# LEVEL II SCOUR ANALYSIS FOR BRIDGE 81 (MARSUS00020081) on U.S. HIGHWAY 2, crossing the WINOOSKI RIVER, MARSHFIELD, VERMONT

Open-File Report 97-809

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

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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 81 (MARSUS00020081) ON U.S. HIGHWAY 2, CROSSING THE WINOOSKI RIVER, MARSHFIELD, VERMONT

*By* **Michael A. Ivanoff**

## INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure MARSUS00020081 on U.S. Highway 2 crossing the Winooski River, Marshfield, 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 central Vermont. The 50.2-$mi^2$ drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture upstream of the bridge while the immediate banks have dense woody vegetation. Downstream of the bridge is forested with buildings near the bridge on the right bank.

In the study area, the Winooski River has an incised, sinuous channel with a slope of approximately 0.03 ft/ft, an average channel top width of 83 ft and an average bank height of 10 ft. The channel bed material ranges from cobble to boulder with a median grain size ($D_{50}$) of 64.0 mm (0.210 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 23, 1996, indicated that the reach was stable.

The U.S. Highway 2 crossing of the Winooski River is a 49-ft-long, two-lane bridge consisting of one 47-foot concrete T-beam span (Vermont Agency of Transportation, written communication, November 1, 1995). The opening length of the structure parallel to the bridge face is 44.9 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 1 ft deeper than the mean thalweg depth was observed near the upstream left wingwall during the Level I assessment. The scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) at the upstream end of the upstream left and right wingwall, the downstream end of the downstream left wingwall, and along the upstream left and right banks. There was also type-3 stone fill (less than 48 inches diameter) at the downstream left bank and type-2 stone fill (less than 36 inches diameter) along the downstream right bank. 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 2.1 to 4.2 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 14.3 to 14.4 ft. The worst-case left abutment scour occurred at the incipient roadway-overtopping and 500-year discharge. Right abutment scour ranged from 15.3 to 18.5 ft. The worst-case right abutment scour occurred at the 100-year and the incipient roadway-overtopping 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) give “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.

Marshfield, VT. Quadrangle, 1:24,000, 1986

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*** MARSUS00020081 ***Stream*** Winooski River

***County*** Washington ***Road*** U.S. 2 ***District*** 6

## Description of Bridge

***Bridge length*** 49.0 ***ft*** ***Bridge width*** 30.9 ***ft*** ***Max span length*** 47.0 ***ft***

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

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

***Stone fill on abutment?*** No ***Date of inspection*** 7/23/96

***Description of stone fill*** Type-1, around the upstream end of the upstream left and upstream right wingwalls. Also type-1 around the downstream end of the downstream left wingwall.

Abutments and wingwalls are concrete. There is a one ft deep scour hole near the upstream left wingwall.

***Brief description of piers/abutments***

Yes

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

is a mild channel bend in the upstream reach. The scour hole and a cut bank has developed in the location where the bend impacts the upstream left 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*** | 7/23/96 | 0 | 0 |
| ***Level II*** | 7/23/96 | 0 | 0 |

***Potential for debris*** Low. There is some debris caught on the banks and trees are leaning over the channel upstream.

***Describe any features near or at the bridge that may affect flow (include observation date)*** None as of 7/23/96.

## Description of the Geomorphic Setting

***General topography*** The channel is located within a moderate relief valley with a flat to slightly irregular narrow flood plain.

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

***Date of inspection*** 7/23/96

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

## Description of the Channel

***Average top width*** 83 *ft* ***Average depth*** 10 *ft*

***Predominant bed material*** Bedrock/ Boulders ***Bank material*** Cobbles/Boulders

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

7/23/96

***Vegetative co*** Trees and brush with some pasture near the bridge.

***DS left:*** Trees and brush with buildings near the bridge.

***DS right:*** Short grass and brush with a few trees.

***US left:*** Short grass and brush with a few trees.

***US right:***

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

None, 7/23/96.

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

## Hydrology

***Drainage area*** 50.2 ***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***: There are a couple houses and businesses on the right flood plain area.

***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*** 6,170 ***ft³/s*** ***Q500*** 9,300 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(50.2/58.0)exp 0.67] with the peak discharges in the Flood Insurance Study for Marshfield, VT (Federal Emergency Management Agency, 1996). The drainage area adjusted discharges are within a range of several flood frequency curves based on empirical methods (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*** Subtract 415.7 ft from the USGS arbitrary survey datum to obtain the datum used in the VTAOT plans.

***Description of reference marks used to determine USGS datum.*** RM1 is a chiseled X on top of the curb above the upstream end of the left abutment (elev. 500.71 ft, arbitrary survey datum). RM2 is a spike in a pole 5 ft above the ground, 20 ft from the DS right corner of the bridge, and 7 ft from the edge of the road (elev. 503.92 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 | -37 | 1 | Exit section |
| FULLV | 0 | 2 | Downstream Full-valley section (Templated from EXITX) |
| BRIDG | 0 | 1 | Bridge section |
| RDWAY | 16 | 1 | Road Grade section |
| APTEM | 64 | 1 | Approach section as surveyed (Used as a template) |
| APPRO | 76 | 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 0.070, and overbank "n" values ranged from 0.035 to 0.045.

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 0.0289 ft/ft which was estimated from the 100-year discharge water surface elevation presented in the Flood Insurance Study for Marshfield, VT (Federal Emergency Management Agency, 1996).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0047 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* 500.7 *ft*
*Average low steel elevation* 496.2 *ft*

*100-year discharge* 6,170 *ft³/s*
*Water-surface elevation in bridge opening* 496.3 *ft*
*Road overtopping?* No *Discharge over road* -- *ft³/s*
*Area of flow in bridge opening* 535 *ft²*
*Average velocity in bridge opening* 11.5 *ft/s*
*Maximum WSPRO tube velocity at bridge* 13.5 *ft/s*

*Water-surface elevation at Approach section with bridge* 499.5
*Water-surface elevation at Approach section without bridge* 496.9
*Amount of backwater caused by bridge* 2.6 *ft*

*500-year discharge* 9,300 *ft³/s*
*Water-surface elevation in bridge opening* 496.3 *ft*
*Road overtopping?* Yes *Discharge over road* 2,150 *ft³/s*
*Area of flow in bridge opening* 535 *ft²*
*Average velocity in bridge opening* 13.2 *ft/s*
*Maximum WSPRO tube velocity at bridge* 15.4 */s*

*Water-surface elevation at Approach section with bridge* 501.7
*Water-surface elevation at Approach section without bridge* 500.1
*Amount of backwater caused by bridge* 1.6 *ft*

*Incipient overtopping discharge* 6,290 *ft³/s*
*Water-surface elevation in bridge opening* 496.3 *ft*
*Area of flow in bridge opening* 535 *ft²*
*Average velocity in bridge opening* 11.8 *ft/s*
*Maximum WSPRO tube velocity at bridge* 13.8 *ft/s*

*Water-surface elevation at Approach section with bridge* 499.7
*Water-surface elevation at Approach section without bridge* 497.0
*Amount of backwater caused by bridge* 2.7 *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 channel bottom is predominantly bedrock upstream and through the bridge which will limit scour. The results of the scour analysis for the 100-year and 500-year discharges are presented in Tables 1 and 2 and the scour depths are presented graphically in Figure 8.

At this site, the 100-year and incipient roadway-overtopping discharges resulted in unsubmerged orifice flow. The 500-year discharge resulted in submerged 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).

For comparison, estimates of contraction scour were also computed for the discharges resulting in orifice flow by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144). The results are 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 also 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.

