# LEVEL II SCOUR ANALYSIS FOR BRIDGE 21 (WALDTH00450021) on TOWN HIGHWAY 45, crossing JOES BROOK, WALDEN, VERMONT

Open-File Report 97-799

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

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

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By MICHAEL A. IVANOFF AND LAURA MEDALIE

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**Pembroke, New Hampshire**

**1997**

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

U.S. GEOLOGICAL SURVEY
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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 21 (WALDTH00450021) ON TOWN HIGHWAY 45, CROSSING JOES BROOK, WALDEN, VERMONT

*By* **Michael A. Ivanoff and Laura Medalie**

## INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WALDTH00450021 on Town Highway 45 crossing Joes Brook, Walden, 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 VTAOT files state that the stream is Coles Brook, both the USGS and the VTAOT maps state that it is Joes Brook.

The site is in the New England Upland section of the New England physiographic province in central Vermont. The 18.7-$mi^2$ drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture upstream and downstream of the bridge while the immediate banks have dense woody vegetation.

In the study area, Joes Brook has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 76 ft and an average bank height of 5 ft. The channel bed material ranges from sand to boulder with a median grain size ($D_{50}$) of 75.4 mm (0.247 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 27, 1995, indicated that the reach was stable.

The Town Highway 45 crossing of Joes Brook is a 35-ft-long, one-lane bridge consisting of one 29-foot steel-beam span with a wooden deck (Vermont Agency of Transportation, written communication, April 5, 1995). The opening length of the structure parallel to the bridge face is 26.2 ft. The bridge is supported by vertical, “laid-up” concrete block abutments with no wingwalls. The channel is skewed approximately zero degrees to the opening while the computed opening-skew-to-roadway is 5 degrees.

The scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) along the upstream left bank and along the entire base length of the left abutment. There is also type-2 stone fill (less than 36 inches diameter) along the entire base length of the right abutment. 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 1.5 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge, which was less than the 100-year discharge. Abutment scour ranged from 12.4 to 24.4 ft. The worst-case abutment scour occurred at the 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.

St. Johnsbury, VT. Quadrangle, 1:25,000, 1983

NORTH

Figure 1. Location of study area on USGS 1:25,000 scale map.

Figure 2. Location of study area on Vermont Agency of Transportation town highway map.

# LEVEL II SUMMARY

***Structure Number*** WALDTH00450021 ***Stream*** Joes Brook

***County*** Caledonia ***Road*** TH 45 ***District*** 7

## Description of Bridge

***Bridge length*** 35 ***ft*** ***Bridge width*** 15.9 ***ft*** ***Max span length*** 29 ***ft***

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

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

***Stone fill on abutment?*** Yes ***Date of inspection*** 7/27/95

***Description of stone fill*** Type-1, along the base of the left abutment and type-2, along the base of the right abutment.

***Brief description of piers/abutments*** Abutments are "laid-up" concrete blocks.

***Is bridge skewed to flood flow according to*** Yes ***survey?*** ***Angle*** No 0

There is a moderate channel bend in the upstream reach. Moderate fluvial erosion has developed in the location where the bend impacts the upstream right bank.

***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*** | 7/27/95 | 0 | 0 |
| ***Level II*** | 8/7/95 | 0 | 0 |

***Potential for debris*** Low.

***Describe any features near or at the bridge that may affect flow (include observation date)***

None as of 7/27/95.

## Description of the Geomorphic Setting

***General topography*** The channel is located within a moderate relief valley with a flat to slightly irregular flood plain with steep valley walls on both sides.

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

***Date of inspection*** 7/27/95

***DS left:*** Moderately sloped channel bank to a narrow flood plain.

***DS right:*** Steep channel bank to a narrow flood plain.

***US left:*** Steep channel bank to a narrow flood plain

***US right:*** Narrow flood plain.

## Description of the Channel

***Average top width*** 76 ***ft*** ***Average depth*** 5 ***ft***

***Predominant bed material*** Sand / Cobbles ***Bank material*** Silt / Sand

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

7/27/95

***Vegetative co*** Brush with pasture on the flood plain.

***DS left:*** Trees and brush with pasture on the flood plain.

***DS right:*** Brush with pasture on the flood plain.

***US left:*** Pasture and brush.

***US right:***

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

None, 7/27/95.

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

## Hydrology

***Drainage area*** 18.7 ***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*** 2,540 ***ft³/s*** ***Q500*** 5,600 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(18.7/18.8)exp 0.67] with bridge number 27 over Joes Brook in Cabot. Bridge number 27 has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 27 is 18.8 square miles. The discharges are within a range defined by several empirical flood frequency curves (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)*** USGS survey

***Datum tie between USGS survey and VTAOT plans*** None.

***Description of reference marks used to determine USGS datum.*** RM1 is a painted high point on top of ledge on the upstream side of the left road approach, 40 ft from the house (elev. 504.98 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the right abutment (elev. 498.92 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 | -46 | 1 | Exit section |
| FULLV | 0 | 2 | Downstream Full-valley section (Templated from EXITX) |
| BRIDG | 0 | 1 | Bridge section |
| RDWAY | 10 | 1 | Road Grade section |
| APPRO | 45 | 3 | Modelled Approach section (Templated from APTEM) |
| APTEM | 45 | 1 | Approach section as surveyed (Used as a template) |

[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 0.045 to 0.064 and overbank "n" values ranged from 0.045 to 0.050.

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 0.0092 ft/ft, which was from surveyed points downstream of the bridge.

The approach section (APTEM) was surveyed one bridge length upstream of the upstream face as recommended by Shearman and others (1986). The surveyed approach section (APTEM) was truncated at the top of the right bank by templating. This prevents flow beyond the right high bank into the low lying area, establishing the modelled approach section (APPRO). This location also provides a consistent method for determining scour variables.

For the incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles for the discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

## Bridge Hydraulics Summary

***Average bridge embankment elevation*** 501.3 ***ft***
***Average low steel elevation*** 498.8 ***ft***

***100-year discharge*** 2,540 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 498.9 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 228 ***$ft^3/s$***
***Area of flow in bridge opening*** 248 ***$ft^2$***
***Average velocity in bridge opening*** 9.3 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 11.6 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 500.9
***Water-surface elevation at Approach section without bridge*** 496.2
***Amount of backwater caused by bridge*** 4.7 ***ft***

***500-year discharge*** 5,600 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 498.9 ***ft***
***Road overtopping?*** Yes ***Discharge over road*** 2,740 ***$ft^3/s$***
***Area of flow in bridge opening*** 248 ***$ft^2$***
***Average velocity in bridge opening*** 11.6 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 14.4 ***/s***

***Water-surface elevation at Approach section with bridge*** 502.9
***Water-surface elevation at Approach section without bridge*** 499.1
***Amount of backwater caused by bridge*** 3.8 ***ft***

***Incipient overtopping discharge*** 2,070 ***$ft^3/s$***
***Water-surface elevation in bridge opening*** 495.2 ***ft***
***Area of flow in bridge opening*** 152 ***$ft^2$***
***Average velocity in bridge opening*** 13.6 ***ft/s***
***Maximum WSPRO tube velocity at bridge*** 17.8 ***ft/s***

***Water-surface elevation at Approach section with bridge*** 498.9
***Water-surface elevation at Approach section without bridge*** 495.2
***Amount of backwater caused by bridge*** 3.7 ***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.

