60       7.41       7.10       6.34       4.27

     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
      WSEL  SA#    AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1     212     23505     30     41                         3179
    499.59          212     23505     30     41  1.00      0     31     3179

     VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      12.

           WSEL     LEW     REW    AREA        K        Q    VEL
         501.85  -194.2   127.6   173.8    5980.     787.   4.53

 X STA.      -194.2     -163.8     -154.5     -147.1     -141.1     -135.8
   A(I)            14.0        9.3        8.6        7.6        7.4
   V(I)            2.81       4.22       4.58       5.17       5.35

 X STA.      -135.8     -131.2     -126.9     -122.7     -118.4     -114.0
   A(I)             6.8        6.7        6.6        6.5        6.6
   V(I)            5.77       5.85       5.93       6.01       5.96

 X STA.      -114.0     -109.4     -104.6      -99.5      -94.3      -88.6
   A(I)             6.8        6.8        7.1        7.0        7.5
   V(I)            5.83       5.79       5.58       5.58       5.23

 X STA.       -88.6      -82.4      -75.5      -66.1       99.3      127.6
   A(I)             7.8        8.3        9.5       18.3       14.4
   V(I)            5.06       4.72       4.12       2.15       2.73

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      54.
      WSEL  SA#    AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1     604     42412    233    234                         5516
              2     400     47221     57     59                         6027
              3      49      1214     49     49                          278
    502.08         1053     90847    339    342  1.28   -243     95     9293

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      54.

           WSEL     LEW     REW    AREA        K        Q    VEL
         502.08  -244.2    94.9  1053.0   90847.    2600.   2.47

 X STA.      -244.2     -191.4     -156.0     -124.9      -95.3      -73.6
   A(I)            87.2       77.0       71.0       71.8       63.5
   V(I)            1.49       1.69       1.83       1.81       2.05

 X STA.       -73.6      -56.5      -41.8      -28.4      -15.2       -2.8
   A(I)            57.7       54.6       52.3       51.8       53.7
   V(I)            2.25       2.38       2.49       2.51       2.42

 X STA.        -2.8        3.1        6.8       10.2       13.7       17.0
   A(I)            41.3       33.9       32.3       32.5       32.3
   V(I)            3.15       3.84       4.03       4.00       4.03

 X STA.        17.0       20.6       24.3       28.3       34.0       94.9
   A(I)            33.7       33.9       35.8       43.3       93.4
   V(I)            3.86       3.84       3.63       3.00       1.39
```

```
       U.S. Geological Survey WSPRO Input File tops039.wsp
       Hydraulic analysis for structure  TOPSTH00510039  Date: 12-JUN-97
       TH 51 crossing Tabor Branch Waits River, 0.1 miles to juntion TH 1
          *** RUN DATE & TIME: 10-17-97  13:14
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      257     21739     0     75                     16895088
  501.07           257     21739     0     75  1.00      0     31 16895088

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

        WSEL     LEW     REW    AREA        K        Q    VEL
      501.07     0.0    31.0   256.7   21739.    2069.   8.06

X STA.        0.0         3.2         5.1         6.7         8.1         9.3
  A(I)            21.3        14.4        13.0        12.5        11.4
  V(I)            4.85        7.18        7.95        8.30        9.04

X STA.        9.3        10.5        11.7        12.9        14.1        15.3
  A(I)            11.4        11.1        10.8        11.0        10.9
  V(I)            9.10        9.33        9.54        9.39        9.50

X STA.       15.3        16.6        17.8        19.1        20.4        21.8
  A(I)            11.1        11.0        11.4        11.4        11.4
  V(I)            9.28        9.40        9.08        9.09        9.07

X STA.       21.8        23.2        24.6        26.2        27.9        31.0
  A(I)            11.9        12.2        12.8        14.3        21.2
  V(I)            8.67        8.45        8.11        7.23        4.87

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      221     24977    30     42                         3386
  499.89           221     24977    30     42  1.00      0     31     3386

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      12.

        WSEL     LEW     REW    AREA        K        Q    VEL
      502.16  -204.4   131.0   246.1    9267.    1234.   5.01

X STA.     -204.4      -168.6      -157.9      -149.8      -143.0      -137.0
  A(I)            19.5        13.0        11.4        10.6        10.0
  V(I)            3.16        4.73        5.40        5.82        6.18

X STA.     -137.0      -131.7      -126.7      -121.9      -116.9      -111.7
  A(I)             9.5         9.3         9.0         9.2         9.3
  V(I)            6.52        6.62        6.88        6.73        6.67

X STA.     -111.7      -106.5      -101.0       -95.1       -88.9       -82.2
  A(I)             9.1         9.5         9.7        10.1        10.5
  V(I)            6.74        6.49        6.34        6.09        5.87

X STA.      -82.2       -75.0       -65.6       -48.3       107.7       131.0
  A(I)            10.8        12.3        16.3        29.7        17.2
  V(I)            5.70        5.00        3.78        2.08        3.59

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      54.

    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      686     52038   236    236                         6639
            2      420     51191    57     59                         6481
            3       68      1867    58     58                          416
  502.43          1174    105096   350    353  1.26   -246    104    10857

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      54.

        WSEL     LEW     REW    AREA        K        Q    VEL
      502.43  -247.0   103.5  1173.7  105096.    3300.   2.81

X STA.     -247.0      -196.9      -164.7      -135.0      -106.5       -83.8
  A(I)            93.0        80.1        77.6        76.2        69.2
  V(I)            1.77        2.06        2.13        2.16        2.39

X STA.      -83.8       -65.2       -49.5       -35.7       -22.6        -9.4
  A(I)            65.1        60.9        57.7        56.0        56.4
  V(I)            2.54        2.71        2.86        2.95        2.93

X STA.       -9.4         0.5         5.2         9.0        12.7        16.4
  A(I)            55.8        40.7        36.5        36.2        37.2
  V(I)            2.95        4.05        4.53        4.55        4.44

X STA.       16.4        20.1        24.2        28.5        34.9       103.5
  A(I)            36.5        38.9        39.9        48.7       111.0
  V(I)            4.52        4.25        4.13        3.39        1.49
```

```
       U.S. Geological Survey WSPRO Input File tops039.wsp
       Hydraulic analysis for structure  TOPSTH00510039  Date: 12-JUN-97
       TH 51 crossing Tabor Branch Waits River, 0.1 miles to juntion TH 1
          *** RUN DATE & TIME: 10-17-97  13:14
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      160     15616    30     38                         2091
  497.89           160     15616    30     38  1.00      0     31     2091

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.89     0.0    31.0   160.5   15616.    1890.  11.78

X STA.        0.0         3.7        5.7        7.3        8.6        9.7
  A(I)            14.0        9.2        8.2        7.7        7.1
  V(I)            6.76      10.23      11.55      12.24      13.37

X STA.        9.7        10.8       11.9       13.0       14.1       15.2
  A(I)             7.0        6.6        6.7        6.8        6.7
  V(I)           13.56      14.39      14.13      13.96      14.20

X STA.       15.2        16.3       17.5       18.8       20.0       21.3
  A(I)             6.7        6.8        6.9        7.1        7.1
  V(I)           14.03      13.86      13.68      13.22      13.37

X STA.       21.3        22.7       24.2       25.7       27.5       31.0
  A(I)             7.4        7.6        8.0        9.3       13.7
  V(I)           12.77      12.43      11.87      10.18       6.88

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      54.