## 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* | 2.1 | 4.2 | 2.4 |
| *Depth to armoring* | 15.7 | 14.4 | 16.0 |
| ***Left overbank*** | -- | -- | -- |
| ***Right overbank*** | -- | -- | -- |

| Local scour: | 100-yr discharge | 500-yr discharge | Incipient overtopping discharge |
|---|---|---|---|
| ***Abutment scour*** | | | |
| *Left abutment* | 14.3 | 14.4 | 14.4 |
| *Right abutment* | 18.5 | 15.3 | 18.5 |
| ***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* | 3.4 | 3.3 | 3.4 |
| *Right abutment* | 3.4 | 3.3 | 3.4 |
| ***Piers:*** | -- | -- | -- |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |

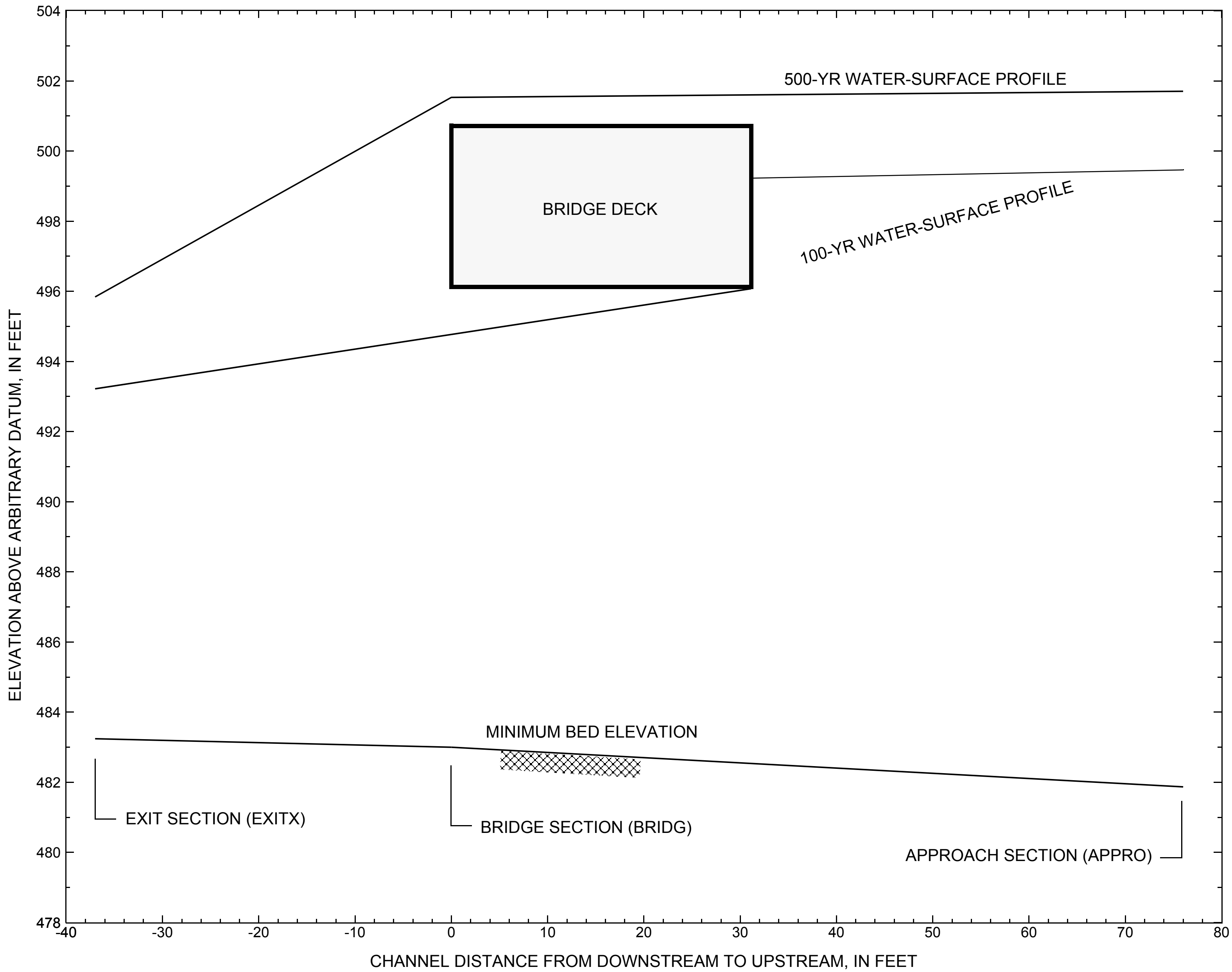


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure MARSUS00020081 on U.S. Highway 2, crossing the Winooski River, Marshfield, Vermont.

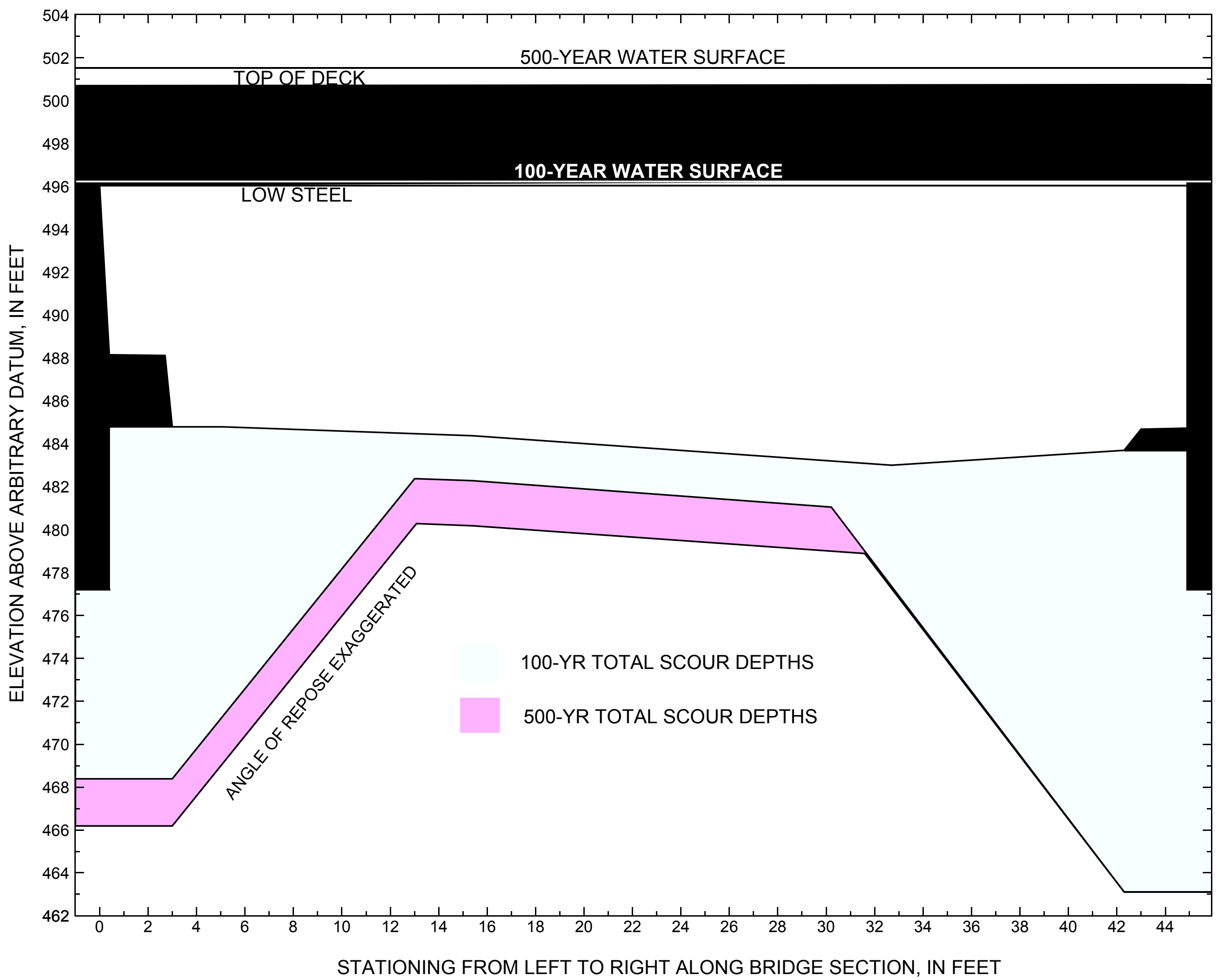


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure MARSUS00020081 on U.S. Highway 2, crossing the Winooski River, Marshfield, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure MARSUS00020081 on U.S. Highway 2, crossing the Winooski River, Marshfield, Vermont.

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

| Description | Station[1] | VTAOT minimum bridge seat elevation (feet) | Surveyed minimum low-chord elevation[2] (feet) | Bottom of footing 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 6,170 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | 80.4 | 496.0 | 477.2 | 484.8 | 2.1 | 14.3 | -- | 16.4 | 468.4 | -8.8 |
| Right abutment | 44.9 | 80.5 | 496.3 | 477.2 | 483.7 | 2.1 | 18.5 | -- | 20.6 | 463.1 | -14.1 |

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 MARSUS00020081 on U.S. Highway 2, crossing the Winooski River, Marshfield, Vermont.