At this site, the 100-year and 500-year discharges resulted in unsubmerged orifice flow. 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 these discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). The results of the 100-year and 500-year scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8. The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

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

Abutment scour 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. The results of the 100-year and 500-year scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in 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 | 1.4 | 1.5 |
| *Depth to armoring* | 39.1 | 16.2 | 33.9 |
| *Left overbank* | -- | -- | -- |
| *Right overbank* | -- | -- | -- |
| *Local scour:* | | | |
| *Abutment scour* | | | |
| *Left abutment* | 14.1 | 16.4 | 12.4 |
| *Right abutment* | 19.3 | 24.4 | 17.9 |
| *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* | 2.3 | 3.3 | 2.5 |
| *Right abutment* | 2.3 | 3.3 | 2.5 |
| *Piers:* | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |

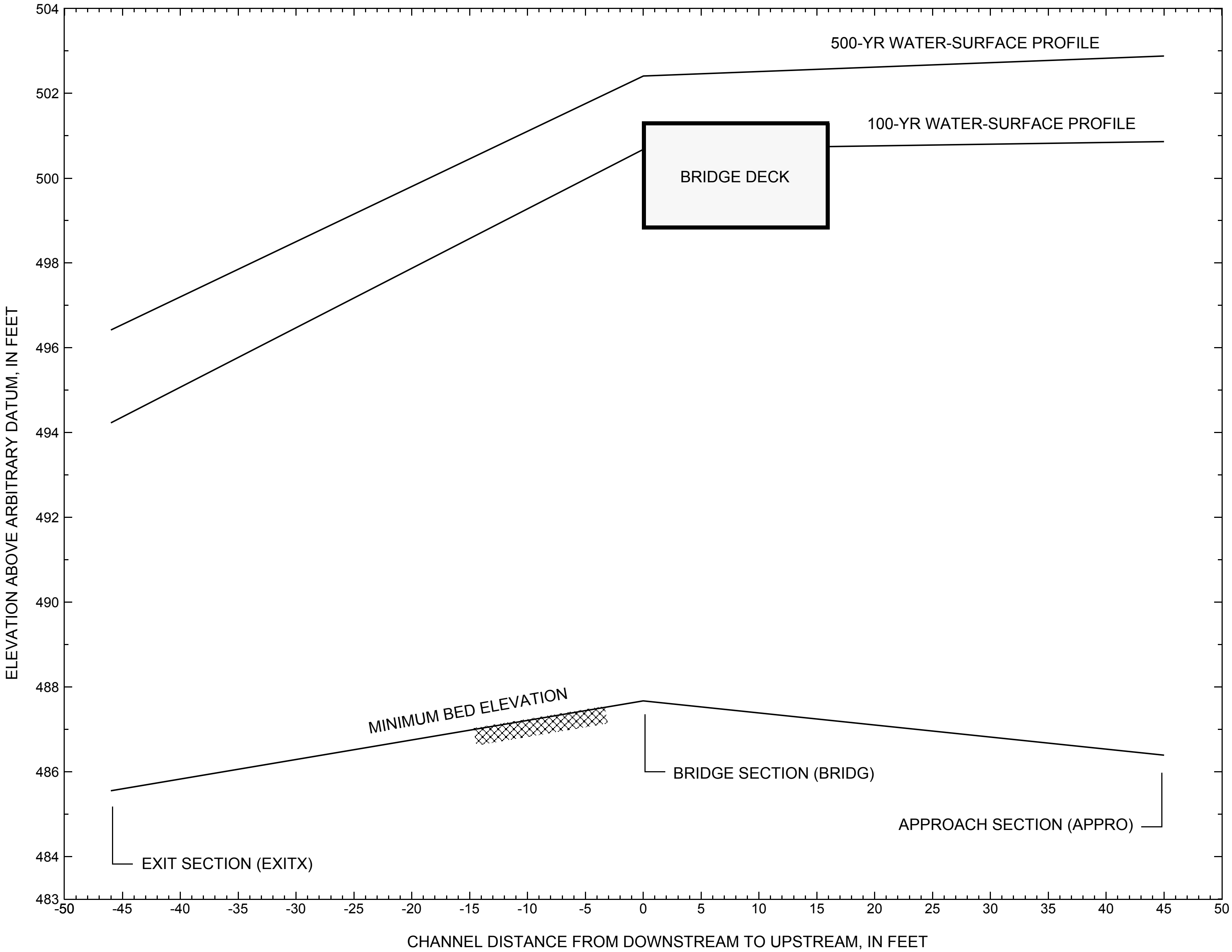


Figure 7. Water-surface profiles for the 100-year and 500-year discharges at structure WALDTH00450021 on Town Highway 45, crossing Joes Brook, Walden, Vermont.

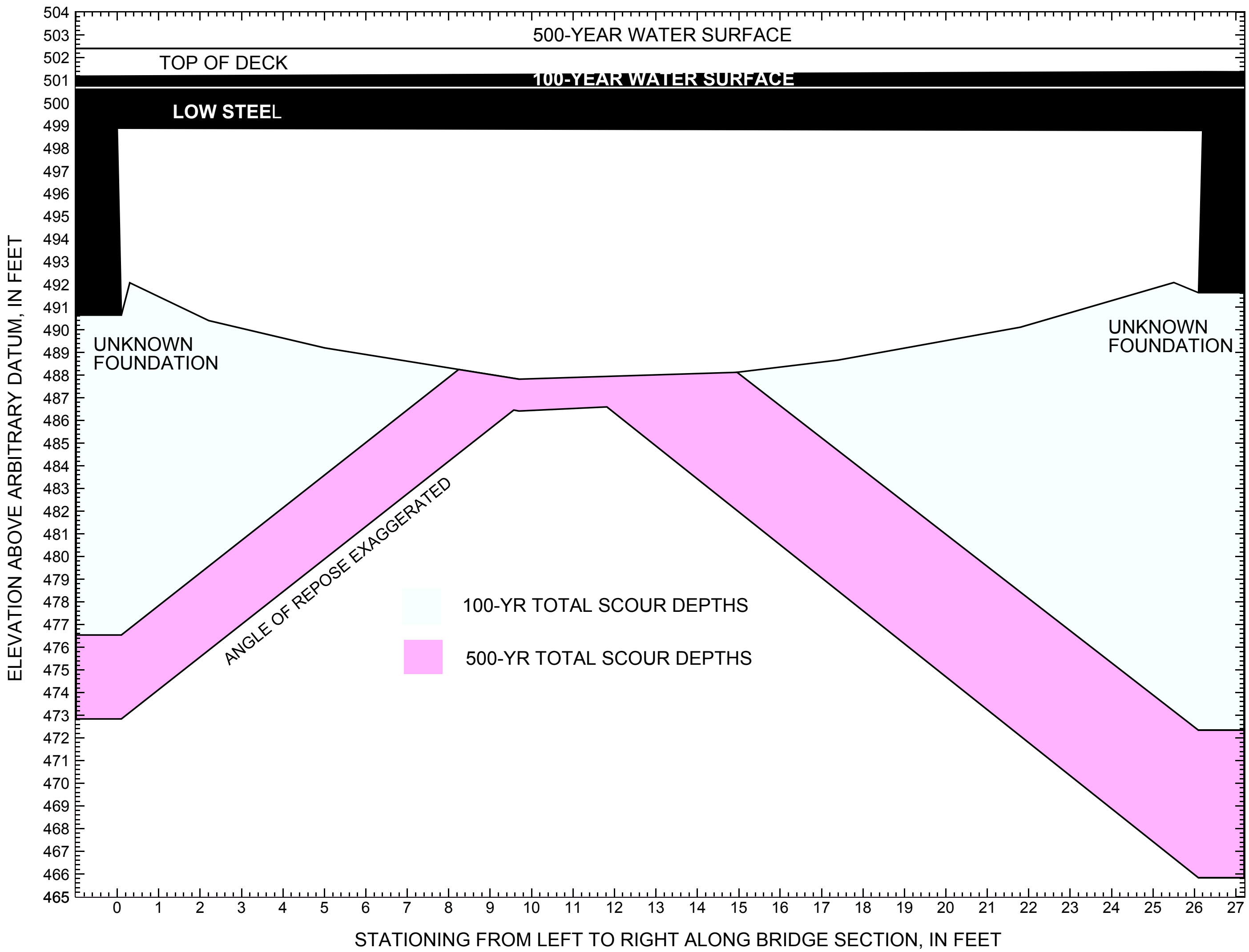


Figure 8. Scour elevations for the 100-year and 500-year discharges at structure WALDTH00450021 on Town Highway 45, crossing Joes Brook, Walden, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure WALDTH00450021 on Town Highway 45, crossing Joes Brook, Walden, 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 2,540 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 498.9 | -- | 490.6 | 0.0 | 14.1 | -- | 14.1 | 476.5 | -- |
| Right abutment | 26.2 | -- | 498.8 | -- | 491.6 | 0.0 | 19.3 | -- | 19.3 | 472.3 | -- |

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 WALDTH00450021 on Town Highway 45, crossing Joes Brook, Walden, 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 5,600 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 498.9 | -- | 490.6 | 1.4 | 16.4 | -- | 17.8 | 472.8 | -- |
| Right abutment | 26.2 | -- | 498.8 | -- | 491.6 | 1.4 | 24.4 | -- | 25.8 | 465.8 | -- |

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, 1983, St. Johnsbury, Vermont 7.5 X 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:25,000.