    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      237      9236   220    220                         1391
            2      308     30567    57     59                         4075
            3        2        14     9      9                            4
  500.46           546     39817   286    289  1.49   -230     55     3509

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      54.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.46  -231.2    55.2   546.4   39817.    1890.   3.46

X STA.     -231.2       -91.6      -57.4      -37.3      -20.9       -6.1
  A(I)            80.4       52.5       42.8       37.4       36.1
  V(I)            1.17       1.80       2.21       2.52       2.62

X STA.       -6.1         0.5        3.6        6.0        8.2       10.3
  A(I)            26.8       19.9       17.7       17.1       16.2
  V(I)            3.52       4.75       5.33       5.53       5.82

X STA.       10.3        12.4       14.6       16.6       18.7       20.9
  A(I)            16.5       16.6       16.4       17.0       16.7
  V(I)            5.72       5.70       5.75       5.56       5.65

X STA.       20.9        23.2       25.7       28.4       32.0       55.2
  A(I)            17.5       18.7       19.6       23.4       37.0
  V(I)            5.39       5.06       4.82       4.04       2.56
```

# WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File tops039.wsp
        Hydraulic analysis for structure  TOPSTH00510039  Date: 12-JUN-97
        TH 51 crossing Tabor Branch Waits River, 0.1 miles to juntion TH 1
           *** RUN DATE & TIME: 10-17-97  13:14

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                         WSI,CRWS =   498.99     499.20

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******   -234      486  0.74 *****  499.94  499.20    2600  499.20
       -23 ******     63    34463  1.67 ***** *******    0.95    5.35

FULLV:FV       24   -236      605  0.46  0.11  500.04 *******    2600  499.59
         0     24     76    44417  1.59  0.00    0.00    0.69    4.30
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.98     499.57     499.41

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   499.09     518.21    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   499.09     518.21     499.41

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.59

APPRO:AS       54   -101      341  1.13  0.32  500.68  499.41    2600  499.55
        54     54     44    26080  1.25  0.34   -0.01    0.98    7.62
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
             WS1,WSSD,WS3,RGMIN =   502.52       0.00     498.73     500.26

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
             WS3,WSIU,WS1,LSEL =   498.78     501.37     501.48     501.07

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

            <<<<<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       24      0      257  0.78 *****  501.85  497.42    1813  501.07
         0 ******     31    21739  1.00 ***** *******    0.43    7.07

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.386  0.000  501.07 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.    37.  0.03  0.12  502.17    0.00    787.  501.85

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    705.   160.  -194.   -35.   1.6   1.0   5.1   4.5   1.3   3.0
   RT:     81.    52.    76.   128.   0.7   0.4   3.5   4.3   0.7   2.8

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPRO:AS       22   -243     1053  0.12  0.06  502.20  499.41    2600  502.08
        54     24     95    90790  1.28  0.46    0.00    0.28    2.47

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW     REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -24.  -235.     63.   2600.   34463.      486.    5.35  499.20
   FULLV:FV       0.  -237.     76.   2600.   44417.      605.    4.30  499.59
   BRIDG:BR       0.     0.     31.   1813.   21739.      257.    7.07  501.07
   RDWAY:RG      12.*******    705.    787.******************    2.00  501.85
   APPRO:AS      54.  -244.     95.   2600.   90790.     1053.    2.47  502.08

  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    499.20    0.95  491.59  518.34************  0.74  499.94  499.20
   FULLV:FV  ********    0.69  491.59  518.34  0.11  0.00  0.46  500.04  499.59
   BRIDG:BR    497.42    0.43  491.52  501.07************  0.78  501.85  501.07
   RDWAY:RG  ****************  500.26  518.26  0.03******  0.12  502.17  501.85
   APPRO:AS    499.41    0.28  492.15  518.21  0.06  0.46  0.12  502.20  502.08
```

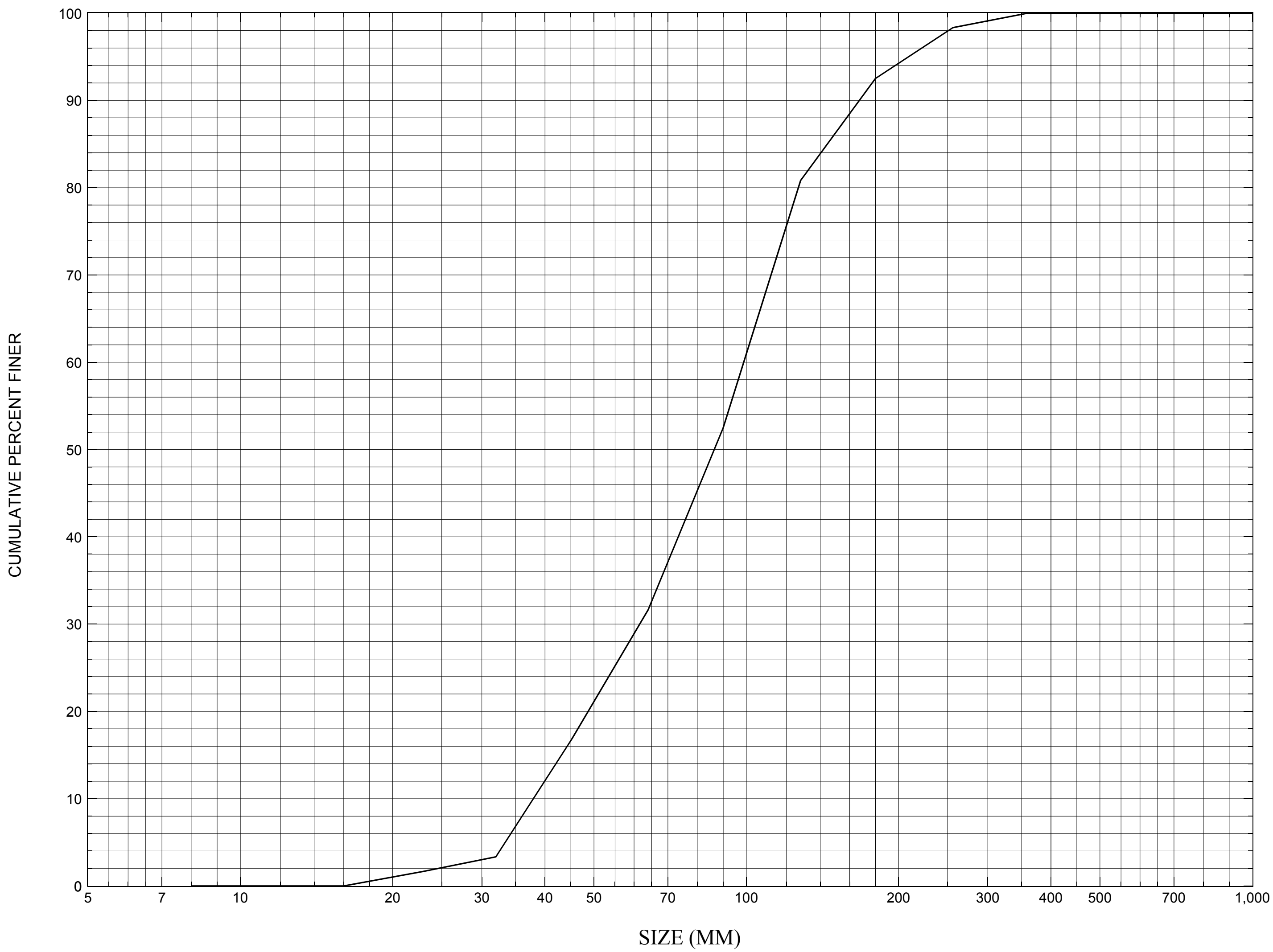
```
       U.S. Geological Survey WSPRO Input File tops039.wsp
       Hydraulic analysis for structure  TOPSTH00510039  Date: 12-JUN-97
       TH 51 crossing Tabor Branch Waits River, 0.1 miles to juntion TH 1
          *** RUN DATE & TIME: 10-17-97  13:14

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                           WSI,CRWS =   499.34     499.49

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******   -236      575  0.83 *****  500.32  499.49    3300  499.49
       -23 ******     73    41753  1.61 ***** *******    0.94    5.74

FULLV:FV       24   -238      703  0.52  0.12  500.42 *******    3300  499.89
         0     24     87    53367  1.53  0.00   -0.02    0.70    4.70
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.20     499.76     500.42

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   499.39     518.21    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   499.39     518.21     500.42

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   500.42     518.21     500.42

APPRO:AS       54   -230      535  0.88 *****  501.30  500.42    3300  500.42
        54     54     54    38869  1.49 ***** *******    0.97    6.17
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   504.21       0.00     499.77     500.26

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   499.46     501.95     502.06     501.07

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

            <<<<<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       24      0      257  1.01 *****  502.08  497.86    2069  501.07
         0 ******     31    21739  1.00 ***** *******    0.49    8.06

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.426  0.000  501.07 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.    37.  0.04  0.16  502.55    0.00   1234.  502.16

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1050.   182.  -205.   -22.   1.9   1.1   5.7   5.0   1.5   3.1
   RT:    184.    75.    56.   131.   1.1   0.5   4.1   4.8   0.9   2.9

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPRO:AS       22   -246     1172  0.16  0.09  502.58  500.42    3300  502.43
        54     28    103   104923  1.26  0.39    0.00    0.30    2.82

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ****** ********

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -24.  -237.    73.   3300.   41753.     575.    5.74  499.49
   FULLV:FV       0.  -239.    87.   3300.   53367.     703.    4.70  499.89
   BRIDG:BR       0.     0.    31.   2069.   21739.     257.    8.06  501.07
   RDWAY:RG      12.******* 1050.   1234.*****************    2.00  502.16
   APPRO:AS      54.  -247.   103.   3300.  104923.    1172.    2.82  502.43

  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    499.49    0.94  491.59  518.34************  0.83  500.32  499.49
   FULLV:FV  ********    0.70  491.59  518.34  0.12  0.00  0.52  500.42  499.89
   BRIDG:BR    497.86    0.49  491.52  501.07************  1.01  502.08  501.07
   RDWAY:RG  ***************  500.26  518.26  0.04******  0.16  502.55  502.16
   APPRO:AS    500.42    0.30  492.15  518.21  0.09  0.39  0.16  502.58  502.43
```

# WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File tops039.wsp
       Hydraulic analysis for structure  TOPSTH00510039  Date: 12-JUN-97
       TH 51 crossing Tabor Branch Waits River, 0.1 miles to juntion TH 1
          *** RUN DATE & TIME: 10-17-97  13:14

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******   -229      289  0.97 *****  499.44  498.40    1890  498.47
       -23 ******     43    21661  1.46 ***** *******    1.14    6.54

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.50

FULLV:FV       24   -233      460  0.44  0.12  499.55 *******    1890  499.11
         0     24     60    32441  1.68  0.00   -0.01    0.75    4.11
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.84     499.18     497.96

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   498.61     518.21    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   498.61     518.21     497.96

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  0.69

APPRO:AS       54    -86      292  0.79  0.27  499.99  497.96    1890  499.20
        54     54     43    22247  1.21  0.17    0.00    0.84    6.47
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   500.46       0.00     497.89     500.26

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   500.43      1890.         0.

 ===280 REJECTED FLOW CLASS 4 SOLUTION.

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

 ===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                       YU/Z,WSIU,WS = 1.07     501.68     501.72

 ===270 REJECTED FLOW CLASS 2 (5) SOLUTION.

           <<<<<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       24      0      161  2.16  0.25  500.05  497.54    1890  497.89
         0     24     31    15621  1.00  0.35    0.00    0.90   11.77

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  1.000 ******  501.07 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS       22   -230      548  0.28  0.14  500.74  497.96    1890  500.46
        54     24     55    39914  1.49  0.56    0.00    0.54    3.45

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.761  0.291   28234.    -1.    30.   500.38

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -24.  -230.    43.   1890.   21661.     289.    6.54  498.47
   FULLV:FV       0.  -234.    60.   1890.   32441.     460.    4.11  499.11
   BRIDG:BR       0.     0.    31.   1890.   15621.     161.   11.77  497.89
   RDWAY:RG      12.**************      0.       0.       0.    2.00********
   APPRO:AS      54.  -231.    55.   1890.   39914.     548.    3.45  500.46