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

| Description | Station[1] | VTAOT minimum bridge seat elevation (feet) | Surveyed minimum low-chord elevation[2] (feet) | Bottom of footing 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 9,300 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | 80.4 | 496.0 | 477.2 | 484.8 | 4.2 | 14.4 | -- | 18.6 | 466.2 | -11.0 |
| Right abutment | 44.9 | 80.5 | 496.3 | 477.2 | 483.7 | 4.2 | 15.3 | -- | 19.5 | 464.2 | -13.0 |

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, 1986, Marshfield, 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 mars081.wsp
T2        Hydraulic analysis for structure MARSUS00020081   Date: 28-OCT-97
T3        Bridge 81 on US route 2 over the Winooski River Marshfield, 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           6170.0   9300.0  6290.0
SK          0.0289   0.0289  0.0289
*
XS   EXITX    -37
GR         -276.9, 505.23   -251.0, 503.11   -195.3, 500.39   -112.9, 500.57
GR          -13.8, 498.47      0.0, 493.53      6.8, 486.48      9.7, 484.84
GR           18.3, 484.49     25.1, 484.81     32.3, 483.24     34.4, 483.64
GR           42.9, 484.13     49.4, 483.96     54.8, 485.88     62.5, 494.39
GR           70.9, 498.16    119.7, 500.01
N           0.035        0.070        0.045
SA                 -13.8         70.9
*
XS   FULLV      0  * * *   0.0117
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.16       0.0
GR            0.0, 496.04      0.4, 488.15      2.7, 488.12      2.9, 486.56
GR            3.0, 484.79      5.1, 484.79      9.8, 484.62     15.4, 484.38
GR           24.0, 483.67     32.7, 483.00     42.3, 483.70     43.0, 484.68
GR           44.9, 484.73     44.9, 496.27      0.0, 496.04
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      31.9      3.2    500.7     48.3
N           0.040
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     16      30.9     1
GR         -312.5, 505.14   -165.4, 501.02     -1.9, 499.69     -1.8, 500.69
GR            0.0, 500.70     45.0, 500.75     46.8, 500.77     46.9, 500.05
GR          129.6, 500.47    210.7, 500.37    228.7, 503.33    261.2, 505.17
*          148.0, 499.99    167.3, 498.26    190.5, 498.61
*
XT   APTEM     64
GR         -266.9, 502.51    -74.0, 496.57    -63.0, 494.35    -57.5, 492.90
GR          -31.7, 492.82    -13.2, 492.49     -6.6, 492.15      0.0, 486.56
GR            2.5, 485.05      7.8, 481.81     31.2, 483.25     32.1, 483.31
GR           56.2, 484.73     60.8, 486.64     69.2, 496.47    101.6, 500.05
GR          128.8, 500.23    210.7, 500.37    229.1, 503.81    245.3, 504.91
*
AS   APPRO     76 * * * 0.0047
GT
N           0.040        0.069        0.043
SA                  -6.6         69.2
*
HP 1 BRIDG 496.27 1 496.27
HP 2 BRIDG 496.27 * * 6170
HP 1 BRIDG 494.72 1 494.72
HP 1 APPRO 499.46 1 499.46
HP 2 APPRO 499.46 * * 6170
HP 1 BRIDG 496.27 1 496.27
HP 2 BRIDG 496.27 * * 7059
HP 2 RDWAY 501.53 * * 2146
HP 1 APPRO 501.70 1 501.70
```

APPENDIX B:

# WSPRO OUTPUT FILE

# WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File mars081.wsp
      Hydraulic analysis for structure MARSUS00020081   Date: 28-OCT-97
      Bridge 81 on US route 2 over the Winooski River Marshfield, VT by MAI
         *** RUN DATE & TIME: 11-04-97  11:15
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     535.   56318.     0.   112.                          0.
 496.27          535.   56318.     0.   112.  1.00     0.    45.      0.


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

       WSEL     LEW     REW    AREA        K        Q    VEL
     496.27     0.0    44.9   534.7   56318.    6170.  11.54

X STA.        0.0        5.1        7.7       10.1       12.3       14.5
  A(I)            46.6       28.9       27.5       25.7       25.1
  V(I)            6.62      10.68      11.21      12.01      12.27

X STA.       14.5       16.6       18.6       20.6       22.5       24.3
  A(I)            24.9       23.8       23.9       23.5       23.1
  V(I)           12.39      12.96      12.90      13.13      13.36

X STA.       24.3       26.2       28.0       29.7       31.5       33.2
  A(I)            22.9       23.1       22.9       23.0       22.9
  V(I)           13.50      13.34      13.50      13.42      13.47

X STA.       33.2       35.0       36.9       38.9       41.1       44.9
  A(I)            23.6       24.2       25.6       28.3       45.2
  V(I)           13.09      12.73      12.06      10.88       6.82

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

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     470.   65745.    45.    65.                       8645.
 494.72          470.   65745.    45.    65.  1.00     0.    45.   8645.

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      76.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     546.   46117.   159.   160.                       5733.
           2    1094.  130606.    76.    84.                      23588.
           3      39.    1735.    27.    27.                        268.
 499.46         1679.  178458.   262.   271.  1.09  -166.    96.  23132.


  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      76.

       WSEL     LEW     REW    AREA        K        Q    VEL
     499.46  -166.0    95.7  1679.0  178458.    6170.   3.67

X STA.     -166.0      -62.5      -45.5      -32.1      -19.5       -8.3
  A(I)           176.6      107.5       88.0       83.9       77.5
  V(I)            1.75       2.87       3.51       3.68       3.98

X STA.       -8.3        1.6        6.7       10.5       14.3       18.1
  A(I)            99.8       78.3       66.9       65.7       64.8
  V(I)            3.09       3.94       4.61       4.70       4.76

X STA.       18.1       21.9       25.9       30.0       34.1       38.4
  A(I)            64.6       65.7       66.8       66.4       67.8
  V(I)            4.78       4.70       4.62       4.65       4.55

X STA.       38.4       42.9       47.5       52.5       58.1       95.7
  A(I)            71.1       70.5       74.8       82.2      140.3
  V(I)            4.34       4.38       4.13       3.75       2.20
```

# WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File mars081.wsp
        Hydraulic analysis for structure MARSUS00020081   Date: 28-OCT-97
        Bridge 81 on US route 2 over the Winooski River Marshfield, VT by MAI
           *** RUN DATE & TIME: 11-04-97  11:15
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      535.   56318.     0.   112.                            0.
   496.27          535.   56318.     0.   112.  1.00     0.    45.      0.


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.27     0.0    44.9   534.7   56318.    7059.  13.20

X STA.         0.0        5.1        7.7        10.1       12.3       14.5
  A(I)            46.6       28.9       27.5       25.7       25.1
  V(I)            7.57      12.21      12.83      13.74      14.04

X STA.        14.5       16.6       18.6       20.6       22.5       24.3
  A(I)            24.9       23.8       23.9       23.5       23.1
  V(I)           14.17      14.82      14.76      15.02      15.29

X STA.        24.3       26.2       28.0       29.7       31.5       33.2
  A(I)            22.9       23.1       22.9       23.0       22.9
  V(I)           15.44      15.26      15.44      15.35      15.41

X STA.        33.2       35.0       36.9       38.9       41.1       44.9
  A(I)            23.6       24.2       25.6       28.3       45.2
  V(I)           14.98      14.57      13.79      12.45       7.81


    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      16.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.53  -183.6   217.8   435.3   15687.    2146.   4.93

X STA.      -183.6     -127.9     -103.9      -86.3      -71.3      -58.3
  A(I)            29.5       21.9       19.1       18.1       17.2
  V(I)            3.64       4.90       5.62       5.91       6.22

X STA.       -58.3      -47.3      -37.2      -28.0      -19.6       -9.8
  A(I)            15.7       15.3       14.7       14.0       17.1
  V(I)            6.84       7.01       7.32       7.69       6.29

X STA.        -9.8       26.5       60.7       78.6       94.5      112.1
  A(I)            37.5       36.0       24.5       20.3       21.0
  V(I)            2.86       2.98       4.38       5.28       5.10

X STA.       112.1      132.7      153.8      173.9      193.3      217.8
  A(I)            22.6       22.7       22.1       21.9       24.1
  V(I)            4.75       4.73       4.85       4.90       4.46