# APPENDIX A:

# WSPRO INPUT FILE

# WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File wald021.wsp
T2        Hydraulic analysis for structure WALDTH00450021   Date: 21-APR-97
T3        Bridge 21 on Town Highway 45 over Joes Brook in Walden, VT by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2540.0   5600.0  2070.0
SK          0.0092   0.0092  0.0092
*
XS   EXITX    -46
GR         -302.2, 508.96   -271.7, 509.48   -263.0, 506.34   -232.6, 503.24
GR         -201.3, 504.43   -147.8, 505.99   -127.9, 506.62   -104.7, 503.04
GR          -57.6, 499.52    -27.0, 496.08    -15.6, 493.74     -8.9, 493.10
GR            0.0, 493.26      2.0, 492.20      5.7, 487.36     12.4, 486.67
GR           17.0, 485.82     24.4, 485.55     31.7, 486.08     35.3, 487.16
GR           40.1, 488.70     41.3, 492.13     43.3, 493.88     48.4, 494.79
GR           53.9, 492.75     60.0, 493.40     68.7, 495.69     80.9, 492.85
GR           89.7, 495.33    121.5, 496.18    152.2, 493.52    215.3, 495.99
GR          359.5, 501.51    429.9, 502.32    657.4, 498.59    748.8, 506.31
N           0.045        0.050        0.050
SA                 -15.6         43.3
*
XS   FULLV      0  * * *   0.0317
*
*              SRD     LSEL    XSSKEW
BR   BRIDG      0    498.84       5.0
GR            0.0, 498.89      0.1, 490.64      0.3, 492.07      2.2, 490.40
GR            5.0, 489.20      9.7, 487.82     12.9, 487.67     17.4, 488.66
GR           21.8, 490.11     25.5, 492.08     26.2, 491.63     26.2, 498.79
GR            0.0, 498.89
*
*         BRTYPE  BRWDTH
CD            1      20.1
N           0.045
*
*              SRD    EMBWID   IPAVE
XR   RDWAY     10       15.9     2
GR         -450.2, 510.31   -319.2, 505.77   -312.2, 509.29   -283.7, 509.45
GR         -260.0, 507.28   -189.0, 505.86   -118.3, 501.49    -63.3, 499.59
GR           -8.6, 500.88     -3.6, 500.88     -3.6, 501.13      0.0, 501.19
GR           26.1, 501.38     30.4, 501.42     30.5, 501.00     33.5, 501.03
GR           76.6, 499.94     94.8, 500.11    153.6, 503.32    240.4, 503.81
GR          326.3, 503.50
* GR           495.5, 500.62    603.1, 501.30    635.7, 501.42    739.5, 513.94
*
XT   APTEM     45
GR         -285.1, 509.84   -165.8, 508.44   -132.4, 503.84    -98.3, 501.36
GR          -79.9, 498.12    -57.6, 496.83    -40.4, 495.30    -22.0, 493.89
GR          -13.5, 494.63     -6.9, 493.72     -6.2, 491.63     -2.6, 488.50
GR            0.0, 487.35      5.2, 486.39     11.5, 486.40     19.5, 487.79
GR           27.5, 488.18     34.3, 489.36     41.8, 491.85     56.8, 492.16
GR           84.9, 492.96    107.1, 495.29    168.0, 503.71    303.6, 504.58
GR          375.6, 502.75    434.6, 499.44    589.8, 499.29    656.6, 505.51
GR          734.1, 516.08
*
AS   APPRO     45
GT          * * 303.6
```

```
N           0.050        0.064        0.050
SA                  -6.9         84.9
*
HP 1 BRIDG   498.89 1 498.89
HP 2 BRIDG   498.89 * * 2310
*  Downstream Bridge face
HP 1 BRIDG   495.59 1 495.59
HP 2 RDWAY   500.68 * * 228
HP 1 APPRO   500.86 1 500.86
HP 2 APPRO   500.86 * * 2540
*
HP 1 BRIDG   498.89 1 498.89
HP 2 BRIDG   498.89 * * 2887
*  Downstream Bridge face
HP 1 BRIDG   497.76 1 497.76
HP 2 RDWAY   502.41 * * 2739
HP 1 APPRO   502.88 1 502.88
HP 2 APPRO   502.88 * * 5600
*
HP 1 BRIDG   495.15 1 495.15
HP 2 BRIDG   495.15 * * 2070
HP 1 APPRO   498.91 1 498.91
HP 2 APPRO   498.91 * * 2070
*
EX
ER
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# APPENDIX B:

# **WSPRO OUTPUT FILE**

```
       U.S. Geological Survey WSPRO Input File wald021.wsp
       Hydraulic analysis for structure WALDTH00450021   Date: 21-APR-97
       Bridge 21 on Town Highway 45 over Joes Brook in Walden, VT by MAI
          *** RUN DATE & TIME: 06-02-97  13:39
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      248.   18934.     0.    71.                          0.
  498.89           248.   18934.     0.    71.  1.00     0.    26.      0.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      498.89     0.0    26.2   248.0   18934.    2310.   9.32

X STA.         0.0        3.0        4.6        5.9        7.1        8.2
  A(I)            23.4       14.7       12.8       11.7       11.2
  V(I)            4.94       7.84       9.04       9.89      10.32

X STA.         8.2        9.2       10.1       11.0       11.9       12.8
  A(I)            10.5       10.4       10.1       10.0       10.1
  V(I)           10.97      11.11      11.41      11.50      11.46

X STA.        12.8       13.7       14.7       15.6       16.6       17.7
  A(I)             9.9       10.1       10.2       10.5       10.8
  V(I)           11.63      11.48      11.35      11.01      10.69

X STA.        17.7       18.8       20.1       21.5       23.2       26.2
  A(I)            11.3       11.8       12.4       14.2       21.8
  V(I)           10.22       9.82       9.28       8.14       5.29

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       163     14226     26     38                       2317
  495.59            163     14226     26     38  1.00      0     26     2317

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.68   -94.9   105.2    68.1    1382.     228.   3.35

X STA.       -94.9      -78.0      -73.1      -69.6      -66.8      -64.4
  A(I)             4.9        3.3        2.8        2.6        2.4
  V(I)            2.33       3.47       4.01       4.44       4.68

X STA.       -64.4      -62.2      -59.9      -57.5      -54.8      -51.8
  A(I)             2.4        2.4        2.4        2.5        2.6
  V(I)            4.78       4.83       4.81       4.61       4.39

X STA.       -51.8      -48.1      -43.6      -37.0       66.1       72.6
  A(I)             2.8        3.1        3.6        9.1        3.6
  V(I)            4.04       3.71       3.17       1.25       3.13

X STA.        72.6       77.1       81.4       86.3       91.9      105.2
  A(I)             3.2        3.1        3.3        3.5        4.7
  V(I)            3.62       3.71       3.49       3.26       2.44

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      395.   31746.    89.    89.                       4730.
            2      980.  107849.    92.    95.                      18181.
            3      262.   20156.    62.    63.                       3039.
  500.86          1637.  159752.   243.   247.  1.07   -95.   147.  23300.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

        WSEL     LEW     REW    AREA        K        Q    VEL
      500.86   -95.5   147.4  1636.9  159752.    2540.   1.55

X STA.       -95.5      -49.2      -31.7      -18.9       -6.1        0.6
  A(I)           133.9       96.7       85.3       85.4       79.8
  V(I)            0.95       1.31       1.49       1.49       1.59

X STA.         0.6        5.1        9.3       13.5       18.1       23.0
  A(I)            63.9       60.5       59.9       63.1       63.9
  V(I)            1.99       2.10       2.12       2.01       1.99

X STA.        23.0       28.1       33.7       41.0       50.1       59.5
  A(I)            65.0       67.6       76.6       81.3       82.2
  V(I)            1.96       1.88       1.66       1.56       1.55

X STA.        59.5       69.2       79.9       90.4      103.7      147.4
  A(I)            82.7       87.4       82.0       87.7      132.0
```

```
  V(I)            1.54      1.45      1.55      1.45      0.96
        U.S. Geological Survey WSPRO Input File wald021.wsp
        Hydraulic analysis for structure WALDTH00450021   Date: 21-APR-97
        Bridge 21 on Town Highway 45 over Joes Brook in Walden, VT by MAI
           *** RUN DATE & TIME: 06-02-97  13:39
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     248.   18934.     0.    71.                          0.
   498.89          248.   18934.     0.    71.  1.00     0.    26.      0.

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     498.89     0.0    26.2   248.0   18934.    2887.  11.64

X STA.        0.0        3.0        4.6        5.9        7.1        8.2
  A(I)            23.4       14.7       12.8       11.7       11.2
  V(I)            6.17       9.80      11.29      12.36      12.89

X STA.        8.2        9.2       10.1       11.0       11.9       12.8
  A(I)            10.5       10.4       10.1       10.0       10.1
  V(I)           13.71      13.88      14.26      14.37      14.32

X STA.       12.8       13.7       14.7       15.6       16.6       17.7
  A(I)             9.9       10.1       10.2       10.5       10.8
  V(I)           14.53      14.35      14.18      13.76      13.36

X STA.       17.7       18.8       20.1       21.5       23.2       26.2
  A(I)            11.3       11.8       12.4       14.2       21.8
  V(I)           12.77      12.27      11.60      10.17       6.61

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     220.   21746.    26.    43.                       3620.
   497.76          220.   21746.    26.    43.  1.00     0.    26.   3620.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

       WSEL     LEW     REW    AREA        K        Q    VEL
     502.41  -133.2   136.9   453.7   20333.    2739.   6.04

X STA.     -133.2      -97.6      -84.8      -75.7      -68.3      -62.0
  A(I)            33.4       23.7       20.4       18.6       17.4
  V(I)            4.11       5.78       6.71       7.38       7.88

X STA.      -62.0      -55.6      -48.8      -41.5      -33.1      -23.3
  A(I)            17.2       17.4       17.6       18.4       19.5
  V(I)            7.95       7.85       7.77       7.43       7.03

X STA.      -23.3      -10.4       11.9       38.5       52.7       63.6
  A(I)            22.3       28.9       31.2       24.0       21.8
  V(I)            6.14       4.73       4.40       5.70       6.29

X STA.       63.6       72.8       81.2       90.3      100.9      136.9
  A(I)            20.8       20.4       21.7       23.6       35.4
  V(I)            6.59       6.72       6.31       5.80       3.87

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     595.   53636.   112.   113.                       7763.
             2    1166.  143949.    92.    95.                      23576.
             3     403.   35926.    77.    78.                       5222.
   502.88         2163.  233511.   281.   286.  1.07  -119.   162.  32882.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

       WSEL     LEW     REW    AREA        K        Q    VEL
     502.88  -119.2   162.0  2163.1  233511.    5600.   2.59

X STA.     -119.2      -58.8      -39.4      -25.8      -13.8       -2.6
  A(I)           186.9      132.0      111.3      104.8      113.3
  V(I)            1.50       2.12       2.52       2.67       2.47

X STA.       -2.6        3.2        8.2       13.1       18.4       23.9
  A(I)            89.6       82.3       80.6       82.3       83.6
  V(I)            3.13       3.40       3.47       3.40       3.35

X STA.       23.9       29.8       36.5       45.4       54.8       64.7
  A(I)            86.5       91.2      102.5      102.1      104.9
  V(I)            3.24       3.07       2.73       2.74       2.67

X STA.       64.7       75.0       85.6       96.7      111.8      162.0
  A(I)           107.4      106.6      102.7      118.8      173.9
```

```
  V(I)            2.61       2.63       2.73       2.36       1.61
        U.S. Geological Survey WSPRO Input File wald021.wsp
        Hydraulic analysis for structure WALDTH00450021   Date: 21-APR-97
        Bridge 21 on Town Highway 45 over Joes Brook in Walden, VT by MAI
           *** RUN DATE & TIME: 06-02-97  13:39
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     152.   12797.    26.    37.                         2078.
   495.15          152.   12797.    26.    37.  1.00     0.    26.   2078.



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

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.15     0.0    26.2   151.7   12797.    2070.  13.64

X STA.        0.0        3.6        5.3        6.6        7.7        8.7
  A(I)            15.5        9.4        8.0        7.3        6.7
  V(I)            6.67      11.03      12.91      14.11      15.43

X STA.        8.7        9.6       10.4       11.2       12.0       12.8
  A(I)             6.4        6.1        6.1        5.8        5.8
  V(I)           16.05      17.01      17.09      17.81      17.72

X STA.       12.8       13.6       14.4       15.3       16.2       17.1
  A(I)             6.0        5.8        6.2        6.2        6.3
  V(I)           17.35      17.77      16.82      16.82      16.44

X STA.       17.1       18.2       19.4       20.8       22.5       26.2
  A(I)             6.7        7.1        7.8        8.8       13.7
  V(I)           15.41      14.57      13.21      11.75       7.56

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     233.   14413.    77.    78.                         2291.
             2     801.   77070.    92.    95.                        13436.
             3     154.    9839.    48.    49.                         1553.
   498.91         1188.  101322.   218.   222.  1.10   -84.   133.  15037.



    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      45.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.91   -84.4   133.3  1187.9  101322.    2070.   1.74

X STA.      -84.4      -34.3      -19.2       -4.8        0.5        4.3
  A(I)           106.3       69.6       72.0       55.6       45.4
  V(I)            0.97       1.49       1.44       1.86       2.28

X STA.        4.3        7.7       11.1       14.7       18.5       22.5
  A(I)            42.7       42.0       44.0       44.4       45.1
  V(I)            2.42       2.46       2.35       2.33       2.30

X STA.       22.5       26.9       31.5       37.1       44.9       54.1
  A(I)            47.2       48.2       52.5       59.2       62.9
  V(I)            2.19       2.15       1.97       1.75       1.65

X STA.       54.1       63.5       73.4       84.3       96.1      133.3
  A(I)            63.2       63.8       66.5       63.5       93.7
  V(I)            1.64       1.62       1.56       1.63       1.11
```

# WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File wald021.wsp
        Hydraulic analysis for structure WALDTH00450021   Date: 21-APR-97
        Bridge 21 on Town Highway 45 over Joes Brook in Walden, VT by MAI
           *** RUN DATE & TIME: 06-02-97  13:39

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

EXITX:XS   ******   -18.     337.  0.99 *****  495.22  491.94   2540.  494.23
      -46. ******   170.   26468.  1.12 ***** *******    0.82    7.53

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.81     494.37     493.40

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.73     510.94    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.73     510.94     493.40

FULLV:FV      46.     1.     239.  1.76  0.54  496.16  493.40   2540.  494.40
        0.    46.    81.   20864.  1.00  0.39    0.02    0.81   10.63
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  2.21

APPRO:AS      45.   -51.     668.  0.25  0.30  496.46 *******   2540.  496.21
       45.    45.   114.   46195.  1.10  0.00    0.00    0.35    3.80
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   500.38       0.00     495.99     499.59

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   495.92     500.17     500.26     498.84

 ===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      46.     0.     248.  1.35 *****  500.24  495.59   2310.  498.89
        0. ******    26.   18934.  1.00 ***** *******    0.53    9.32

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****    5.  0.448  0.000  498.84 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    29.  0.01  0.04  500.89    0.00    228.  500.68

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    142.    77.   -95.   -17.   1.1   0.5   3.6   3.4   0.8   2.8
   RT:     86.    58.    48.   105.   0.7   0.4   3.4   3.4   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      25.   -95.    1637.  0.04  0.06  500.90  493.06   2540.  500.86
       45.    30.   147.  159762.  1.07  0.54    0.00    0.11    1.55

   FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -46.   -18.   170.   2540.   26468.     337.    7.53  494.23
   FULLV:FV       0.     1.    81.   2540.   20864.     239.   10.63  494.40
   BRIDG:BR       0.     0.    26.   2310.   18934.     248.    9.32  498.89
   RDWAY:RG      10.*******   142.    228.*********      0.    2.00  500.68
   APPRO:AS      45.   -95.   147.   2540.  159762.    1637.    1.55  500.86