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    498.40    1.14  491.59  518.34************  0.97  499.44  498.47
   FULLV:FV  ********    0.75  491.59  518.34  0.12  0.00  0.44  499.55  499.11
   BRIDG:BR    497.54    0.90  491.52  501.07  0.25  0.35  2.16  500.05  497.89
   RDWAY:RG  ****************  500.26  518.26************  0.08  501.78********
   APPRO:AS    497.96    0.54  492.15  518.21  0.14  0.56  0.28  500.74  500.46
```

APPENDIX C:

# BED-MATERIAL PARTICLE-SIZE DISTRIBUTION




Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure TOPSTH00510039, in Topsham, Vermont.

APPENDIX D:

# HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

# Structure Number TOPSTH00510039

## General Location Descriptive

Data collected by *(First Initial, Full last name)* E. BOEHMLER

Date *(MM/DD/YY)* 03 / 28 / 95

Highway District Number *(I - 2; nn)* 07

County *(FIPS county code; I - 3; nnn)* 017

Town *(FIPS place code; I - 4; nnnnn)* 73075

Mile marker *(I - 11; nnn.nnn)* 000000

Waterway *(I - 6)* Tabor Branch Waits River

Road Name *(I - 7):* -

Route Number TH051

Vicinity *(I - 9)* 0.1 MI JCT TH 51 + TH 1

Topographic Map East Corinth

Hydrologic Unit Code: 01080103

Latitude *(I - 16; nnnn.n)* 44064

Longitude *(i - 17; nnnnn.n)* 72140

## Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10091200390912

Maintenance responsibility *(I - 21; nn)* 03

Maximum span length *(I - 48; nnnn)* 0032

Year built *(I - 27; YYYY)* 1985

Structure length *(I - 49; nnnnnn)* 000034

Average daily traffic, ADT *(I - 29; nnnnnn)* 000010

Deck Width *(I - 52; nn.n)* 174

Year of ADT *(I - 30; YY)* 93

Channel & Protection *(I - 61; n)* 8

Opening skew to Roadway *(I - 34; nn)* 10

Waterway adequacy *(I - 71; n)* 7

Operational status *(I - 41; X)* A

Underwater Inspection Frequency *(I - 92B; XYY)* N

Structure type *(I - 43; nnn)* 101

Year Reconstructed *(I - 106)* 0000

Approach span structure type *(I - 44; nnn)* 000

Clear span (*nnn.n ft*) 030.0

Number of spans *(I - 45; nnn)* 001

Vertical clearance from streambed (*nnn.n ft*) 008.0

Number of approach spans *(I - 46; nnnn)* 0000

Waterway of full opening (*nnn.n* $ft^2$) 240.0

Comments:

**The structural inspection report of 8/30/93 indicates the structure is a concrete slab type bridge. The abutment walls and wingwalls are concrete. Each abutment has fine diagonal cracks and small leaks reported at the top corners. There is stone and boulder fill placed in front of the abutment walls and wingwalls and partially along the banks. The streambed is mainly gravel and boulders. The footings are not exposed and there has been little, if any, settling. Channel scour is reported as normal. Point bar and debris accumulation problems are noted as minor at this site. The crossing is reported as being in good condition, since the bridge is relatively new.**

## Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *($mi^2$)*: 17.5

Terrain character: -

Stream character & type: -

Streambed material: Gravel and boulders.

Discharge Data *(cfs)*: $Q_{2.33}$ - $Q_{10}$ 1400 $Q_{25}$ 1900

$Q_{50}$ 2300 $Q_{100}$ 2600 $Q_{500}$ -

Record flood date *(MM / DD / YY)*: - / / Water surface elevation *(ft)*: -

Estimated Discharge *(cfs)*: - Velocity at Q 25 *(ft/s)*: 11.2

Ice conditions *(Heavy, Moderate, Light)* : - Debris *(Heavy, Moderate, Light)*: -

The stage increases to maximum highwater elevation (*Rapidly, Not rapidly*): -

The stream response is (*Flashy, Not flashy*): -

Describe any significant site conditions upstream or downstream that may influence the stream's stage: -

Watershed storage area (*in percent*): - %

The watershed storage area is: - (*1-mainly at the headwaters; 2- uniformly distributed; 3-immediatly upstream oi the site*)

Water Surface Elevation Estimates for Existing Structure:

| Peak discharge frequency | $Q_{2.33}$ | $Q_{10}$ | $Q_{25}$ | $Q_{50}$ | $Q_{100}$ |
|---|---|---|---|---|---|
| Water surface elevation (*ft*) | - | 498.3 | 499.8 | 500.9 | 501.8 |
| Velocity (*ft / sec*) | - | - | 11.2 | - | - |

Long term stream bed changes: -

Is the roadway overtopped below the $Q_{100}$? (*Yes, No, Unknown*): Y Frequency: Q30

Relief Elevation (*ft*): - Discharge over roadway at $Q_{100}$ (*$ft^3$/ sec*): -

Are there other structures nearby? (*Yes, No, Unknown*): U *If No or Unknown, type ctrl-n os*

Upstream distance (*miles*): - Town: Topsham Year Built: -

Highway No. : TH01 Structure No. : 10 Structure Type: Concrete slab

Clear span (*ft*): 22.0 Clear Height (*ft*): 13.0 Full Waterway (*$ft^2$*): 286.0

Downstream distance (*miles*): - Town: Topsham Year Built: 1960

Highway No. : TH63 Structure No. : 25 Structure Type: Steel stringer

Clear span (*ft*): 33.0 Clear Height (*ft*): 8.0 Full Waterway ($ft^2$): 264.0

Comments:

**The hydraulics report recommended that class II stone fill be used for channel and bridge protection.**

## USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 17.44 $mi^2$

Lake/pond/swamp area 0.03 $mi^2$

Watershed storage *(ST)* 0.2 %

Bridge site elevation 840 ft

Headwater elevation 2346 ft

Main channel length 7.19 mi

10% channel length elevation 880 ft

85% channel length elevation 1840 ft

Main channel slope *(S)* 178.03 ft / mi

Watershed Precipitation Data

Average site precipitation - in

Average headwater precipitation - in

Maximum 2yr-24hr precipitation event *(I24,2)* - in

Average seasonal snowfall *(Sn)* - ft

## Bridge Plan Data

Are plans available? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: 01 / 1985

Project Number FTH 3550 Minimum channel bed elevation: 492.0

Low superstructure elevation: USLAB 500.45 DSLAB 500.11 USRAB 500.53 DSRAB 500.14

Benchmark location description:

**BM on top of concrete, at the downstream end of the right abutment near where the abutment meets the wingwall, elevation 502.45.**

Reference Point (*MSL, Arbitrary, Other*): Arbitrary Datum (*NAD27, NAD83, Other*): Arbitrary

Foundation Type: 1 (*1-Spreadfooting; 2-Pile; 3- Gravity; 4-Unknown*)

If 1: Footing Thickness 2.0 Footing bottom elevation: 489.0

If 2: Pile Type: ____ (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: _______

If 3: Footing bottom elevation: ______

Is boring information available? N *If no, type ctrl-n bi* Number of borings taken: -

Foundation Material Type: 3 (*1-regolith, 2-bedrock, 3-unknown*)

Briefly describe material at foundation bottom elevation or around piles:

-

Comments:

**Other points shown on the plans with elevations are: 1) the point on top of the upstream right wingwall concrete at the streamward edge where the concrete slope changes from horizontal to downward, elevation 502.87, and 2) the point at the same location but on the upstream left wingwall, elevation 502.79. Plans indicate that class II stone fill is placed along the abutments under the bridge. The superstructure elevations given above are bridge seat elevations from the plans.**

## Cross-sectional Data

Is cross-sectional data available? **Y** *If no, type ctrl-n xs*

Source (*FEMA, VTAOT, Other*)? **VTAOT**

Comments: **There are several cross sections printed and kept with the plans and may be retrieved when needed. No bridge cross sections are reproducible due to differences between VTAOT and USGS survey methods.**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | - | - | - | - | - | - | - | - | - | - | - |
| Feature | - | - | - | - | - | - | - | - | - | - | - |
| Low cord elevation | - | - | - | - | - | - | - | - | - | - | - |
| Bed elevation | - | - | - | - | - | - | - | - | - | - | - |
| Low cord to bed length | - | - | - | - | - | - | - | - | - | - | - |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | - | - | - | - | - | - | - | - | - | - | - |
| Feature | - | - | - | - | - | - | - | - | - | - | - |
| Low cord elevation | - | - | - | - | - | - | - | - | - | - | - |
| Bed elevation | - | - | - | - | - | - | - | - | - | - | - |
| Low cord to bed length | - | - | - | - | - | - | - | - | | - | - |

Source (*FEMA, VTAOT, Other*)? -

Comments: -

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | - | - | - | - | - | - | - | - | - | - | - |
| Feature | - | - | - | - | - | - | - | - | - | - | - |
| Low cord elevation | - | - | -- | - | - | - | - | - | - | - | - |
| Bed elevation | - | - | - | - | - | - | - | - | - | - | - |
| Low cord to bed length | - | - | - | - | - | - | - | - | - | - | - |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | - | - | - | - | - | - | - | - | - | - | - |
| Feature | - | - | - | - | - | - | - | - | - | - | - |
| Low cord elevation | - | - | - | - | - | - | - | - | - | - | - |
| Bed elevation | - | - | - | - | - | - | - | - | - | - | - |
| Low cord to bed length | - | - | - | - | - | - | - | - | - | - | - |

APPENDIX E:

# LEVEL I DATA FORM

U. S. Geological Survey
Bridge Field Data Collection and Processing Form

Qa/Qc Check by: **EW** Date: **03/26/96**