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      76.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      985.   95946.   232.   233.                        11505.
            2     1264.  166106.    76.    84.                        29286.
            3      265.   13494.   148.   149.                         2009.
   501.70         2513.  275546.   456.   465.  1.15  -239.   218.  31187.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      76.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.70  -238.8   217.5  2513.3  275546.    9300.   3.70

X STA.      -238.8     -110.6      -72.7      -53.8      -40.6      -28.3
  A(I)           253.0      171.6      137.6      115.7      108.5
  V(I)            1.84       2.71       3.38       4.02       4.28

X STA.       -28.3      -16.9       -5.9        3.6        9.0       13.7
  A(I)           103.2      101.8      132.0      102.3       91.1
  V(I)            4.51       4.57       3.52       4.55       5.10

X STA.        13.7       18.5       23.2       28.3       33.3       38.6
  A(I)            92.6       91.2       94.0       93.4       95.2
  V(I)            5.02       5.10       4.95       4.98       4.88

X STA.        38.6       44.2       49.9       56.2       67.8      217.5
  A(I)            99.7       98.7      107.9      150.3      273.2
  V(I)            4.66       4.71       4.31       3.09       1.70
```

```
        U.S. Geological Survey WSPRO Input File mars081.wsp
        Hydraulic analysis for structure MARSUS00020081   Date: 28-OCT-97
        Bridge 81 on US route 2 over the Winooski River Marshfield, VT by MAI
           *** RUN DATE & TIME: 11-04-97  11:15
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     535.   56318.     0.   112.                           0.
   496.27          535.   56318.     0.   112.  1.00     0.    45.      0.


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.27     0.0    44.9   534.7   56318.    6290.  11.76

X STA.         0.0        5.1        7.7       10.1       12.3       14.5
  A(I)            46.6       28.9       27.5       25.7       25.1
  V(I)            6.75      10.88      11.43      12.25      12.51

X STA.        14.5       16.6       18.6       20.6       22.5       24.3
  A(I)            24.9       23.8       23.9       23.5       23.1
  V(I)           12.63      13.21      13.15      13.38      13.62

X STA.        24.3       26.2       28.0       29.7       31.5       33.2
  A(I)            22.9       23.1       22.9       23.0       22.9
  V(I)           13.76      13.60      13.76      13.68      13.73

X STA.        33.2       35.0       36.9       38.9       41.1       44.9
  A(I)            23.6       24.2       25.6       28.3       45.2
  V(I)           13.34      12.98      12.29      11.10       6.95


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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     476.   66929.    45.    65.                        8806.
   494.85          476.   66929.    45.    65.  1.00     0.    45.   8806.

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      76.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     592.   50848.   169.   169.                        6294.
             2    1115.  134856.    76.    84.                       24277.
             3      47.    2213.    29.    29.                         336.
   499.74         1754.  187917.   273.   282.  1.09  -175.    98.  24143.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      76.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.74  -175.1    98.3  1753.9  187917.    6290.   3.59

X STA.      -175.1      -66.8      -48.3      -34.4      -22.3      -10.8
  A(I)           185.3      114.3       94.9       84.4       82.1
  V(I)            1.70       2.75       3.31       3.73       3.83

X STA.       -10.8        0.1        5.7        9.8       13.7       17.5
  A(I)            99.9       83.1       73.0       67.8       66.9
  V(I)            3.15       3.79       4.31       4.64       4.70

X STA.        17.5       21.5       25.5       29.6       33.8       38.3
  A(I)            68.1       67.2       69.3       69.0       72.0
  V(I)            4.62       4.68       4.54       4.56       4.37

X STA.        38.3       42.8       47.5       52.8       58.5       98.3
  A(I)            72.2       73.2       80.1       85.5      145.7
  V(I)            4.35       4.30       3.93       3.68       2.16
```

```
        U.S. Geological Survey WSPRO Input File mars081.wsp
        Hydraulic analysis for structure MARSUS00020081   Date: 28-OCT-97
        Bridge 81 on US route 2 over the Winooski River Marshfield, VT by MAI
           *** RUN DATE & TIME: 11-04-97  11:15

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

EXITX:XS   ******     0.     471.  2.67 *****  495.89  492.26   6170.  493.22
      -37. ******    61.   36295.  1.00 ***** *******    0.83   13.11

FULLV:FV      37.    -2.     538.  2.05  0.89  496.77 *******   6170.  494.72
        0.    37.    62.   43551.  1.00  0.00   -0.01    0.70   11.48
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"      KRATIO =  2.61

APPRO:AS      76.   -82.    1143.  0.47  0.58  497.35 *******   6170.  496.89
       76.    76.    72.  113794.  1.03  0.00    0.00    0.36    5.40
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   492.60     497.30     497.60     496.16

 ===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      37.     0.     535.  2.02 *****  498.29  492.54   6095.  496.27
        0. ******    45.   56318.  1.00 ***** *******    0.58   11.40

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   2.  0.466  0.000  496.16 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      16.        <<<<<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      44.  -166.    1680.  0.23  0.18  499.69  490.51   6170.  499.46
       76.    48.    96.  178537.  1.09  0.71   -0.01    0.27    3.67


        U.S. Geological Survey WSPRO Input File mars081.wsp
        Hydraulic analysis for structure MARSUS00020081   Date: 28-OCT-97
        Bridge 81 on US route 2 over the Winooski River Marshfield, VT by MAI
           *** RUN DATE & TIME: 11-04-97  11:15
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -37.     0.    61.   6170.   36295.     471.   13.11  493.22
   FULLV:FV      0.     -2.    62.   6170.   43551.     538.   11.48  494.72
   BRIDG:BR      0.      0.    45.   6095.   56318.     535.   11.40  496.27
   RDWAY:RG      16.**************      0.******************     1.00********
   APPRO:AS      76.  -166.    96.   6170.  178537.    1680.    3.67  499.46

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************

        U.S. Geological Survey WSPRO Input File mars081.wsp
        Hydraulic analysis for structure MARSUS00020081   Date: 28-OCT-97
        Bridge 81 on US route 2 over the Winooski River Marshfield, VT by MAI
           *** RUN DATE & TIME: 11-04-97  11:15
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    492.26    0.83  483.24  505.23************  2.67  495.89  493.22
   FULLV:FV  ********    0.70  483.67  505.66  0.89  0.00  2.05  496.77  494.72
   BRIDG:BR    492.54    0.58  483.00  496.27************  2.02  498.29  496.27
   RDWAY:RG  ****************  499.69  505.17************  0.17  500.69********
   APPRO:AS    490.51    0.27  481.87  504.97  0.18  0.71  0.23  499.69  499.46
```

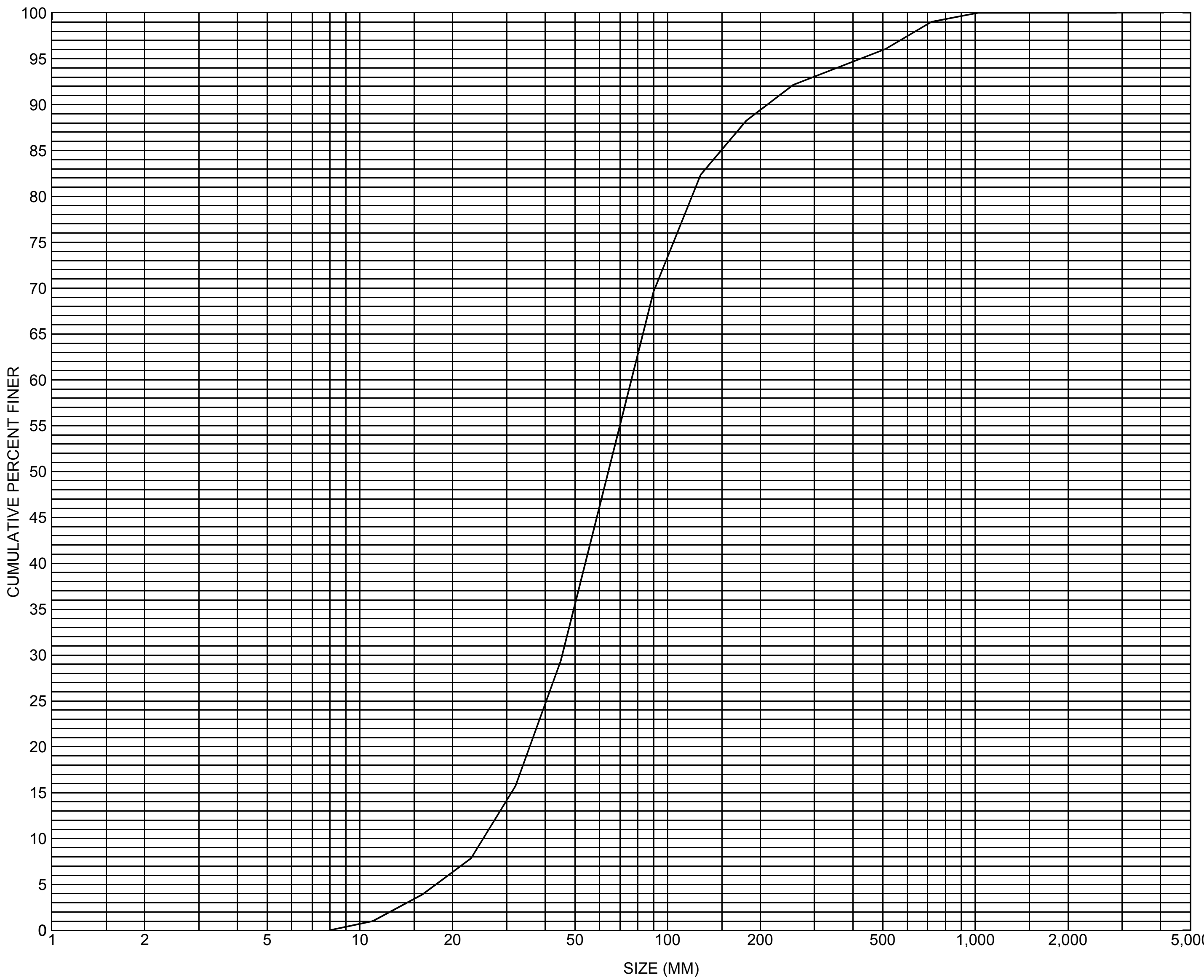
```
        U.S. Geological Survey WSPRO Input File mars081.wsp
        Hydraulic analysis for structure MARSUS00020081   Date: 28-OCT-97
        Bridge 81 on US route 2 over the Winooski River Marshfield, VT by MAI
           *** RUN DATE & TIME: 11-04-97  11:15