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    491.94    0.82  485.55  509.48************  0.99  495.22  494.23
   FULLV:FV    493.40    0.81  487.01  510.94  0.54  0.39  1.76  496.16  494.40
   BRIDG:BR    495.59    0.53  487.67  498.89************  1.35  500.24  498.89
   RDWAY:RG  ****************  499.59  510.31  0.01******  0.04  500.89  500.68
   APPRO:AS    493.06    0.11  486.39  516.08  0.06  0.54  0.04  500.90  500.86
```

# WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File wald021.wsp
        Hydraulic analysis for structure WALDTH00450021   Date: 21-APR-97
        Bridge 21 on Town Highway 45 over Joes Brook in Walden, VT by MAI
           *** RUN DATE & TIME: 06-02-97  13:39

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

EXITX:XS   ******   -30.     740.  1.32 *****  497.74  496.31   5600.  496.42
      -46. ******   226.   58350.  1.49 ***** *******    0.96    7.57

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   495.92     510.94    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   495.92     510.94     497.76

 ===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 "FULLV"
                  WSBEG,WSEND,CRWS =   497.76     510.94     497.76

FULLV:FV      46.   -29.     712.  1.43 *****  499.19  497.76   5600.  497.76
        0.    46.   224.   55948.  1.49 ***** *******    1.01    7.87
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  1.89

APPRO:AS      45.   -85.    1223.  0.36  0.24  499.43 *******   5600.  499.07
       45.    45.   134.  105630.  1.09  0.00    0.00    0.36    4.58
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   508.88       0.00     498.83     499.59

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   498.25     502.55     502.67     498.84

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

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                  QRD,QRDMAX,RATIO =    2739.      2722.    1.01

            <<<<<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      46.     0.     248.  2.11 *****  501.00  496.58   2887.  498.89
        0. ******    26.   18934.  1.00 ***** *******    0.67   11.64

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.491  0.000  498.84 ****** ****** ******

    XSID:CODE     SRD   FLEN     HF   VHD      EGL      ERR       Q    WSEL
   RDWAY:RG       10.    29.  0.02  0.11  502.98     0.00    2739.  502.41

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1555.   146.  -133.    13.   2.8   1.8   6.9   6.1   2.3   3.0
   RT:   1185.   124.    13.   137.   2.5   1.6   6.6   6.0   2.2   3.0

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

APPRO:AS      25.  -119.    2163.  0.11  0.13  502.99  495.36   5600.  502.88
       45.    32.   162.  233537.  1.07  0.38    0.00    0.17    2.59

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS      -46.   -30.   226.   5600.   58350.     740.    7.57  496.42
   FULLV:FV        0.   -29.   224.   5600.   55948.     712.    7.87  497.76
   BRIDG:BR        0.     0.    26.   2887.   18934.     248.   11.64  498.89
   RDWAY:RG       10.******* 1555.   2739.******************    2.00  502.41
   APPRO:AS       45.  -119.   162.   5600.  233537.    2163.    2.59  502.88

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     496.31    0.96  485.55  509.48************  1.32  497.74  496.42
   FULLV:FV     497.76    1.01  487.01  510.94************  1.43  499.19  497.76
   BRIDG:BR     496.58    0.67  487.67  498.89************  2.11  501.00  498.89
   RDWAY:RG  ****************  499.59  510.31  0.02******  0.11  502.98  502.41
```

```
   APPRO:AS    495.36    0.17  486.39  516.08  0.13  0.38  0.11  502.99  502.88
        U.S. Geological Survey WSPRO Input File wald021.wsp
        Hydraulic analysis for structure WALDTH00450021   Date: 21-APR-97
        Bridge 21 on Town Highway 45 over Joes Brook in Walden, VT by MAI
           *** RUN DATE & TIME: 06-02-97  13:39

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

EXITX:XS   ******     0.     245.  1.11 *****  494.19  491.26   2070.  493.08
      -46. ******    82.   21564.  1.01 ***** *******    0.66    8.44

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.83     493.33     492.71

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.58     510.94    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.58     510.94     492.71

FULLV:FV      46.     2.     196.  1.73  0.58  495.07  492.71   2070.  493.34
        0.    46.    41.   15860.  1.00  0.31    0.00    0.83   10.54
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  2.00

APPRO:AS      45.   -39.     507.  0.28  0.38  495.45 *******   2070.  495.17
       45.    45.   106.   31761.  1.08  0.00    0.00    0.40    4.08
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    2070.      495.15

            <<<<<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      46.     0.     152.  3.20 *****  498.34  495.15   2070.  495.15
        0.    46.    26.   12781.  1.10 ***** *******    1.05   13.65

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  0.952 ******  498.84 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.        <<<<<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      25.   -84.    1188.  0.05  0.09  498.96  492.47   2070.  498.91
       45.    29.   133.  101382.  1.10  0.53    0.00    0.14    1.74

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.819  0.650   35536.     5.    31.   498.90

  FIRST USER DEFINED TABLE.

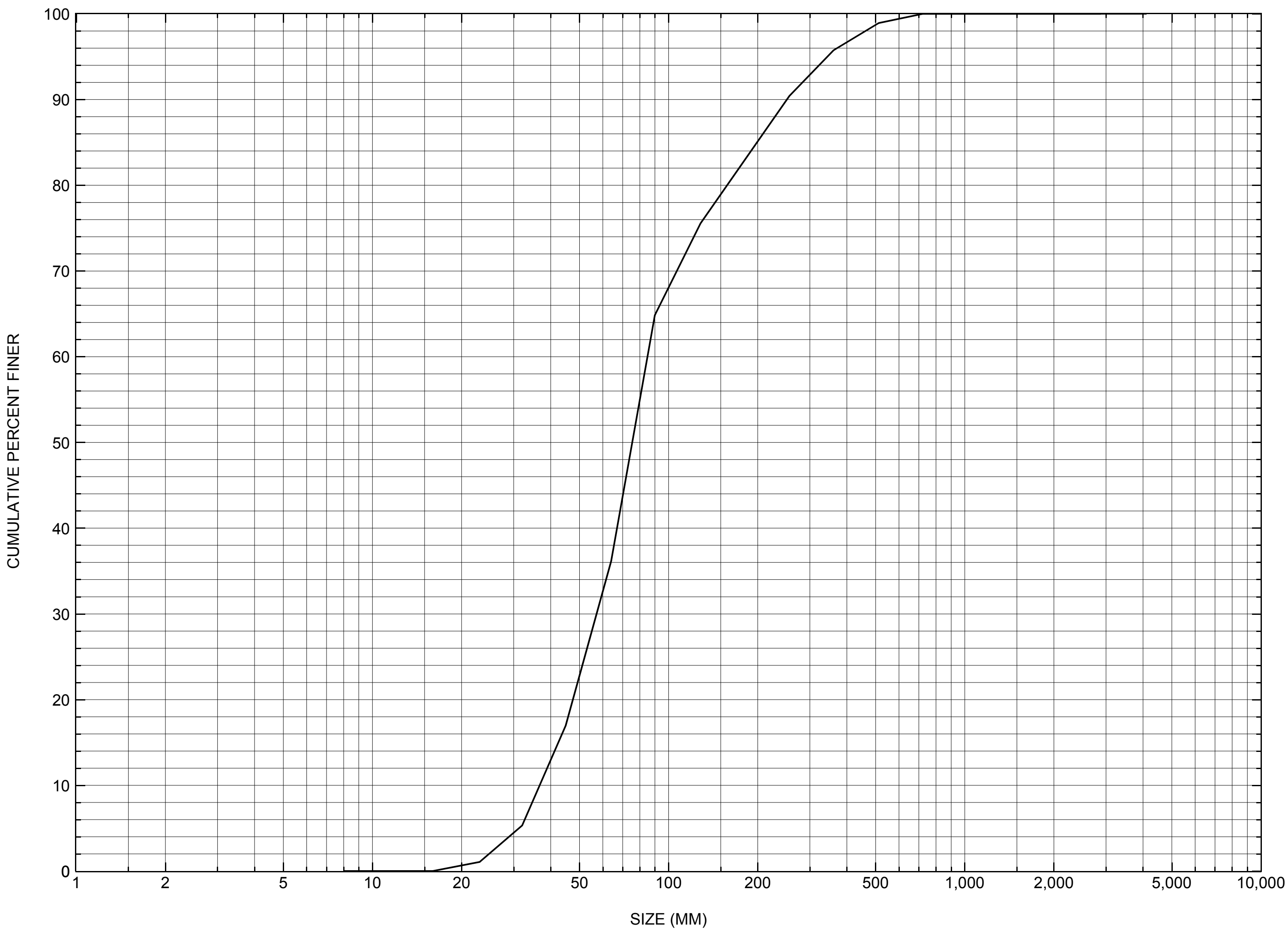
    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -46.     0.    82.   2070.   21564.     245.    8.44  493.08
   FULLV:FV       0.     2.    41.   2070.   15860.     196.   10.54  493.34
   BRIDG:BR       0.     0.    26.   2070.   12781.     152.   13.65  495.15
   RDWAY:RG      10.**************      0.******************    2.00********
   APPRO:AS      45.   -84.   133.   2070.  101382.    1188.    1.74  498.91

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    491.26    0.66  485.55  509.48************  1.11  494.19  493.08
   FULLV:FV    492.71    0.83  487.01  510.94  0.58  0.31  1.73  495.07  493.34
   BRIDG:BR    495.15    1.05  487.67  498.89************  3.20  498.34  495.15
   RDWAY:RG  ****************  499.59  510.31**********************************
   APPRO:AS    492.47    0.14  486.39  516.08  0.09  0.53  0.05  498.96  498.91
```

