# LEVEL II SCOUR ANALYSIS FOR BRIDGE 5 (MORRTH00060005) on TOWN HIGHWAY 6, crossing BEDELL BROOK, MORRISTOWN, VERMONT

Open-File Report 97-793

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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# LEVEL II SCOUR ANALYSIS FOR BRIDGE 5 (MORRTH00060005) on TOWN HIGHWAY 6, crossing BEDELL BROOK, MORRISTOWN, VERMONT

By ERICK M. BOEHMLER and JAMES R. DEGNAN

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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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Denver, CO 80225-0286

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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 5 (MORRTH00060005) ON TOWN HIGHWAY 6, CROSSING BEDELL BROOK, MORRISTOWN, VERMONT

**By Erick M. Boehmler and James R. Degnan**

## INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure MORRTH00060005 on Town Highway 6 crossing Bedell Brook, Morristown, 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 Green Mountain section of the New England physiographic province in north-central Vermont. The 6.28-$mi^2$ drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover consists of pasture, shrubs, and brushland.

In the study area, Bedell Brook has a sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 56 ft and an average bank height of 4 ft. The predominant channel bed material is gravel with a median grain size ($D_{50}$) of 35.8 mm (0.117 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 16, 1996, indicated that the reach was laterally unstable. There are wide point bars and cut-banks with slipping bank material noted upstream and downstream of this site.

The Town Highway 6 crossing of Bedell Brook is a 44-ft-long, two-lane bridge consisting of one 42-foot concrete T-beam span (Vermont Agency of Transportation, written communication, October 26, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 45 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole up to 1.5 ft deeper than the mean thalweg depth was observed along the left abutment and upstream and downstream left wingwalls during the Level I assessment. The scour protection measure at this site was type-4 stone fill (less than 60 inches diameter) on the left bank and left wingwall upstream, the left abutment and the downstream left wingwall. 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). 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 1.1 to 2.0 feet. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 3.9 to 8.6 feet. The worst-case abutment scour occurred at the 500-year event. 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.

MORRISVILLE, 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*** MORRTH00060005 ***Stream*** Bedell Brook

***County*** Lamoille ***Road*** TH 6 ***District*** 6

### Description of Bridge

***Bridge length*** 44 ***ft*** ***Bridge width*** 23.8 ***ft*** ***Max span length*** 42 ***ft***

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

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

***Stone fill on abutment?*** Yes ***Date of inspection*** 7/16/96

***Description of stone fill*** Type-4 along the upstream left bank and wingwall, the left abutment and the downstream left wingwall.

Abutments and wingwalls are concrete. There is a scour hole up to 1.5 feet below the average thalweg depth along the left abutment and the upstream and downstream left wingwalls.

***Is bridge skewed to flood flow according to*** Yes ***survey?*** Yes ***Angle*** 45

There is a severe channel bend in the upstream reach. The scour hole has developed in the location where the flow impacts the upstream left wingwall and the left abutment.

***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*** | 7/16/96 | 0 | 0 |
| ***Level II*** | 7/16/96 | 0 | 0 |

***Potential for debris*** Moderate. There is some debris caught on the point bar under the bridge and some vegetation on unstable bank material upstream.

***Describe any features near or at the bridge that may affect flow (include observation date)*** There is a narrow point bar noted in the assessment of 7/16/96, which horizontally blocks the right-most one-quarter of the bridge opening during low flows.

## Description of the Geomorphic Setting

***General topography*** The channel is located in a moderate relief valley setting with a narrow, irregular flood plain and moderately sloping valley walls overall.

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

***Date of inspection*** 7/16/96

***DS left:*** Steep channel bank and valley wall.

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

***US left:*** Steep channel bank and valley wall.

***US right:*** Mildly sloping channel bank to a narrow flood plain.

## Description of the Channel

***Average top width*** 56 ***ft*** ***Average depth*** 4 ***ft***

***Predominant bed material*** Gravel / Sand ***Bank material*** Silt, Clay / Sand

Sinuous with alluvial channel boundaries and wide point bars.

7/16/96

***Vegetative co*** Trees, shrubs, and brush.

***DS left:*** Trees, shrubs, and brush.

***DS right:*** Trees and shrubs.

***US left:*** Trees and shrubs.

***US right:***

***Do banks appear stable?*** No

The assessment on 7/16/96 noted a large cut-bank on the left bank upstream with slumping bank material, a cut bank on the left bank downstream, and point bars on the right bank through the reach. The reach bends severely in the area of this site.

***date of observation.***

There is some debris noted in the assessment of 7/16/96 caught on the point bar on the right bank just upstream of the bridge.