Computerized by: **EW** Date: **03/26/96**
Reviewd by: **LKS** Date: **07/14/97**

# Structure Number **TOPSTH00510039**

## A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **T. SEVERANCE** Date *(MM/DD/YY)* **08** / **31** / 19**95**
2. Highway District Number **07** Mile marker **-**
County **Orange (017)** Town **Topsham (73075)**
Waterway *(I - 6)* **Tabor Branch Waits River** Road Name **-**
Route Number **TH005** Hydrologic Unit Code: **101080103**
3. Descriptive comments:
**The bridge is located 0.1 miles from the junction of TH 5 and TH 1.**

## B. Bridge Deck Observations

4. Surface cover... LBUS **4** RBUS **4** LBDS **4** RBDS **4** Overall **4**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US **2** UB **1** DS **1** *(**1**- pool; **2**- riffle)*
6. Bridge structure type **1** *( **1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length **34** *(feet)* Span length **32** *(feet)* Bridge width **17.4** *(feet)*

### Road approach to bridge:

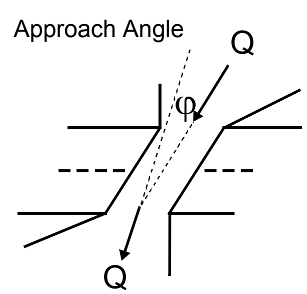
8. LB **1** RB **1** *( **0** even, **1**- lower, **2**- higher)*
9. LB **2** RB **2** *( **1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left **2.9:1** US right **2.8:1**

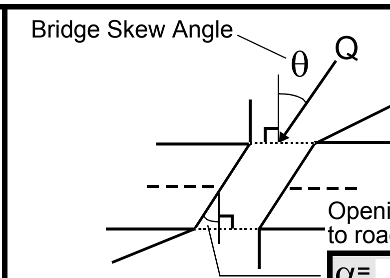
| | Protection | | 13.Erosion | 14.Severity |
|---|---|---|---|---|
| | 11.Type | 12.Cond. | | |
| LBUS | 0 | - | 0 | 0 |
| RBUS | 0 | - | 0 | 0 |
| RBDS | 0 | - | 0 | 0 |
| LBDS | 0 | - | 0 | 0 |

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*
*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

### Channel approach to bridge (BF):

15. Angle of approach: **30** 16. Bridge skew: **5**




Opening skew to roadway $\alpha$= **10.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **0** feet **US** *(US, UB, DS)* to **30** feet **US**
Channel impact zone 2: Exist? **N** *(Y or N)*
Where? ____ *(LB, RB)* Severity ____
Range? ____ feet ____ *(US, UB, DS)* to ____ feet ____

*Impact Severity: **0**- none to very slight; **1**- Slight; **2**- Moderate; **3**- Severe*

18. Bridge Type: **1a**

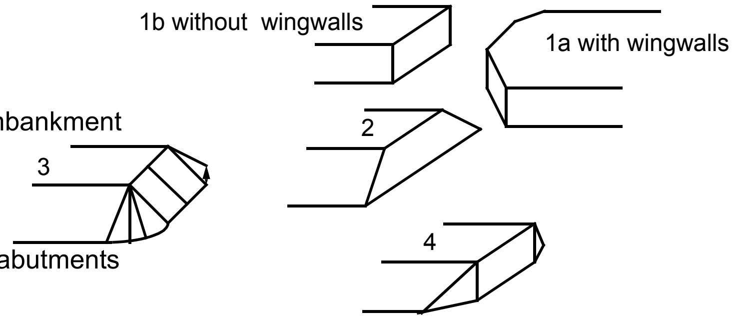
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls parallel to abut. face

3- Spill through abutments

4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.




19. Bridge Deck Comments (surface cover variations, measured bridge and span lengths, bridge type variations, approach overflow width, etc.)

**#4: The surface cover at the site is primarily pasture with trees and shrubs along immediate banks of channel**
**#7: VT AOT bridge measurements differ from the following field measured values: bridge length = 33.8 feet; span length = 32.2 feet; bridge width = 17.5 feet**
**The bridge has a concrete deck with Armco guard rails.**
**There is an electric fence downstream on the left and right bank parallel to road and channel. The fence also extends along the upstream left bank and upstream left road approach.**

## C. Upstream Channel Assessment

| 20. SRD | 21. Bank height (BF) LB | 21. Bank height (BF) RB | 22. Bank angle (BF) LB | 22. Bank angle (BF) RB | 26. % Veg. cover (BF) LB | 26. % Veg. cover (BF) RB | 27. Bank material (BF) LB | 27. Bank material (BF) RB | 28. Bank erosion (BF) LB | 28. Bank erosion (BF) RB |
|---|---|---|---|---|---|---|---|---|---|---|
| **30.0** | **5.0** | | | **7.0** | **1** | **1** | **2** | **2** | **0** | **1** |

23. Bank width **20.0**  24. Channel width **20.0**  25. Thalweg depth **56.5**  29. Bed Material **4**

30 .Bank protection type: LB **2** RB **2**  31. Bank protection condition: LB **1** RB **1**

*SRD - Section ref. dist. to US face*  *% Vegetation (Veg) cover: **1**- 0 to 25%; **2**- 26 to 50%; **3**- 51 to 75%; **4**- 76 to 100%*
*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*
*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*
*Bank protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

32. Comments (bank material variation, minor inflows, protection extent, etc.):

**The left and right banks are well protected. Type-2 stone fill extends upstream for 60 feet on the right bank and 63 feet on the left bank.**
**#38: Bedrock also surfaces from 49 feet upstream to 62 feet upstream.**

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **32** 35. Mid-bar width: **8**

36. Point bar extent: **9** feet **US** (US, UB) to **44** feet **US** (US, UB, DS) positioned **80** %LB to **100** %RB

37. Material: **4**

38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):

**There is a large segment of bedrock surfacing in the center of the channel at mid-bar (28 feet to 40 feet). There is an additional point bar on left bank extending from 60 feet to 130 feet upstream. The point bar is positioned from 0% left bank to 20% right bank. The mid-bar distance is 92 feet while the mid-bar width is 6 feet. The point bar material is cobble.**

39. Is a cut-bank present? **Y** (Y or if N type ctrl-n cb) 40. Where? **RB** (LB or RB)

41. Mid-bank distance: **78** 42. Cut bank extent: **63** feet **US** (US, UB) to **130** feet **US** (US, UB, DS)

43. Bank damage: **1** ( *1*- eroded and/or creep; *2*- slip failure; *3*- block failure)

44. Cut bank comments (eg. additional cut banks, protection condition, etc.):

**With a range pole, one can penetrate horizontally beneath the overhanging bank material up to 3.5 feet. Tree roots are exposed in the cut-bank area.**

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **72**

47. Scour dimensions: Length **30** Width **5** Depth : **1** Position **55** %LB to **90** %RB

48. Scour comments (eg. additional scour areas, local scouring process, etc.):

**-**

49. Are there major confluences? **N** (Y or if N type ctrl-n mc) 50. How many? **-**

51. Confluence 1: Distance **-** 52. Enters on **-** (LB or RB) 53. Type **-** ( *1*- perennial; *2*- ephemeral)

Confluence 2: Distance **-** Enters on **-** (LB or RB) Type **-** ( *1*- perennial; *2*- ephemeral)

54. Confluence comments (eg. confluence name):

**There are no major confluences at the site upstream.**

## D. Under Bridge Channel Assessment

55. Channel restraint (BF)? LB **2** RB ______ (*1*- natural bank; *2*- abutment; *3*- artificial levee)

| 56. Height (BF) LB | 56. Height (BF) RB | 57 Angle (BF) LB | 57 Angle (BF) RB | 61. Material (BF) LB | 61. Material (BF) RB | 62. Erosion (BF) LB | 62. Erosion (BF) RB |
|---|---|---|---|---|---|---|---|
| **24.0** | | **1.0** | | **2** | **7** | **7** | **0** |

58. Bank width (BF) **-** 59. Channel width **-** 60. Thalweg depth **90.0** 63. Bed Material **0**

*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*

*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*

64. Comments (bank material variation, minor inflows, protection extent, etc.):

**4**

**There is 0.5 feet of channel scour beneath the bridge (refer to sketch on Pg. 45). The scour is 2 to 3 feet long. The protection along the abutments was in good condition, as of 08/30/95.**

65. **Debris and Ice** Is there debris accumulation? ____ *(Y or N)* 66. Where? N____ *(1- Upstream; 2- At bridge; 3- Both)*

67. Debris Potential -____ *( 1- Low; 2- Moderate; 3- High)* 68. Capture Efficiency 1____ *( 1- Low; 2- Moderate; 3- High)*

69. Is there evidence of ice build-up? 1___ *(Y or N)* Ice Blockage Potential N____ *( 1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

**1**

**-**

| Abutments | 71. Attack ∠(BF) | 72. Slope ∠ (Qmax) | 73. Toe loc. (BF) | 74. Scour Condition | 75. Scour depth | 76. Exposure depth | 77. Material | 78. Length |
|---|---|---|---|---|---|---|---|---|
| LABUT | | 5 | 90 | 2 | 0 | - | - | 90.0 |
| RABUT | 1 | - | 90 | | | 2 | 0 | 30.5 |

*Pushed: LB or RB* *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
*Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed*
Materials: *1*- Concrete; *2*- Stone masonry or drywall; *3*- steel or metal; *4*- wood

79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

**-**

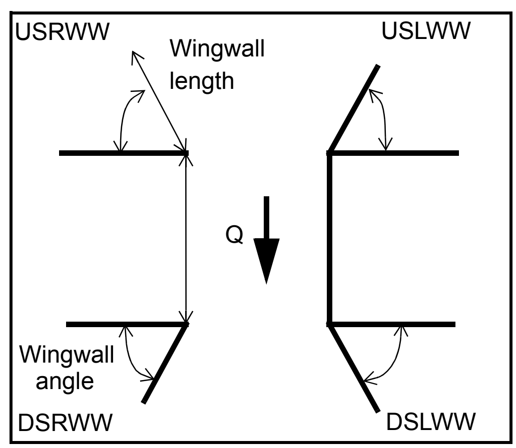
**-**

**1**

**Both abutments are in good condition. There was no debris noted underneath the bridge as of 08/30/95.**

80. **Wingwalls**:

| | Exist? | Material? | Scour Condition? | Scour depth? | Exposure depth? | 81. Angle? | Length? |
|---|---|---|---|---|---|---|---|
| USLWW: | | | | | | 30.5 | |
| USRWW: | Y | | 1 | | 0 | 1.0 | |
| DSLWW: | - | | - | | Y | 23.5 | |
| DSRWW: | 1 | | 0 | | - | 23.5 | |




*Wingwall materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood*

82. **Bank / Bridge Protection**:

| Location | USLWW | USRWW | LABUT | RABUT | LB | RB | DSLWW | DSRWW |
|---|---|---|---|---|---|---|---|---|
| Type | - | 0 | Y | - | 1 | 1 | 1 | 1 |
| Condition | Y | - | 1 | - | 1 | 1 | 1 | 1 |
| Extent | 1 | - | 0 | 2 | 2 | 2 | 2 | - |

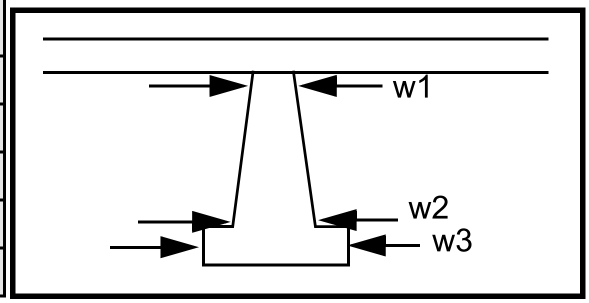
*Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee*
*Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed*
*Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other*