# APPENDIX C:

# BED-MATERIAL PARTICLE-SIZE DISTRIBUTION




Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WALDTH00450021, in Walden, Vermont.

APPENDIX D:

# HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WALDTH00450021

## General Location Descriptive

Data collected by *(First Initial, Full last name)* M. IVANOFF

Date *(MM/DD/YY)* 04 / 05 / 95

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

County *(FIPS county code; I - 3; nnn)* 005

Town *(FIPS place code; I - 4; nnnnn)* 75700

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

Waterway *(I - 6)* JOES BROOK

Road Name *(I - 7):* -

Route Number TH045

Vicinity *(I - 9)* 0.1 MI TO JCT W VT15

Topographic Map St. Johnsbury

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44261

Longitude *(i - 17; nnnnn.n)* 72133

## Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10031500210315

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

Maximum span length *(I - 48; nnnn)* 0029

Year built *(I - 27; YYYY)* 1991

Structure length *(I - 49; nnnnnn)* 000035

Average daily traffic, ADT *(I - 29; nnnnnn)* 000030

Deck Width *(I - 52; nn.n)* 159

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

Channel & Protection *(I - 61; n)* 6

Opening skew to Roadway *(I - 34; nn)* 00

Waterway adequacy *(I - 71; n)* 6

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

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

Structure type *(I - 43; nnn)* 302

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 11.5

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

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

Comments:

**The structural inspection report of 06/07/93 indicates the structure is a steel stringer type bridge with a wooden deck. The abutments are "laid up" concrete blocks. Some stone and boulder stone fill has been placed along the entire base length of the abutments and around the ends. The embankment has partially slid out at the downstream end of the left abutment. Some erosion along the banks is reported from past flooding. Stone fill has partially eroded away from the left abutment.**

## Bridge Hydrologic Data

Is there hydrologic data available? **N** *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: -

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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*) | - | - | - | - | - |
| Velocity (*ft / sec*) | - | - | - | - | - |

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at $Q_{100}$ (*ft³/ sec*): -

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

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

Highway No. : - Structure No. : - Structure Type: -

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft²*): -

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

Highway No. : - Structure No. : - Structure Type: -

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway ($ft^2$): -

Comments:

-

## USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 18.73 $mi^2$

Lake/pond/swamp area .374 $mi^2$

Watershed storage *(ST)* 2.0 %

Bridge site elevation 1558 ft

Headwater elevation 2500 ft

Main channel length 9.931 mi

10% channel length elevation 1595 ft

85% channel length elevation 2149 ft

Main channel slope *(S)* 74.4 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? N *If no, type ctrl-n pl*   Date issued for construction *(MM / YYYY)*: - / -

Project Number -   Minimum channel bed elevation: -

Low superstructure elevation: USLAB -   DSLAB -   USRAB -   DSRAB -

Benchmark location description:

**NO BENCHMARK INFORMATION**

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

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

If 1: Footing Thickness ____   Footing bottom elevation: ____

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:

**NO FOUNDATION MATERIAL INFORMATION**

Comments:

**NO PLANS.**

## Cross-sectional Data

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

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

Comments: **This cross-section is of the upstream face. The low chord elevation is from the survey log done for this report on 08/07/95. The low chord to bed length data is from the sketch attached to a bridge inspection report dated 06/07/93.**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | 0 | 8.7 | 10.7 | 15.7 | 25.7 | - | - | - | - | - | - |
| Feature | LAB | - | - | - | RAB | - | - | - | - | - | - |
| Low chord elevation | 498.9 | 497.7 | 497.5 | 495.9 | 495.5 | - | - | - | - | - | - |
| Bed elevation | 491.3 | 486.6 | 485.7 | 485.4 | 488.6 | - | - | - | - | - | - |
| Low chord-bed | 7.6 | 11.1 | 11.8 | 11.5 | 6.9 | - | - | - | - | - | - |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | - | - | - | - | - | - | - | - | - | - | - |
| Feature | - | - | - | - | - | - | - | - | - | - | - |
| Low chord elevation | - | - | - | - | - | - | - | - | - | - | - |
| Bed elevation | - | - | - | - | - | - | - | - | - | - | - |
| Low chord-bed | - | - | - | - | - | - | - | - | - | - | - |

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

Comments:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | - | - | - | - | - | - | - | - | - | - | - |
| Feature | - | - | - | - | - | - | - | - | - | - | - |
| Low chord elevation | - | - | - | - | - | - | - | - | - | - | - |
| Bed elevation | - | - | - | - | - | - | - | - | - | - | - |
| Low chord-bed | - | - | - | - | - | - | - | - | - | - | - |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | - | - | - | - | - | - | - | - | - | - | - |
| Feature | - | - | - | - | - | - | - | - | - | - | - |
| Low chord elevation | - | - | - | - | - | - | - | - | - | - | - |
| Bed elevation | - | - | - | - | - | - | - | - | - | - | - |
| Low chord-bed | - | - | - | - | - | - | - | - | - | - | - |

APPENDIX E:

# LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **3/22/96**

Computerized by: **RB** Date: **3/26/96**

Reviewd by: **MAI** Date: **10/14/97**

Structure Number **WALDTH00450021**

## A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **L. Medalie** Date *(MM/DD/YY)* **7** / **27** / 19**95**

2. Highway District Number **07** Mile marker **000**

County **Caledonia (005)** Town **Walden (75700)**

Waterway *(I - 6)* **Joes Brook** Road Name **-**

Route Number **TH045** Hydrologic Unit Code: **01080102**

3. Descriptive comments:

**This bridge is located 0.1 miles from the junction with VT 15. This site was revisited for Level II analysis on 8/7/95 after the high water event on 8/5 and 8/6; some additional comments and observations were made.**

## 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 **1** UB **2** 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 **35** *(feet)* Span length **29** *(feet)* Bridge width **15.9** *(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 **--** US right **--**

| | Protection | | 13.Erosion | 14.Severity |
|---|---|---|---|---|
| | 11.Type | 12.Cond. | | |
| LBUS | 0 | - | 3 | 2 |
| RBUS | 2 | 2 | 1 | 1 |
| RBDS | 0 | - | 1 | 1 |
| LBDS | 0 | - | 3 | 2 |

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

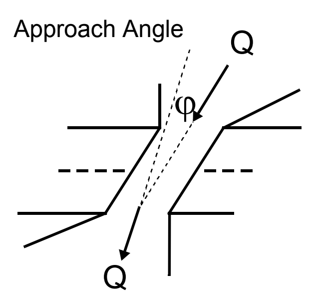
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

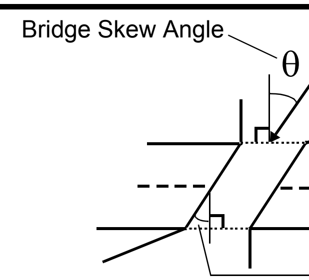
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

### Channel approach to bridge (BF):

15. Angle of approach: **0** 16. Bridge skew: **0**




α= **5.0**

17. Channel impact zone 1: Exist? **Y** *(Y or N)*

Where? **RB** *(LB, RB)* Severity **2**

Range? **15** feet **US** *(US, UB, DS)* to **25** 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: **1b**

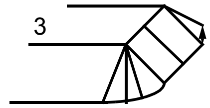
1a- Vertical abutments with wingwalls

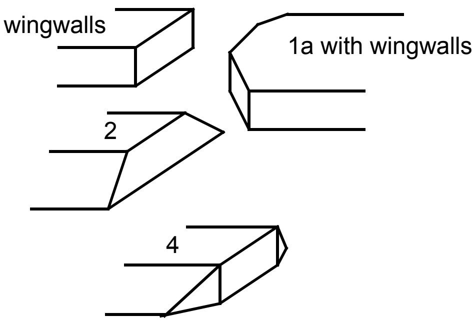
1b- Vertical abutments without wingwalls

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.)