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

EXITX:XS   ******    -6.     643.  3.25 *****  499.09  494.68   9300.  495.84
      -37. ******    66.   54654.  1.00 ***** *******    0.85   14.46

FULLV:FV      37.   -10.     736.  2.49  0.90  499.98 *******   9300.  497.50
        0.    37.    68.   64849.  1.00  0.00   -0.01    0.73   12.64
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  3.07

APPRO:AS      76.  -185.    1843.  0.43  0.51  500.49 *******   9300.  500.06
       76.    76.   101.  199342.  1.09  0.00    0.00    0.37    5.05
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   497.50     496.16

            <<<<<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      37.     0.     535.  2.71 *****  498.98  493.40   7059.  496.27
        0. ******    45.   56318.  1.00 ***** *******    0.67   13.20

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   6.  0.800  0.000  496.16 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      16.    45.  0.05  0.25  501.89   -0.01    2146.  501.53

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1077.   208.  -183.    24.   1.8   1.0   5.5   5.0   1.4   3.1
   RT:   1069.   193.    24.   218.   1.5   1.1   5.6   4.9   1.5   3.1

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

APPRO:AS      44.  -239.    2513.  0.25  0.22  501.94  493.65   9300.  501.70
       76.    50.   218.  275483.  1.15  0.71   -0.01    0.30    3.70

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

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

        U.S. Geological Survey WSPRO Input File mars081.wsp
        Hydraulic analysis for structure MARSUS00020081   Date: 28-OCT-97
        Bridge 81 on US route 2 over the Winooski River Marshfield, VT by MAI
           *** RUN DATE & TIME: 11-04-97  11:15
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXITX:XS     -37.    -6.    66.   9300.   54654.     643.   14.46  495.84
   FULLV:FV       0.   -10.    68.   9300.   64849.     736.   12.64  497.50
   BRIDG:BR       0.     0.    45.   7059.   56318.     535.   13.20  496.27
   RDWAY:RG      16.******* 1077.   2146.******************    1.00  501.53
   APPRO:AS      76.  -239.   218.   9300.  275483.    2513.    3.70  501.70

    XSID:CODE   XLKQ   XRKQ      KQ
   APPRO:AS  ***********************

        U.S. Geological Survey WSPRO Input File mars081.wsp
        Hydraulic analysis for structure MARSUS00020081   Date: 28-OCT-97
        Bridge 81 on US route 2 over the Winooski River Marshfield, VT by MAI
           *** RUN DATE & TIME: 11-04-97  11:15
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    494.68    0.85  483.24  505.23************  3.25  499.09  495.84
   FULLV:FV  ********    0.73  483.67  505.66  0.90  0.00  2.49  499.98  497.50
   BRIDG:BR    493.40    0.67  483.00  496.27************  2.71  498.98  496.27
   RDWAY:RG  ****************  499.69  505.17  0.05******  0.25  501.89  501.53
   APPRO:AS    493.65    0.30  481.87  504.97  0.22  0.71  0.25  501.94  501.70
```

# WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File mars081.wsp
        Hydraulic analysis for structure MARSUS00020081   Date: 28-OCT-97
        Bridge 81 on US route 2 over the Winooski River Marshfield, VT by MAI
           *** RUN DATE & TIME: 11-04-97  11:15

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

EXITX:XS   ******     0.     477.  2.71 *****  496.03  492.34   6290.  493.32
      -37. ******    62.   36978.  1.00 ***** *******    0.83   13.19

FULLV:FV      37.    -2.     546.  2.06  0.89  496.92 *******   6290.  494.85
        0.    37.    63.   44458.  1.00  0.00    0.00    0.70   11.52
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  2.62

APPRO:AS      76.   -87.    1165.  0.47  0.58  497.50 *******   6290.  497.03
       76.    76.    74.  116380.  1.03  0.00    0.00    0.36    5.40
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   492.71     497.48     497.78     496.16

 ===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      37.     0.     535.  2.13 *****  498.40  492.69   6256.  496.27
        0. ******    45.   56318.  1.00 ***** *******    0.60   11.70

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   2.  0.471  0.000  496.16 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      16.        <<<<<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      44.  -175.    1753.  0.22  0.18  499.96  490.61   6290.  499.74
       76.    48.    98.  187834.  1.09  0.70   -0.01    0.26    3.59

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   499.69

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

        U.S. Geological Survey WSPRO Input File mars081.wsp
        Hydraulic analysis for structure MARSUS00020081   Date: 28-OCT-97
        Bridge 81 on US route 2 over the Winooski River Marshfield, VT by MAI
           *** RUN DATE & TIME: 11-04-97  11:15
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -37.     0.    62.   6290.   36978.     477.   13.19  493.32
   FULLV:FV       0.    -2.    63.   6290.   44458.     546.   11.52  494.85
   BRIDG:BR       0.     0.    45.   6256.   56318.     535.   11.70  496.27
   RDWAY:RG      16.**************      0.       0.       0.    1.00********
   APPRO:AS      76.  -175.    98.   6290.  187834.    1753.    3.59  499.74

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  **********************

        U.S. Geological Survey WSPRO Input File mars081.wsp
        Hydraulic analysis for structure MARSUS00020081   Date: 28-OCT-97
        Bridge 81 on US route 2 over the Winooski River Marshfield, VT by MAI
           *** RUN DATE & TIME: 11-04-97  11:15
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF     HO   VHD      EGL    WSEL
   EXITX:XS    492.34    0.83  483.24  505.23************  2.71  496.03  493.32
   FULLV:FV  ********    0.70  483.67  505.66  0.89  0.00  2.06  496.92  494.85
   BRIDG:BR    492.69    0.60  483.00  496.27************  2.13  498.40  496.27
   RDWAY:RG  ****************  499.69  505.17************  0.22  499.91********
   APPRO:AS    490.61    0.26  481.87  504.97  0.18  0.70  0.22  499.96  499.74
```

# APPENDIX C:

# BED-MATERIAL PARTICLE-SIZE DISTRIBUTION




Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure MARSUS00020081, in Marshfield, Vermont.