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
1
2
1
1

## Piers:

84. Are there piers? **Th** (Y or if N type ctrl-n pr)

| 85. Pier no. | width (w) feet | | | elevation (e) feet | | |
|---|---|---|---|---|---|---|
| | w1 | w2 | w3 | e@w1 | e@w2 | e@w3 |
| Pier 1 | | | | 50.0 | 12.5 | 55.0 |
| Pier 2 | 9.5 | | | 55.0 | 10.0 | 50.0 |
| Pier 3 | | - | - | 13.0 | - | - |
| Pier 4 | - | - | - | - | - | - |




| Level 1 Pier Descr. | 1 | 2 | 3 | 4 | |
|---|---|---|---|---|---|
| 86. Location (BF) | ere | Level I | | - | *LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP* |
| 87. Type | were | asses | | - | ***1**- Solid pier, **2**- column, **3**- bent* |
| 88. Material | no | smen | N | - | ***1**- Wood; **2**- concrete; **3**- metal; **4**- stone* |
| 89. Shape | prob | t. | - | - | ***1**- Round; **2**- Square; **3**- Pointed* |
| 90. Inclined? | lems | | - | - | *Y- yes; N- no* |
| 91. Attack ∠ (BF) | obse | | - | - | |
| 92. Pushed | rved | | - | - | *LB or RB* |
| 93. Length (feet) | - | - | - | - | |
| 94. # of piles | at | | - | - | |
| 95. Cross-members | the | | - | - | ***0**- none; **1**- laterals; **2**- diagonals; **3**- both* |
| 96. Scour Condition | time | | - | - | ***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed* |
| 97. Scour depth | of | | - | - | |
| 98. Exposure depth | the | | - | - | |

99. Pier comments (eg. undermined penetration, protection and protection extent, unusual scour processes, etc.):
-
-
-
-
-
-
-
-
-
-

## E. Downstream Channel Assessment

100.

| SRD | Bank height (BF) LB | Bank height (BF) RB | Bank angle (BF) LB | Bank angle (BF) RB | % Veg. cover (BF) LB | % Veg. cover (BF) RB | Bank material (BF) LB | Bank material (BF) RB | Bank erosion (BF) LB | Bank erosion (BF) RB |
|---|---|---|---|---|---|---|---|---|---|---|
| - | - | | | - | - | - | - | - | - | - |

Bank width (BF) - Channel width - Thalweg depth - Bed Material -

Bank protection type (Qmax): LB - RB - Bank protection condition: LB - RB -

*SRD - Section ref. dist. to US face* *% Vegetation (Veg) cover: **1**- 0 to 25%; **2**- 26 to 50%; **3**- 51 to 75%; **4**- 76 to 100%*
*Bed and bank Material: **0**- organics; **1**- silt / clay, < 1/16mm; **2**- sand, 1/16 - 2mm; **3**- gravel, 2 - 64mm; **4**- cobble, 64 - 256mm; **5**- boulder, > 256mm; **6**- bedrock; **7**- manmade*
*Bank Erosion: **0**- not evident; **1**- light fluvial; **2**- moderate fluvial; **3**- heavy fluvial / mass wasting*
*Bank protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

Comments (eg. bank material variation, minor inflows, protection extent, etc.):
-
-
-
-
-
-
**There are no piers.**

101. Is a drop structure present? ____ *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet
103. Drop: - feet 104. Structure material: 1 *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*
105. Drop structure comments (eg. downstream scour depth):
**1**
**2**
**2**
**0**
**0**
**4**

106. Point/Side bar present? 2 (Y or N. if N type ctrl-n pb) Mid-bar distance: 2 Mid-bar width: 1

Point bar extent: 1 feet Th (US, UB, DS) to e left feet and (US, UB, DS) positioned rig %LB to ht %RB

Material: ba

Point or side bar comments (Circle Point or Side; note additional bars, material variation, status, etc.):

**nks are protected with type-2 stone fill.**
**The left bank protection extends from 0 feet downstream to 34 feet downstream.**
**The right bank protection extends from 0 feet downstream to 32 feet downstream.**

Is a cut-bank present? ____ (Y or if N type ctrl-n cb) Where? ____ (LB or RB) Mid-bank distance: ____

Cut bank extent: ____ feet ____ (US, UB, DS) to ____ feet ____ (US, UB, DS)

Bank damage: ____ ( **1**- eroded and/or creep; **2**- slip failure; **3**- block failure)

Cut bank comments (eg. additional cut banks, protection condition, etc.):

**N**

Is channel scour present? - (Y or if N type ctrl-n cs) Mid-scour distance: Ther

Scour dimensions: Length e is Width no Depth: dro Positioned p %LB to stru %RB

Scour comments (eg. additional scour areas, local scouring process, etc.):

**cture at this site.**

Are there major confluences? ____ (Y or if N type ctrl-n mc) How many? ____

Confluence 1: Distance Y Enters on 53 (LB or RB) Type 4.5 ( **1**- perennial; **2**- ephemeral)

Confluence 2: Distance 45 Enters on DS (LB or RB) Type 61 ( **1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

**DS**
**85**

## F. Geomorphic Channel Assessment

107. Stage of reach evolution 100

***1***- *Constructed*
***2***- *Stable*
***3***- *Aggraded*
***4***- *Degraded*
***5***- *Laterally unstable*
***6***- *Vertically and laterally unstable*

108. Evolution comments *(Channel evolution not considering bridge effects; See HEC-20, Figure 1 for geomorphic descriptors)*:

**4**

**Along the left half of the channel, the bed material is bedrock. There is a mid-channel bar extending from 92 feet downstream to 139 feet downstream with a mid-bar width of 9 feet at 116 feet downstream.**

**Y**
**LB**
**55**
**52**
**DS**
**60**
**DS**
**1**

## 109. G. Plan View Sketch

- T

| | | | |
|---|---|---|---|
| point bar (pb) | debris | flow (Q) | stone wall |
| cut-bank (cb) | rip rap or stone fill | cross-section | other wall |
| scour hole | | ambient channel | |

# APPENDIX F:

# SCOUR COMPUTATIONS

**SCOUR COMPUTATIONS**

Structure Number: TOPSTH00510039 Town: TOPSHAM
Road Number: TH 51 County: ORANGE
Stream: TABOR BRANCH WAITS RIVER

Initials LKS Date: 07/01/97 Checked: EMB

Analysis of contraction scour, live-bed or clear water?

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1995, p. 28, eq. 16)

Approach Section

| Characteristic | 100 yr | 500 yr | other Q |
|---|---|---|---|
| Total discharge, cfs | 2600 | 3300 | 1890 |
| Main Channel Area, ft2 | 400 | 420 | 308 |
| Left overbank area, ft2 | 604 | 686 | 237 |
| Right overbank area, ft2 | 49 | 68 | 2 |
| Top width main channel, ft | 57 | 57 | 57 |
| Top width L overbank, ft | 233 | 236 | 220 |
| Top width R overbank, ft | 49 | 58 | 9 |
| D50 of channel, ft | 0.2834 | 0.2834 | 0.2834 |
| D50 left overbank, ft | -- | -- | -- |
| D50 right overbank, ft | -- | -- | -- |
| y1, average depth, MC, ft | 7.0 | 7.4 | 5.4 |
| y1, average depth, LOB, ft | 2.6 | 2.9 | 1.1 |
| y1, average depth, ROB, ft | 1.0 | 1.2 | 0.2 |
| Total conveyance, approach | 90847 | 105096 | 39817 |
| Conveyance, main channel | 47221 | 51191 | 30567 |
| Conveyance, LOB | 42412 | 52038 | 9236 |
| Conveyance, ROB | 1214 | 1867 | 14 |
| Percent discrepancy, conveyance | 0.0000 | 0.0000 | 0.0000 |
| Qm, discharge, MC, cfs | 1351.4 | 1607.4 | 1450.9 |
| Ql, discharge, LOB, cfs | 1213.8 | 1634.0 | 438.4 |
| Qr, discharge, ROB, cfs | 34.7 | 58.6 | 0.7 |
| Vm, mean velocity MC, ft/s | 3.4 | 3.8 | 4.7 |
| Vl, mean velocity, LOB, ft/s | 2.0 | 2.4 | 1.8 |
| Vr, mean velocity, ROB, ft/s | 0.7 | 0.9 | 0.3 |
| Vc-m, crit. velocity, MC, ft/s | 10.2 | 10.3 | 9.8 |
| Vc-l, crit. velocity, LOB, ft/s | ERR | ERR | ERR |
| Vc-r, crit. velocity, ROB, ft/s | ERR | ERR | ERR |

Results

| Live-bed(1) or Clear-Water(0) Contraction Scour? | | | |
|---|---|---|---|
| Main Channel | 0 | 0 | 0 |
| Left Overbank | N/A | N/A | N/A |
| Right Overbank | N/A | N/A | N/A |

**Clear Water Contraction Scour in MAIN CHANNEL**

y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)    Converted to English Units
ys=y2-y_bridge
(Richardson and others, 1995, p. 32, eq. 20, 20a)

| Bridge Section | Q100 | Q500 | Other Q |
|---|---|---|---|
| (Q) total discharge, cfs | 2600 | 3300 | 1890 |
| (Q) discharge thru bridge, cfs | 1813 | 2069 | 1890 |
| Main channel conveyance | 21739 | 21739 | 15616 |
| Total conveyance | 21739 | 21739 | 15616 |
| Q2, bridge MC discharge,cfs | 1813 | 2069 | 1890 |
| Main channel area, ft2 | 257 | 257 | 161 |
| Main channel width (normal), ft | 30.5 | 30.5 | 30.5 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 30.5 | 30.5 | 30.5 |
| y_bridge (avg. depth at br.), ft | 8.42 | 8.43 | 5.28 |
| Dm, median (1.25*D50), ft | 0.35425 | 0.35425 | 0.35425 |
| y2, depth in contraction,ft | 5.52 | 6.18 | 5.72 |
| ys, scour depth (y2-ybridge), ft | -2.90 | -2.24 | **0.44** |

Armoring
Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)
(Federal Highway Administration, 1993)

| Downstream bridge face property | 100-yr | 500-yr | Other Q |
|---|---|---|---|
| Q, discharge thru bridge MC, cfs | 1813 | 2069 | 1890 |
| Main channel area (DS), ft2 | 212 | 221 | 161 |
| Main channel width (normal), ft | 30.5 | 30.5 | 30.5 |
| Cum. width of piers, ft | 0.0 | 0.0 | 0.0 |
| Adj. main channel width, ft | 30.5 | 30.5 | 30.5 |
| D90, ft | 0.5489 | 0.5489 | 0.5489 |
| D95, ft | 0.6868 | 0.6868 | 0.6868 |
| Dc, critical grain size, ft | 0.2903 | 0.3423 | 0.6120 |
| Pc, Decimal percent coarser than Dc | 0.485 | 0.356 | 0.069 |
| Depth to armoring, ft | **0.92** | **1.86** | **24.77** |

**Pressure Flow Scour (contraction scour for orifice flow conditions)**