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

## Hydrology

***Drainage area*** 6.28 ***mi²***

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

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

***Is drainage area considered rural or urban?*** Rural ***Describe any significant urbanization***:

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

***USGS gage description*** --

***USGS gage number*** --

***Gage drainage area*** -- ***mi²***

***Is there a lake/p*** No

**Calculated Discharges**

***Q100*** 1,400 ***ft³/s*** ***Q500*** 2,100 ***ft³/s***

The 100- and 500-year discharges are median values selected from a range of flood frequency curves defined by use of several empirical equations and extrapolated to the 500-year event (Benson, 1962; FHWA, 1983; Johnson and Laraway, unpublished draft, 1972; Johnson and Tasker, 1974; 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 the center point of a chiseled "X" on top of the concrete right abutment at the upstream end (elev. 497.51 feet, arbitrary survey datum). RM2 is the center point of a chiseled "X" on top of the concrete left abutment at the upstream end (elev. 498.05 feet, arbitrary survey datum).

### Cross-Sections Used in WSPRO Analysis

| [1]*Cross-section* | *Section Reference Distance (SRD) in feet* | [2]*Cross-section development* | *Comments* |
|---|---|---|---|
| EXITX | -41 | 1 | Exit section |
| FULLV | 0 | 2 | Downstream Full-valley section (Templated from EXITX) |
| BRIDG | 0 | 1 | Bridge section |
| RDWAY | 13 | 1 | Road Grade section |
| APPRO | 66 | 2 | Approach section |

[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 0.035 to 0.039, 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 0.00962 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1986).

The approach section (APPRO) was surveyed 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.

For the 500-year 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, it was 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* 499.3 *ft*
*Average low steel elevation* 495.1 *ft*

*100-year discharge* 1,400 *ft³/s*
*Water-surface elevation in bridge opening* 489.9 *ft*
*Road overtopping?* No *Discharge over road* -- *ft³/s*
*Area of flow in bridge opening* 135 *ft²*
*Average velocity in bridge opening* 10.3 *ft/s*
*Maximum WSPRO tube velocity at bridge* 12.1 *ft/s*

*Water-surface elevation at Approach section with bridge* 491.9
*Water-surface elevation at Approach section without bridge* 491.0
*Amount of backwater caused by bridge* 0.9 *ft*

*500-year discharge* 2,100 *ft³/s*
*Water-surface elevation in bridge opening* 490.9 *ft*
*Road overtopping?* No *Discharge over road* -- *ft³/s*
*Area of flow in bridge opening* 176 *ft²*
*Average velocity in bridge opening* 11.9 *ft/s*
*Maximum WSPRO tube velocity at bridge* 14.0 */s*

*Water-surface elevation at Approach section with bridge* 493.6
*Water-surface elevation at Approach section without bridge* 492.1
*Amount of backwater caused by bridge* 1.5

*Incipient overtopping discharge* -- *ft³/s*
*Water-surface elevation in bridge opening* -- *ft*
*Area of flow in bridge opening* -- *ft²*
*Average velocity in bridge opening* -- *ft/s*
*Maximum WSPRO tube velocity at bridge* -- *ft/s*

*Water-surface elevation at Approach section with bridge* --
*Water-surface elevation at Approach section without bridge* --
*Amount of backwater caused by bridge* -- *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. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour.

Abutment scour at the left abutment for the 100- and 500-year discharges 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 right abutment for the 100- and 500-year discharges 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* | 1.1 | 2.0 | -- |
| *Depth to armoring* | N/A | N/A | -- |
| *Left overbank* | -- | -- | -- |
| *Right overbank* | -- | -- | -- |

| Local scour: | 100-yr discharge | 500-yr discharge | Incipient overtopping discharge |
|---|---|---|---|
| *Abutment scour* | | | |
| *Left abutment* | 7.3 | 8.6 | -- |
| *Right abutment* | 3.9 | 6.4 | -- |
| *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* | 1.4 | 1.9 | -- |
| *Right abutment* | 1.4 | 1.9 | -- |
| *Piers:* | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |

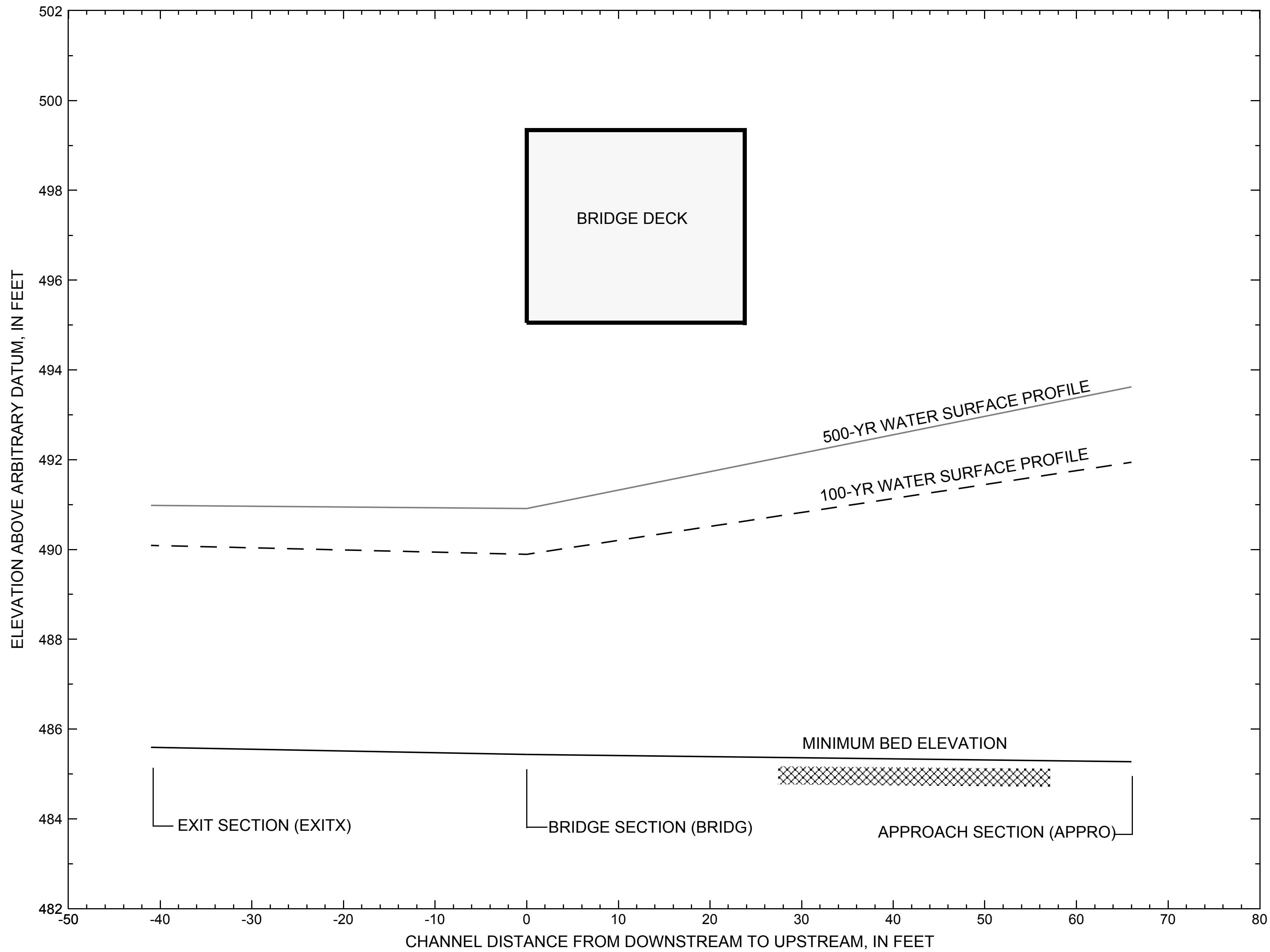


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure MORRTH00060005 on Town Highway 6, crossing Bedell Brook, Morristown, Vermont.