# APPENDIX D:

# HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

# Structure Number MARSUS00020081

## General Location Descriptive

Data collected by *(First Initial, Full last name)* L. Medalie

Date *(MM/DD/YY)* 11 / 1 / 95

Highway District Number *(I - 2; nn)* 06

County *(FIPS county code; I - 3; nnn)* 023

Town *(FIPS place code; I - 4; nnnnn)* 43600

Mile marker *(I - 11; nnn.nnn)* 006850

Waterway *(I - 6)* Winooski River

Road Name *(I - 7)*: US 2

Route Number US 2

Vicinity *(I - 9)* 1.0 mile west of jct VT 232

Topographic Map Marshfield

Hydrologic Unit Code: 2010003

Latitude *(I - 16; nnnn.n)* 44211

Longitude *(i - 17; nnnnn.n)* 72208

## Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20002800811209

Maintenance responsibility *(I - 21; nn)* 01

Maximum span length *(I - 48; nnnn)* 0047

Year built *(I - 27; YYYY)* 1927

Structure length *(I - 49; nnnnnn)* 000049

Average daily traffic, ADT *(I - 29; nnnnnn)* 003080

Deck Width *(I - 52; nn.n)* 309

Year of ADT *(I - 30; YY)* 92

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

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

Waterway adequacy *(I - 71; n)* 5

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

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

Structure type *(I - 43; nnn)* 104

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 45

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

Vertical clearance from streambed (*nnn.n ft*) 13

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

Waterway of full opening (*nnn.n* $ft^2$) 585

Comments:

**According to the structural inspection report dated 7/2/93, the structure is a single span concrete T-beam bridge. Both abutments are concrete. On the left abutment, there is some minor debris in the bridge seat area. The stem of the abutment has areas of staining and minor cracking. There is some scaling near the flow line of the left abutment and its wingwalls. There is a concrete facing on the upstream half of this stem at the footing area which has some heavy scaling. The remainder of the footing is exposed but not undermined. There is some minor scaling at the stem and wingwalls of the right abutment. The footing at the right abutment is on ledge. There is some scaling in the top of the footing and a spalled area at the upstream right corner.** **(Continued on page 33)**

## Bridge Hydrologic Data

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

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 $Q_{100}$ (*$ft^3$/ 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 (*$ft^2$*): -

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

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

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

Comments:

**There is some very slight undermining at the upstream right end underneath the spalled area. The channel takes a moderate turn into the structure and a moderate turn out of it. There is stone fill at the wingwalls upstream and on the right abutment side downstream. There is a log against the left abutment on the downstream end. There is some flood elevation data in the notes for the Winooski River at seven sites in or near Marshfield.**

## USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **50.17** $mi^2$  Lake/pond/swamp area **1.77** $mi^2$

Watershed storage *(ST)* **3.5** %

Bridge site elevation **827** ft  Headwater elevation **1831** ft

Main channel length **9.38** mi

10% channel length elevation **853** ft  85% channel length elevation **1365** ft

Main channel slope *(S)* **73.33** 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):* **-** / ______

Project Number **-** Minimum channel bed elevation: **66.8**

Low superstructure elevation: USLAB **80.41** DSLAB **80.41** USRAB **80.54** DSRAB **80.54**

Benchmark location description:
**BM #1, Drilled hole on top of rock 27 ft left of Stationing 1+79, Elev. 100 ft, approximately 600 ft to the left side (west) of the river, north of the road. BM #2, Spike in 2.5 ft diameter pine 18.5 ft right of Stationing 5+50, Elev. 82.90 ft, approximately 150 ft left of the bridge, upstream of the road.**

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

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

If 1: Footing Thickness **3+** Footing bottom elevation: **61.5**

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

Briefly describe material at foundation bottom elevation or around piles:
**Note in plans states "apparent firm foundation (at left abutment) elev. 62.5 ft".**

Comments:
**BM #3, US BM on top of ledge 22.5 ft right of Stationing 13+50, Elev. 92.90 ft, approximately 600 ft right of the bridge, upstream of the road east of a bandstand, east of the road to Cabot, and across from the saw mill.**
**The approximate high water elevation was noted as 78.5 ft. The elevation of the streambed near the left abutment is 69.5 ft. The low super structure elevations are the bridge seat elevations from the bridge plans. The top of footing at the LABUT (RABUT) = 64.41 (64.54) respectively and a thickness noted as at least 3 ft.**

## Cross-sectional Data

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

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

Comments: NO CROSS SECTIONAL INFORMATION

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

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

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

Comments: -

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

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

APPENDIX E:

# LEVEL I DATA FORM

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

Qa/Qc Check by: **EW** Date: **11/1/96**
Computerized by: **EW** Date: **11/4/96**
Reviewd by: **MAI** Date: **11/6/97**

Structure Number **MARSUS00020081**

## A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R**. **BURNS** Date *(MM/DD/YY)* **07** / **23** / 19**96**
2. Highway District Number **06** Mile marker **006850**
   County **Washington (023)** Town **Marshfield (43600)**
   Waterway *(I - 6)* **Winooski River** Road Name **US 2**
   Route Number **US 2** Hydrologic Unit Code: **02010003**
3. Descriptive comments:
**The site is located 1.0 mile west of the junction with State Route 232.**

## B. Bridge Deck Observations

4. Surface cover... LBUS **4** RBUS **4** LBDS **6** RBDS **2** Overall **2**
*(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 **2** *(**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 **49** *(feet)* Span length **47** *(feet)* Bridge width **30.9** *(feet)*

### Road approach to bridge:

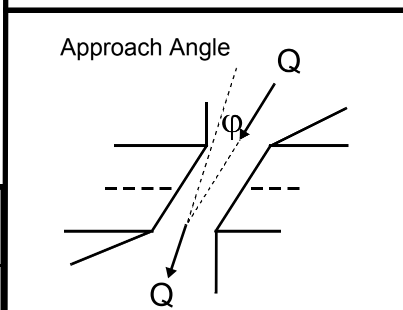
8. LB **2** RB **0** *( **0** even, **1**- lower, **2**- higher)*
9. LB **1** RB **1** *( **1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left **2.0:1** US right **4.3:1**

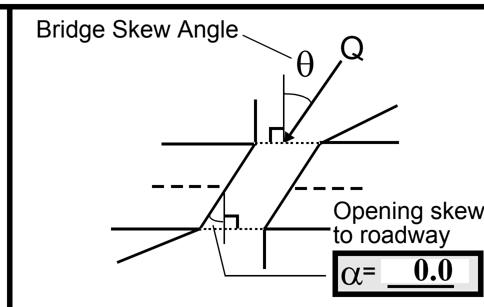
| | Protection | | 13.Erosion | 14.Severity |
|---|---|---|---|---|
| | 11.Type | 12.Cond. | | |
| LBUS | 1 | 1 | 0 | - |
| RBUS | 2 | 1 | 0 | - |
| RBDS | 3 | 1 | 0 | - |
| LBDS | 3 | 1 | 0 | - |

*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: **50** 16. Bridge skew: **10**




17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **30** feet **US** *(US, UB, DS)* to **0** feet **US**
Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **10** feet **DS** *(US, UB, DS)* to **40** feet **DS**

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

18. Bridge Type: **4**

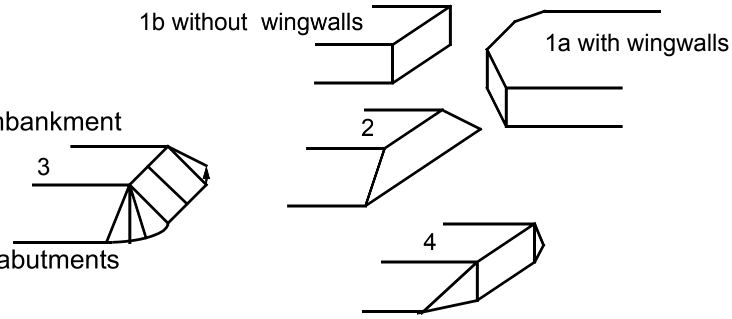
1a- Vertical abutments with wingwalls

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 left bank upstream is a cemetery with shrubs and brush along the banks. The upstream right bank has trees along the immediate bank and then a lawn and a garage. The downstream left bank also has trees along the bank and then a gravel parking lot with forest beyond. The downstream right bank has trees along the immediate bank and then the surface cover is a store with a paved parking lot.**

**11. The downstream left bank road embankment protection is a boulder lined gully which runs along the road. The other three road embankment protections are rock lined slopes along the road embankment down to the stream.**