```
Chang pressure flow equation        Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and other, 1995, p. 144-146)
```

| | Q100 | Q500 | OtherQ |
|---|---|---|---|
| Q, total, cfs | 2600 | 3300 | 1890 |
| Q, thru bridge MC, cfs | 1813 | 2069 | 1890 |
| Vc, critical velocity, ft/s | 10.19 | 10.27 | 9.75 |
| Va, velocity MC approach, ft/s | 3.38 | 3.83 | 4.71 |
| Main channel width (normal), ft | 30.5 | 30.5 | 30.5 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 30.5 | 30.5 | 30.5 |
| qbr, unit discharge, ft2/s | 59.4 | 67.8 | 62.0 |
| Area of full opening, ft2 | 256.7 | 257.0 | 161.0 |
| Hb, depth of full opening, ft | 8.42 | 8.43 | 5.28 |
| Fr, Froude number, bridge MC | 0.43 | 0.49 | 0 |
| Cf, Fr correction factor (<=1.0) | 1.00 | 1.00 | 0.00 |
| **Area at downstream face, ft2 | 212 | 221 | N/A |
| **Hb, depth at downstream face, ft | 6.95 | 7.25 | N/A |
| **Fr, Froude number at DS face | 0.57 | 0.61 | ERR |
| **Cf, for downstream face (<=1.0) | 1.00 | 1.00 | N/A |
| Elevation of Low Steel, ft | 501.07 | 501.07 | 0 |
| Elevation of Bed, ft | 492.65 | 492.64 | -5.28 |
| Elevation of Approach, ft | 502.08 | 502.43 | 0 |
| Friction loss, approach, ft | 0.06 | 0.09 | 0 |
| Elevation of WS immediately US, ft | 502.02 | 502.34 | 0.00 |
| ya, depth immediately US, ft | 9.37 | 9.70 | 5.28 |
| Mean elevation of deck, ft | 502.51 | 502.51 | 0 |
| w, depth of overflow, ft (>=0) | 0.00 | 0.00 | 0.00 |
| Cc, vert contrac correction (<=1.0) | 0.97 | 0.97 | 1.00 |
| **Cc, for downstream face (<=1.0) | 0.924945 | 0.926854 | ERR |
| | | | |
| Ys, scour w/Chang equation, ft | **-2.43** | **-1.59** | N/A |
| Ys, scour w/Umbrell equation, ft | -3.11 | -2.53 | N/A |

**=for UNsubmerged orifice flow using estimated downstream bridge face properties.

| | | | |
|---|---|---|---|
| **Ys, scour w/Chang equation, ft | -0.64 | -0.12 | N/A |