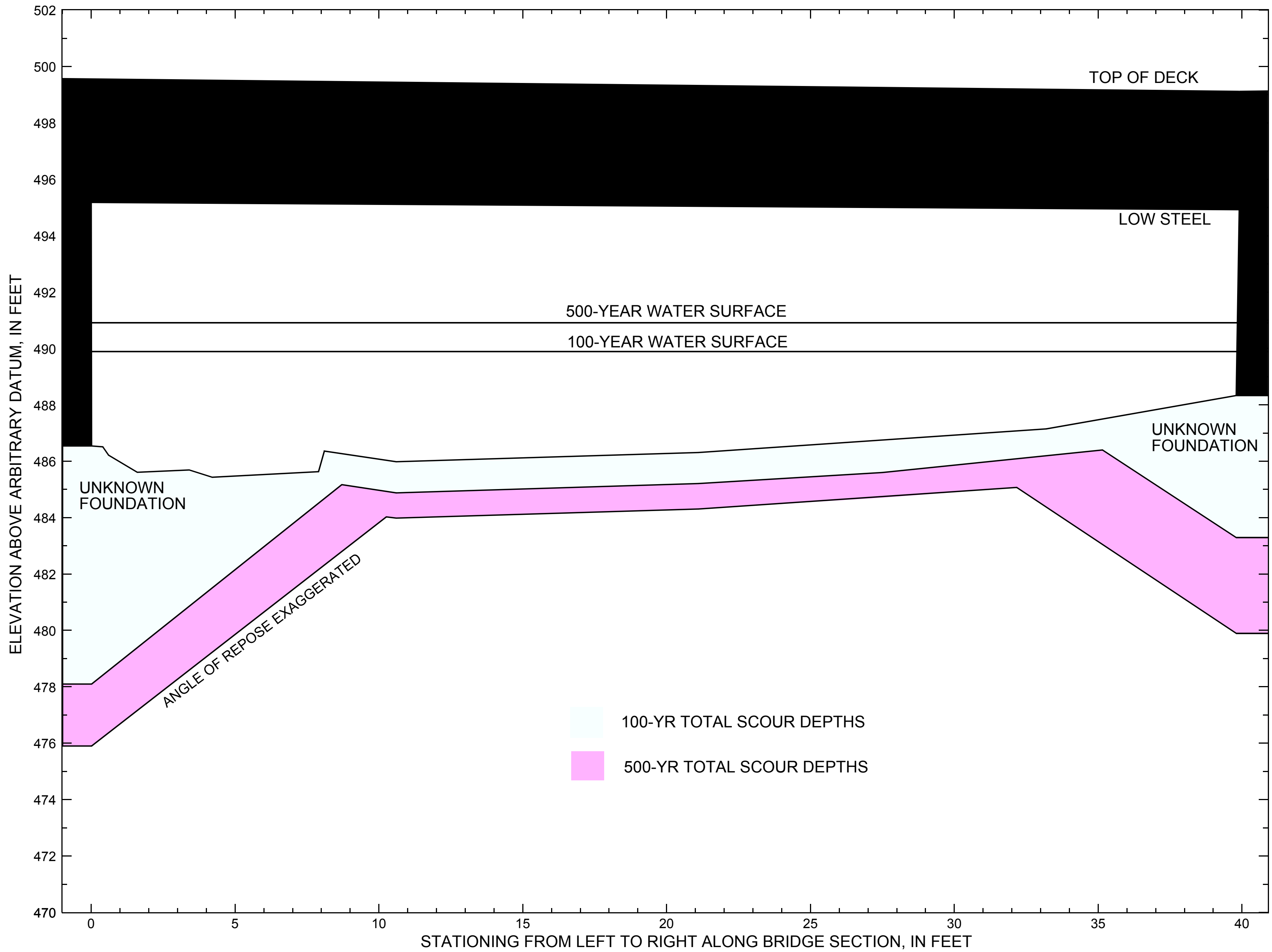


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure MORRTH00060005 on Town Highway 6, crossing Bedell Brook, Morristown, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure MORRTH00060005 on Town Highway 6, crossing Bedell Brook, Morristown, 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 elevation[2] (feet) | Channel elevation at abutment/ pier[2] (feet) | Contraction scour depth (feet) | Abutment scour depth (feet) | Pier scour depth (feet) | Depth of total scour (feet) | Elevation of scour[2] (feet) | Remaining footing/pile depth (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 100-yr. discharge is 1,400 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 495.2 | -- | 486.5 | 1.1 | 7.3 | -- | 8.4 | 478.1 | -- |
| Right abutment | 39.9 | -- | 494.9 | -- | 488.3 | 1.1 | 3.9 | -- | 5.0 | 483.3 | -- |

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 MORRTH00060005 on Town Highway 6, crossing Bedell Brook, Morristown, 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 elevation[2] (feet) | Channel elevation at abutment/ pier[2] (feet) | Contraction scour depth (feet) | Abutment scour depth (feet) | Pier scour depth (feet) | Depth of total scour (feet) | Elevation of scour[2] (feet) | Remaining footing/pile depth (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 500-yr. discharge is 2,100 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 495.2 | -- | 486.5 | 2.0 | 8.6 | -- | 10.6 | 475.9 | -- |
| Right abutment | 39.9 | -- | 494.9 | -- | 488.3 | 2.0 | 6.4 | -- | 8.4 | 479.9 | -- |

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, Morrisville, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Aerial photographs, 1981; Contour interval, 6 meters, Scale 1:24,000.