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| **36.0** | **5.5** | | | **10.0** | **2** | **3** | **543** | **543** | **0** | **0** |

23. Bank width **35.0** 24. Channel width **35.0** 25. Thalweg depth **81.5** 29. Bed Material **654**

30 .Bank protection type: LB **1** RB **1** 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.):

**30. Bank protection on the upstream left bank extends from the upstream end of the left wingwall to 10 ft upstream. On the right bank, the protection extends from the upstream end of the right wingwall to 20 ft upstream.**

**The stream makes an 80 degree turn at 175 ft upstream, then there is a major riffle at 90 ft upstream. At this point, the stream bends again and flows through the bridge.**

**There are large natural boulders along the upstream right bank from 20 ft upstream to 140 ft upstream; and along the left bank from 10 ft upstream to 80 ft upstream.**

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? LB (LB or RB)

41. Mid-bank distance: 90 42. Cut bank extent: 100 feet US (US, UB) to 80 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.):

**On the left side of the major riffle, the bank has eroded.**

**Another cut-bank is on the right bank extending from 180 ft upstream to 140 ft upstream. Here, the stream makes a turn toward the bridge and some large trees have fallen into the channel.**

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 30 US

47. Scour dimensions: Length 20 Width 10 Depth : 1 Position 10 %LB to 40 %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):

**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) 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 |
|---|---|---|---|---|---|---|---|
| 62.5 | | 3.5 | | 2 | 7 | 7 | - |

58. Bank width (BF) - 59. Channel width (Amb) - 60. Thalweg depth (Amb) 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.):

**56**

**-**

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

67. Debris Potential 1____ *( 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**

**There was some debris along the upstream banks with trees leaning over the channel.**

| 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 | | 15 | 90 | 2 | 2 | 0.5 | 5 | 90.0 |
| RABUT | 1 | - | 90 | | | 2 | 2 | 44.5 |

*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.):

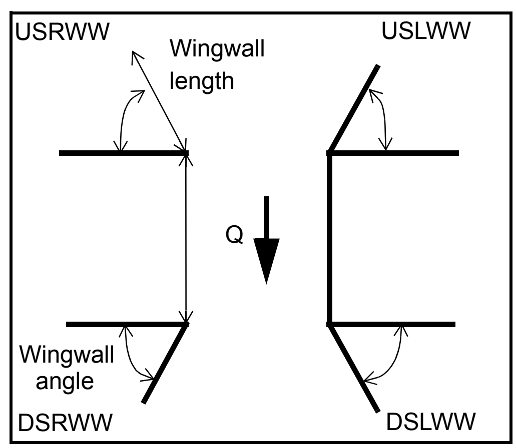
**0**
**1**
**1**

**The LABUT footing has a water depth of 3.5 ft at the upstream end and 1.5 ft at the downstream end. The LABUT footing is exposed 5 ft at the upstream end and 3 ft at the downstream end. The footing is on top of bedrock that is visible midway along the footing.**

**The upstream half of the RABUT footing is exposed 1 ft in the middle where the water depth is 0.5 ft; at the upstream end of the RABUT footing the exposure depth is 0.3 ft. The downstream half of the RABUT footing is presently covered by sand.**

80. **Wingwalls**:

| | Exist? | Material? | Scour Condition? | Scour depth? | Exposure depth? | 81. Angle? | Length? |
|---|---|---|---|---|---|---|---|
| USLWW: | | | | | | 44.5 | |
| USRWW: | Y | | 1 | | 2 | 3.0 | |
| DSLWW: | 0.5 | | 5 | | Y | 32.0 | |
| DSRWW: | 1 | | 0 | | - | 32.0 | |




*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 | - | 2 | Y | - | 1 | 1 | - | - |
| Condition | Y | 0 | 1 | - | 2 | 2 | - | - |
| Extent | 1 | 3 | 0 | 1 | 1 | 0 | 0 | - |

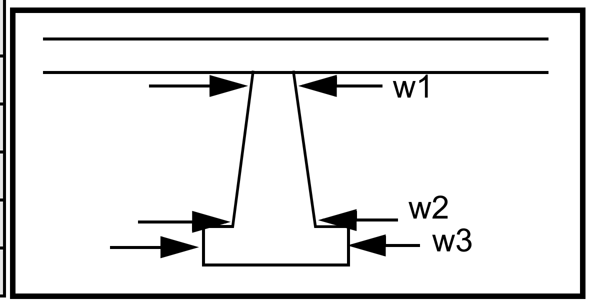
*Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee*
*Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed*
*Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other*

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
**-**
**-**
**-**
**-**
**-**
**1**
**1**
**3**
**0**
**-**
**-**

## 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 | | | | **45.0** | **14.0** | **50.0** |
| Pier 2 | | | | **12.5** | **45.0** | **12.5** |
| Pier 3 | | | - | **45.0** | **17.5** | - |
| Pier 4 | - | - | - | - | - | - |




| Level 1 Pier Descr. | 1 | 2 | 3 | 4 | |
|---|---|---|---|---|---|
| 86. Location (BF) | **e** | **where** | **e it** | **wall** | *LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP* |
| 87. Type | **dow** | **the** | **joins** | **foot-** | ***1**- Solid pier, **2**- column, **3**- bent* |
| 88. Material | **nstre** | **wate** | **the** | **ing is** | ***1**- Wood; **2**- concrete; **3**- metal; **4**- stone* |
| 89. Shape | **am** | **r** | **abut** | **expo** | ***1**- Round; **2**- Square; **3**- Pointed* |
| 90. Inclined? | **left** | **dept** | **ment** | **sed 5** | *Y- yes; N- no* |
| 91. Attack ∠ (BF) | **wing** | **h is** | **.** | **ft at** | |
| 92. Pushed | **wall** | **1.5 ft** | | **the** | *LB or RB* |
| 93. Length (feet) | - | - | - | - | |
| 94. # of piles | **foot-** | **at** | **The** | **cor-** | |
| 95. Cross-members | **ing is** | **the** | **upst** | **ner** | ***0**- none; **1**- laterals; **2**- diagonals; **3**- both* |
| 96. Scour Condition | **expo** | **cor-** | **ream** | **wher** | ***0**- not evident; **1**- evident (comment);<br>**2**- footing exposed; **3**- piling exposed;<br>**4**- undermined footing; **5**- settled; **6**- failed* |
| 97. Scour depth | **sed 3** | **ner** | **left** | **e the** | |
| 98. Exposure depth | **ft** | **wher** | **wing** | **wate** | |

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

**r depth is 3.5 ft.**

**N**

-

## 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 (Amb) - Thalweg depth (Amb) - 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.):

-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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 __-__ feet __-__ *(US, UB, DS)* positioned __-__ %LB to __-__ %RB

Material: __-__

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

**-**
**-**
**-**
**NO PIERS**

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.):

**4**
**3**
**54**

Is channel scour present? __**54**__ *(Y or if N type ctrl-n cs)* Mid-scour distance: __**0**__

Scour dimensions: Length __**0**__ Width __**54**__ Depth: __**3**__ Positioned __**2**__ %LB to __**1**__ %RB

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

**1**
**There are large boulders along the left bank that have been placed from 0 ft downstream to 100 ft downstream.**

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

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

Confluence 2: Distance __**there**__ Enters on __**is a**__ *(LB or RB)* Type __**ston**__ *( **1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

**e fill at the downstream end of the right wingwall to 25 ft downstream.**

## 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 DROP STRUCTURE**

## 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: | MARSUS00020081 | Town: | Marshfield |
| Road Number: | US 2 | County: | Washington |
| Stream: | Winooski River | | |