**7. The bridge dimension values are from the VTAOT files. The measured span length is 26.5 ft, bridge length is 34 ft and deck width is 15.9 ft.**
**4. On the right bank DS and US there are 30 ft wide strips of brush and a few trees along the banks and then pasture.**
**8. The right road approach width is 10 ft and the left road approach width is 11 ft.**

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| **26.5** | **5.0** | | | **3.5** | **3** | **3** | **12** | **1** | **1** | **2** |

23. Bank width **45.0** 24. Channel width **5.0** 25. Thalweg depth **92.5** 29. Bed Material **34**

30 .Bank protection type: LB **1** RB **0** 31. Bank protection condition: LB **2** 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*

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

**26. The vegetation cover consists of strips of brush with a few trees along the bank. On the right bank there are no trees, only weeds from the bridge to 32 feet US. On the left bank the brush and tree cover starts at 7 feet from the bridge.**

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

36. Point bar extent: **-** feet **-** (*US, UB*) to **-** feet **-** (*US, UB, DS*) positioned **-** %LB to **-** %RB

37. Material: **-**

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

**NO POINT BARS**

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: **20** 42. Cut bank extent: **15** feet **US** (*US, UB*) to **25** 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.):

**There is a large bend in the river beginning at about 25 feet US of the bridge.**

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

47. Scour dimensions: Length **-** Width **-** Depth : **-** Position **-** %LB to **-** %RB

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

**NO CHANNEL SCOUR**

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):

**NO MAJOR CONFLUENCES**

## D. Under Bridge Channel Assessment

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

| 56. Height (BF) | | 57 Angle (BF) | | 61. Material (BF) | | 62. Erosion (BF) | |
|---|---|---|---|---|---|---|---|
| LB | RB | LB | RB | LB | RB | LB | RB |
| **37.5** | | **5.5** | | **2** | **7** | **7** | **-** |

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

*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.):

**2345**

**There is significant variability of the bed material. At the US end of the bridge, just below the bridge deck there is a row of cobbles and boulders extending across the channel to form a small drop structure. The water level differs US and DS of this structure by about 1 foot.**

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 | | 0 | 90 | 2 | 0 | - | - | 90.0 |
| RABUT | 1 | 0 | 90 | | | 2 | 0 | 25.5 |

*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.):

**-**

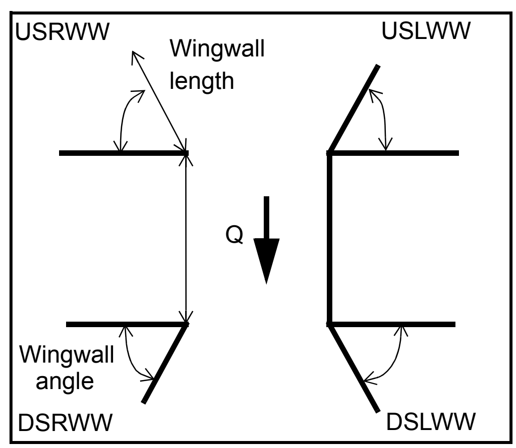
**-**

**1**

**The abutment material consist of "laid-up" concrete blocks; 2 ft X 4 ft X 4 ft.**

80. Wingwalls:

| | Exist? | Material? | Scour Condition? | Scour depth? | Exposure depth? | 81. Angle? | Length? |
|---|---|---|---|---|---|---|---|
| USLWW: | | | | | | 25.5 | |
| USRWW: | N | | - | | - | 4.5 | |
| DSLWW: | - | | - | | N | 18.0 | |
| DSRWW: | - | | - | | - | 22.0 | |




*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 | - | - | N | - | - | - | 1 | 1 |
| Condition | N | - | - | - | - | - | 1 | 1 |
| Extent | - | - | - | - | - | 1 | 2 | - |

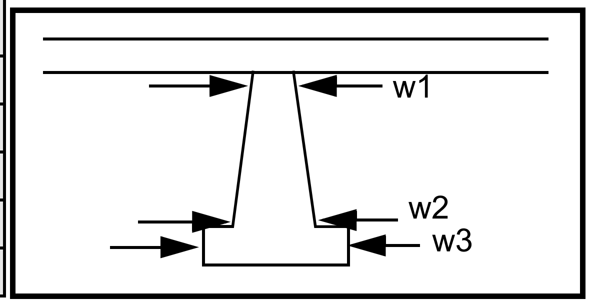
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

## Piers:

84. Are there piers? _-_ *(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 | - | - | - | - | - | - |
| Pier 2 | - | - | - | - | - | - |
| Pier 3 | - | - | - | - | - | - |
| Pier 4 | - | - | - | - | - | - |




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

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 |
|---|---|---|---|---|---|---|---|---|---|---|
| - | - | | | - | - | NO | PIE | RS | | |

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.):

**1**
**2**
**12**
**12**
**1**
**2**
**3245**
**0**
**0**
**-**
**-**
**The DS thalweg measures greater than 6 ft. About 100 feet DS of the bridge the depth increases to greater than 8 feet.**

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**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

105. Drop structure comments (eg. downstream scour depth):

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

Point bar extent: ______ feet ____ *(US, UB, DS)* to **N** feet **-** *(US, UB, DS)* positioned **NO** %LB to **DR** %RB

Material: **OP**

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

**STRUCTURE**

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

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.):

-
-
-
-

Is channel scour present? **NO** *(Y or if N type ctrl-n cs)* Mid-scour distance: **POIN**

Scour dimensions: Length **T** Width **BAR** Depth: **S** Positioned ____ %LB to ____ %RB

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

**N**
-
-

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

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

Confluence 2: Distance **NO** Enters on **CU** *(LB or RB)* Type **T** *( **1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

**BANKS**

## F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

***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)*:

**N**
**-**
**-**
**-**
**-**
**-**
**-**
**NO CHANNEL SCOUR**

**N**

## 109. G. Plan View Sketch

-

| | | | |
|---|---|---|---|
| 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: WALDTH00450021 Town: Walden
Road Number: TH 45 County: Caledonia
Stream: Joes Brook