```
**Ys, scour w/Umbrell equation, ft  -1.65    -1.35    ERR

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen
equation results and the estimated downstream bridge face properties
can also be computed (ys=y2-ybridgeDS)
   y2, from Laursen's equation, ft  5.52     6.18     5.72
   WSEL at downstream face, ft      499.59   499.89   --
   Depth at downstream face, ft     6.95     7.25     N/A
Ys, depth of scour (Laursen), ft    -1.43    -1.06    N/A
```

**Abutment Scour**

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and others, 1995, p. 48, eq. 28)

| Characteristic | Left Abutment 100 yr Q | Left Abutment 500 yr Q | Left Abutment Other Q | Right Abutment 100 yr Q | Right Abutment 500 yr Q | Right Abutment Other Q |
|---|---|---|---|---|---|---|
| (Qt), total discharge, cfs | 2600 | 3300 | 1890 | 2600 | 3300 | 1890 |
| a', abut.length blocking flow, ft | 244.5 | 247.3 | 231.5 | 64.1 | 72.7 | 24.4 |
| Ae, area of blocked flow ft2 | 514.4 | 537.57 | 275.19 | 91.81 | 105.4 | 44.8 |
| Qe, discharge blocked abut.,cfs | -- | -- | 564.14 | -- | -- | 126 |
| (If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually) | | | | | | |
| Ve, (Qe/Ae), ft/s | 2.07 | 2.43 | 2.05 | 1.72 | 1.90 | 2.81 |
| ya, depth of f/p flow, ft | 2.10 | 2.17 | 1.19 | 1.43 | 1.45 | 1.84 |
| --Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru) | | | | | | |
| K1 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 |
| --Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US) | | | | | | |
| theta | 80 | 80 | 80 | 100 | 100 | 100 |
| K2 | 0.98 | 0.98 | 0.98 | 1.01 | 1.01 | 1.01 |
| Fr, froude number f/p flow | 0.221 | 0.246 | 0.331 | 0.224 | 0.240 | 0.366 |
| ys, scour depth, ft | 13.97 | 15.14 | 11.91 | **7.00** | **7.62** | **7.54** |

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and others, 1995, p. 49, eq. 29)

| | | | | | | |
|---|---|---|---|---|---|---|
| a'(abut length blocked, ft) | 244.5 | 247.3 | 231.5 | 64.1 | 72.7 | 24.4 |
| y1 (depth f/p flow, ft) | 2.10 | 2.17 | 1.19 | 1.43 | 1.45 | 1.84 |
| a'/y1 | 116.21 | 113.77 | 194.75 | 44.75 | 50.15 | 13.29 |
| Skew correction (p. 49, fig. 16) | 0.98 | 0.98 | 0.98 | 1.02 | 1.02 | 1.02 |
| Froude no. f/p flow | 0.22 | 0.25 | 0.33 | 0.22 | 0.24 | 0.37 |
| Ys w/ corr. factor K1/0.55: | | | | | | |
| vertical | 9.11 | 9.75 | 5.88 | 6.49 | 6.72 | ERR |
| vertical w/ ww's | **7.47** | **8.00** | **4.83** | 5.32 | 5.51 | ERR |
| spill-through | 5.01 | 5.36 | 3.24 | 3.57 | 3.69 | ERR |

Abutment riprap Sizing

Isbash Relationship
D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)
(Richardson and others, 1995, p112, eq. 81,82)

| Characteristic | Q100 | Q500 | Other Q | Q100 | Q500 | Other Q |
|---|---|---|---|---|---|---|
| Fr, Froude Number | 0.82 | 0.56 | 0.9 | 0.82 | 0.56 | 0.9 |
| y, depth of flow in bridge, ft | 5.25 | 6.82 | 5.28 | 5.25 | 6.82 | 5.28 |
| Median Stone Diameter for riprap at: left abutment | | | | right abutment, ft | | |
| Fr<=0.8 (vertical abut.) | ERR | **1.32** | ERR | ERR | **1.32** | ERR |
| Fr>0.8 (vertical abut.) | **2.08** | ERR | **2.14** | **2.08** | ERR | **2.14** |