Initials MAI    Date: 11/4/97  Checked: RLB

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 | 6170 | 9300 | 6290 |
| Main Channel Area, ft2 | 1094 | 1264 | 1115 |
| Left overbank area, ft2 | 546 | 985 | 592 |
| Right overbank area, ft2 | 39 | 265 | 47 |
| Top width main channel, ft | 76 | 76 | 76 |
| Top width L overbank, ft | 159 | 232 | 169 |
| Top width R overbank, ft | 27 | 148 | 29 |
| D50 of channel, ft | 0.21 | 0.21 | 0.21 |
| D50 left overbank, ft | -- | -- | -- |
| D50 right overbank, ft | -- | -- | -- |
| | | | |
| y1, average depth, MC, ft | 14.4 | 16.6 | 14.7 |
| y1, average depth, LOB, ft | 3.4 | 4.2 | 3.5 |
| y1, average depth, ROB, ft | 1.4 | 1.8 | 1.6 |
| | | | |
| Total conveyance, approach | 178458 | 275546 | 187917 |
| Conveyance, main channel | 130606 | 166106 | 134856 |
| Conveyance, LOB | 46117 | 95946 | 50848 |
| Conveyance, ROB | 1735 | 13494 | 2213 |
| Percent discrepancy, conveyance | 0.0000 | 0.0000 | 44.7048 |
| Qm, discharge, MC, cfs | 4515.6 | 5606.3 | 1702.0 |
| Ql, discharge, LOB, cfs | 1594.4 | 3238.3 | 1702.0 |
| Qr, discharge, ROB, cfs | 60.0 | 455.4 | 74.1 |
| | | | |
| Vm, mean velocity MC, ft/s | 4.1 | 4.4 | 1.5 |
| Vl, mean velocity, LOB, ft/s | 2.9 | 3.3 | 2.9 |
| Vr, mean velocity, ROB, ft/s | 1.5 | 1.7 | 1.6 |
| Vc-m, crit. velocity, MC, ft/s | 10.4 | 10.6 | 10.4 |
| 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 | 6170 | 9300 | 6290 |
| (Q) discharge thru bridge, cfs | 6170 | 7059 | 6290 |
| Main channel conveyance | 56318 | 56318 | 56318 |
| Total conveyance | 56318 | 56318 | 56318 |
| Q2, bridge MC discharge,cfs | 6170 | 7059 | 6290 |
| Main channel area, ft2 | 535 | 535 | 535 |
| Main channel width (normal), ft | 44.9 | 44.9 | 44.9 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 44.9 | 44.9 | 44.9 |
| y_bridge (avg. depth at br.), ft | 11.92 | 11.92 | 11.92 |
| Dm, median (1.25*D50), ft | 0.2625 | 0.2625 | 0.2625 |
| y2, depth in contraction,ft | 12.34 | 13.84 | 12.54 |
| ys, scour depth (y2-ybridge), ft | 0.42 | 1.93 | 0.63 |

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 | 6170 | 9300 | 6290 |
| Q, thru bridge MC, cfs | 6170 | 7059 | 6290 |
| Vc, critical velocity, ft/s | 10.39 | 10.65 | 10.43 |
| Va, velocity MC approach, ft/s | 4.13 | 4.44 | 1.53 |
| Main channel width (normal), ft | 44.9 | 44.9 | 44.9 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 44.9 | 44.9 | 44.9 |
| qbr, unit discharge, ft2/s | 137.4 | 157.2 | 140.1 |
| Area of full opening, ft2 | 535.0 | 535.0 | 535.0 |
| Hb, depth of full opening, ft | 11.92 | 11.92 | 11.92 |
| Fr, Froude number, bridge MC | 0.58 | 0.67 | 0.6 |
| Cf, Fr correction factor (<=1.0) | 1.00 | 1.00 | 1.00 |
| **Area at downstream face, ft2 | 470 | N/A | 476 |
| **Hb, depth at downstream face, ft | 10.47 | N/A | 10.60 |
| **Fr, Froude number at DS face | 0.72 | ERR | 0.72 |

| | | | |
|---|---|---|---|
| **Cf, for downstream face (<=1.0) | 1.00 | N/A | 1.00 |
| Elevation of Low Steel, ft | 496.16 | 496.16 | 496.16 |
| Elevation of Bed, ft | 484.24 | 484.24 | 484.24 |
| Elevation of Approach, ft | 499.46 | 501.7 | 499.74 |
| Friction loss, approach, ft | 0.18 | 0.22 | 0.18 |
| Elevation of WS immediately US, ft | 499.28 | 501.48 | 499.56 |
| ya, depth immediately US, ft | 15.04 | 17.24 | 15.32 |
| Mean elevation of deck, ft | 500.73 | 500.73 | 500.73 |
| w, depth of overflow, ft (>=0) | 0.00 | 0.75 | 0.00 |
| Cc, vert contrac correction (<=1.0) | 0.94 | 0.92 | 0.94 |
| **Cc, for downstream face (<=1.0) | 0.906707 | ERR | 0.904979 |
| | | | |
| Ys, scour w/Chang equation, ft | **2.11** | **4.18** | **2.42** |
| Ys, scour w/Umbrell equation, ft | -2.42 | -1.01 | -6.62 |

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

| | | | |
|---|---|---|---|
| **Ys, scour w/Chang equation, ft | 4.12 | N/A | 4.25 |
| **Ys, scour w/Umbrell equation, ft | -0.97 | N/A | -5.30 |

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 | 12.34 | 13.84 | 12.54 |
| WSEL at downstream face, ft | 494.72 | -- | 494.85 |
| Depth at downstream face, ft | 10.47 | N/A | 10.60 |
| Ys, depth of scour (Laursen), ft | 1.87 | N/A | 1.94 |

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 | 6170 | 7059 | 6290 |
| Main channel area (DS), ft2 | 470 | 535 | 476 |
| Main channel width (normal), ft | 44.9 | 44.9 | 44.9 |
| Cum. width of piers, ft | 0.0 | 0.0 | 0.0 |
| Adj. main channel width, ft | 44.9 | 44.9 | 44.9 |
| D90, ft | 0.6920 | 0.6920 | 0.6920 |
| D95, ft | 1.3840 | 1.3840 | 1.3840 |
| Dc, critical grain size, ft | 0.6383 | 0.6140 | 0.6437 |
| Pc, Decimal percent coarser than Dc | 0.109 | 0.113 | 0.108 |
| | | | |
| Depth to armoring, ft | **15.67** | **14.42** | **15.95** |

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 | 6170 | 9300 | 6290 | 6170 | 9300 | 6290 |

| | | | | | | |
|---|---|---|---|---|---|---|
| a', abut.length blocking flow, ft | 166 | 238.8 | 175.1 | 50.8 | 172.6 | 53.4 |
| Ae, area of blocked flow ft2 | 617.17 | 880.66 | 659.98 | 337.15 | 422.45 | 351.79 |
| Qe, discharge blocked abut.,cfs | 1801.14 | -- | 1884.11 | 1099.87 | -- | 1117.48 |

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

| | | | | | | |
|---|---|---|---|---|---|---|
| Ve, (Qe/Ae), ft/s | 2.92 | 3.30 | 2.85 | 3.26 | 2.92 | 3.18 |
| ya, depth of f/p flow, ft | 3.72 | 3.69 | 3.77 | 6.64 | 2.45 | 6.59 |

--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 | 90 | 90 | 90 | 90 | 90 | 90 |
| K2 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Fr, froude number f/p flow | 0.267 | 0.274 | 0.259 | 0.223 | 0.272 | 0.218 |
| ys, scour depth, ft | 19.55 | 22.42 | 19.81 | **18.51** | **15.28** | **18.50** |

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) | 166 | 238.8 | 175.1 | 50.8 | 172.6 | 53.4 |
| y1 (depth f/p flow, ft) | 3.72 | 3.69 | 3.77 | 6.64 | 2.45 | 6.59 |
| a'/y1 | 44.65 | 64.75 | 46.46 | 7.65 | 70.52 | 8.11 |
| Skew correction (p. 49, fig. 16) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Froude no. f/p flow | 0.27 | 0.27 | 0.26 | 0.22 | 0.27 | 0.22 |
| Ys w/ corr. factor K1/0.55: | | | | | | |
| vertical | 17.48 | 17.50 | 17.56 | ERR | 11.58 | ERR |
| vertical w/ ww's | **14.34** | **14.35** | **14.40** | ERR | 9.50 | ERR |
| spill-through | 9.62 | 9.62 | 9.66 | ERR | 6.37 | 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 | 0.72 | 0.67 | 0.72 | 0.72 | 0.67 | 0.72 |
| y, depth of flow in bridge, ft | 10.47 | 11.92 | 10.60 | 10.47 | 11.92 | 10.60 |
| Median Stone Diameter for riprap at: | left abutment | | | right abutment, ft | | |
| Fr<=0.8 (vertical abut.) | **3.36** | **3.31** | **3.40** | **3.36** | **3.31** | **3.40** |
| Fr>0.8 (vertical abut.) | ERR | ERR | ERR | ERR | ERR | ERR |