Initials MAI Date: 05/21/97 Checked: LKS

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 | 2540 | 5600 | 2070 |
| Main Channel Area, ft2 | 980 | 1166 | 801 |
| Left overbank area, ft2 | 395 | 595 | 233 |
| Right overbank area, ft2 | 262 | 403 | 154 |
| Top width main channel, ft | 92 | 92 | 92 |
| Top width L overbank, ft | 89 | 112 | 77 |
| Top width R overbank, ft | 62 | 77 | 48 |
| D50 of channel, ft | 0.2474 | 0.2474 | 0.2474 |
| D50 left overbank, ft | -- | -- | -- |
| D50 right overbank, ft | -- | -- | -- |
| y1, average depth, MC, ft | 10.7 | 12.7 | 8.7 |
| y1, average depth, LOB, ft | 4.4 | 5.3 | 3.0 |
| y1, average depth, ROB, ft | 4.2 | 5.2 | 3.2 |
| Total conveyance, approach | 159752 | 233511 | 101322 |
| Conveyance, main channel | 107849 | 143949 | 77070 |
| Conveyance, LOB | 31746 | 53636 | 14413 |
| Conveyance, ROB | 20156 | 35926 | 9839 |
| Percent discrepancy, conveyance | 0.0006 | 0.0000 | 0.0000 |
| Qm, discharge, MC, cfs | 1714.8 | 3452.1 | 1574.5 |
| Ql, discharge, LOB, cfs | 504.8 | 1286.3 | 294.5 |
| Qr, discharge, ROB, cfs | 320.5 | 861.6 | 201.0 |
| Vm, mean velocity MC, ft/s | 1.7 | 3.0 | 2.0 |
| Vl, mean velocity, LOB, ft/s | 1.3 | 2.2 | 1.3 |
| Vr, mean velocity, ROB, ft/s | 1.2 | 2.1 | 1.3 |
| Vc-m, crit. velocity, MC, ft/s | 10.4 | 10.7 | 10.1 |
| 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 | 2540 | 5600 | 2070 |
| (Q) discharge thru bridge, cfs | 2310 | 2887 | 2070 |
| Main channel conveyance | 18934 | 18934 | 12797 |
| Total conveyance | 18934 | 18934 | 12797 |
| Q2, bridge MC discharge,cfs | 2310 | 2887 | 2070 |
| Main channel area, ft2 | 248 | 248 | 152 |
| Main channel width (normal), ft | 26.1 | 26.1 | 26.1 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 26.1 | 26.1 | 26.1 |
| y_bridge (avg. depth at br.), ft | 9.50 | 9.50 | 5.81 |
| Dm, median (1.25*D50), ft | 0.30925 | 0.30925 | 0.30925 |
| y2, depth in contraction,ft | 8.07 | 9.77 | 7.35 |
| ys, scour depth (y2-ybridge), ft | -1.43 | 0.27 | **1.54** |

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 | 2540 | 5600 | 2070 |
| Q, thru bridge MC, cfs | 2310 | 2887 | 2070 |
| Vc, critical velocity, ft/s | 10.44 | 10.75 | 10.09 |
| Va, velocity MC approach, ft/s | 1.75 | 2.96 | 1.97 |
| Main channel width (normal), ft | 26.1 | 26.1 | 26.1 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 26.1 | 26.1 | 26.1 |
| qbr, unit discharge, ft2/s | 88.5 | 110.6 | 79.3 |
| Area of full opening, ft2 | 248.0 | 248.0 | 151.7 |
| Hb, depth of full opening, ft | 9.50 | 9.50 | 5.81 |
| Fr, Froude number, bridge MC | 0.53 | 0.67 | 0 |
| Cf, Fr correction factor (<=1.0) | 1.00 | 1.00 | 0.00 |
| **Area at downstream face, ft2 | 163 | 220 | N/A |
| **Hb, depth at downstream face, ft | 5.06 | 8.43 | N/A |
| **Fr, Froude number at DS face | 1.37 | 0.80 | ERR |
| **Cf, for downstream face (<=1.0) | 1.00 | 1.00 | N/A |

| | | | |
|---|---|---|---|
| Elevation of Low Steel, ft | 498.84 | 498.84 | 0 |
| Elevation of Bed, ft | 489.34 | 489.34 | -5.81 |
| Elevation of Approach, ft | 500.86 | 502.88 | 0 |
| Friction loss, approach, ft | 0.06 | 0.13 | 0 |
| Elevation of WS immediately US, ft | 500.80 | 502.75 | 0.00 |
| ya, depth immediately US, ft | 11.46 | 13.41 | 5.81 |
| Mean elevation of deck, ft | 501.28 | 501.28 | 0 |
| w, depth of overflow, ft (>=0) | 0.00 | 1.47 | 0.00 |
| Cc, vert contrac correction (<=1.0) | 0.95 | 0.94 | 1.00 |
| **Cc, for downstream face (<=1.0) | 0.79 | 0.910766 | ERR |
| | | | |
| Ys, scour w/Chang equation, ft | **-0.61** | **1.41** | N/A |
| Ys, scour w/Umbrell equation, ft | -5.20 | -3.17 | N/A |

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

| | | | |
|---|---|---|---|
| **Ys, scour w/Chang equation, ft | 4.49 | 2.87 | N/A |
| **Ys, scour w/Umbrell equation, ft | -0.76 | -2.10 | 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 | 31.23 | 25.98 | LOOK-UP |
| WSEL at downstream face, ft | 495.59 | 497.76 | -- |
| Depth at downstream face, ft | 6.25 | 8.43 | N/A |
| Ys, depth of scour (Laursen), ft | 24.98 | 17.55 | ERR |

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 | 2310 | 2887 | 2070 |
| Main channel area (DS), ft2 | 163 | 220 | 151.7 |
| Main channel width (normal), ft | 26.1 | 26.1 | 26.1 |
| Cum. width of piers, ft | 0.0 | 0.0 | 0.0 |
| Adj. main channel width, ft | 26.1 | 26.1 | 26.1 |
| D90, ft | 0.8232 | 0.8232 | 0.8232 |
| D95, ft | 1.1260 | 1.1260 | 1.1260 |
| Dc, critical grain size, ft | 0.9877 | 0.7450 | 0.9454 |
| Pc, Decimal percent coarser than Dc | 0.070 | 0.121 | 0.077 |
| | | | |
| Depth to armoring, ft | **39.12** | **16.22** | **33.85** |

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)

| | Left Abutment | | | Right Abutment | | |
|---|---|---|---|---|---|---|
| Characteristic | 100 yr Q | 500 yr Q | Other Q | 100 yr Q | 500 yr Q | Other Q |
| (Qt), total discharge, cfs | 2540 | 5600 | 2070 | 2540 | 5600 | 2070 |
| a', abut.length blocking flow, ft | 95.5 | 119.2 | 84.4 | 121.3 | 135.9 | 107.2 |
| Ae, area of blocked flow ft2 | 432.9 | 462.2 | 298.3 | 780.1 | 882.2 | 582.1 |
| Qe, discharge blocked abut.,cfs | -- | -- | 404.2 | -- | -- | 950.3 |

(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)

| | | | | | | |
|---|---|---|---|---|---|---|
| Ve, (Qe/Ae), ft/s | 1.32 | 2.22 | 1.36 | 1.48 | 2.53 | 1.63 |
| ya, depth of f/p flow, ft | 4.53 | 3.88 | 3.53 | 6.43 | 6.49 | 5.43 |

--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)

| | | | | | | |
|---|---|---|---|---|---|---|
| K1 | 1 | 1 | 1 | 1 | 1 | 1 |

--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)

| | | | | | | |
|---|---|---|---|---|---|---|
| theta | 85 | 85 | 85 | 95 | 95 | 95 |
| K2 | 0.99 | 0.99 | 0.99 | 1.01 | 1.01 | 1.01 |
| Fr, froude number f/p flow | 0.104 | 0.162 | 0.127 | 0.101 | 0.159 | 0.123 |
| ys, scour depth, ft | **14.06** | **16.43** | **12.39** | **19.27** | **24.37** | **17.93** |

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) | 95.5 | 119.2 | 84.4 | 121.3 | 135.9 | 107.2 |
| y1 (depth f/p flow, ft) | 4.53 | 3.88 | 3.53 | 6.43 | 6.49 | 5.43 |
| a'/y1 | 21.07 | 30.74 | 23.88 | 18.86 | 20.93 | 19.74 |
| Skew correction (p. 49, fig. 16) | 0.98 | 0.98 | 0.98 | 1.01 | 1.01 | 1.01 |
| Froude no. f/p flow | 0.10 | 0.16 | 0.13 | 0.10 | 0.16 | 0.12 |
| Ys w/ corr. factor K1/0.55: | | | | | | |
| vertical | ERR | 15.16 | ERR | ERR | ERR | ERR |
| vertical w/ ww's | ERR | 12.43 | ERR | ERR | ERR | ERR |
| spill-through | ERR | 8.34 | ERR | ERR | ERR | 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)

| Downstream bridge face property | Q100 | Q500 | Other Q | Q100 | Q500 | Other Q |
|---|---|---|---|---|---|---|
| Fr, Froude Number | 1.37 | 0.8 | 1.05 | 1.37 | 0.8 | 1.05 |
| y, depth of flow in bridge, ft | 5.06 | 8.43 | 5.81 | 5.06 | 8.43 | 5.81 |
| Median Stone Diameter for riprap at: | left abutment | | | right abutment, ft | | |
| Fr<=0.8 (vertical abut.) | ERR | **3.34** | ERR | ERR | **3.34** | ERR |
| Fr>0.8 (vertical abut.) | **2.31** | ERR | **2.46** | **2.31** | ERR | **2.46** |