# APPENDIX A:

# **WSPRO INPUT FILE**

# WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File morr005.wsp
T2        Hydraulic analysis for structure MORRTH00060005   Date: 11-MAR-97
T3        Town Highway 6 crossing Bedell Brook, Morristown, VT               EMB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1400.0   2100.0
SK          0.00962  0.00962
*
XS   EXITX    -41
GR         -232.5, 511.17    -90.1, 501.33    -50.5, 499.72    -45.6, 500.21
GR          -19.6, 499.16     -8.6, 494.09     -3.0, 487.83      0.0, 486.42
GR            4.2, 486.28     11.6, 485.59     18.0, 485.81     23.3, 486.14
GR           37.0, 486.57     38.5, 486.70     43.1, 488.60     59.8, 490.01
GR           72.3, 492.11    328.8, 494.23    565.3, 495.82    662.0, 497.57
GR          901.6, 506.39    972.8, 509.37
*
N           0.050        0.039        0.045
SA                -19.6         72.3
*
XS   FULLV      0  * * *   0.0011
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0    495.05      0.0
GR            0.0, 495.18      0.0, 486.54      0.4, 486.51      0.6, 486.22
GR            1.6, 485.61      3.4, 485.69      4.2, 485.43      7.9, 485.63
GR            8.1, 486.36     10.6, 485.98     21.1, 486.31     27.5, 486.70
GR           33.2, 487.15     39.8, 488.33     39.9, 494.92      0.0, 495.18
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      40.7 * *     56.8     13.2
N           0.035
*
*            SRD    EMBWID   IPAVE
XR   RDWAY     13      23.8     1
GR         -262.1, 513.78   -172.6, 507.72      0.0, 499.56     40.7, 499.12
GR          139.0, 497.86    275.6, 497.43    417.0, 498.35    619.7, 500.00
GR          809.8, 503.29    937.2, 508.43
*
AS   APPRO     66
GR          -57.1, 509.27    -30.8, 504.49    -17.2, 494.54      0.0, 486.88
GR            1.9, 485.95      7.4, 485.27     11.8, 486.25     20.1, 486.94
GR           29.3, 487.63     35.0, 487.33     41.9, 488.64     53.6, 489.46
GR           97.2, 491.08    213.5, 492.00    490.6, 495.44    623.8, 496.21
GR          742.7, 498.70    877.8, 502.38    921.0, 508.44
*
N           0.036         0.050
SA                53.6
*
HP 1 BRIDG 489.89 1 489.89
HP 2 BRIDG 489.89 * * 1400
HP 1 APPRO 491.94 1 491.94
HP 2 APPRO 491.94 * * 1400
*
HP 1 BRIDG 490.91 1 490.91
HP 2 BRIDG 490.91 * * 2100
HP 1 APPRO 493.62 1 493.62
```

APPENDIX B:

# WSPRO OUTPUT FILE

# WSPRO OUTPUT FILE

```
     U.S. Geological Survey WSPRO Input File morr005.wsp
     Hydraulic analysis for structure MORRTH00060005   Date: 11-MAR-97
     Town Highway 6 crossing Bedell Brook, Morristown, VT               EMB
        *** RUN DATE & TIME: 03-11-97  16:04

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

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      135     11876     40     46                          1417
489.89           135     11876     40     46  1.00      0     40      1417

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    489.89     0.0    39.8   135.4   11876.    1400.  10.34

X STA.        0.0        2.6        4.2        5.5        6.8        8.5
  A(I)            10.3        6.6        6.1        5.7        6.8
  V(I)            6.80      10.60      11.53      12.37      10.36

X STA.        8.5       10.1       11.6       13.1       14.7       16.3
  A(I)             6.1        5.8        5.9        5.9        6.0
  V(I)           11.50      12.12      11.90      11.96      11.74

X STA.       16.3       17.9       19.5       21.2       23.0       25.0
  A(I)             6.0        6.1        6.2        6.3        6.5
  V(I)           11.72      11.52      11.33      11.03      10.81

X STA.       25.0       27.0       29.2       31.6       34.6       39.8
  A(I)             6.6        7.0        7.3        8.0       10.6
  V(I)           10.62      10.02       9.60       8.79       6.60

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      66.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      275     29283     65     67                          3210
          2      120      3031    152    152                           601
491.94           395     32315    217    219  1.54    -10    206      2430

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      66.

      WSEL     LEW     REW    AREA        K        Q    VEL
    491.94   -11.4   205.9   394.5   32315.    1400.   3.55

X STA.      -11.4       -0.9        2.1        4.4        6.4        8.3
  A(I)            24.2       16.2       14.2       12.9       12.6
  V(I)            2.89       4.32       4.91       5.41       5.55

X STA.        8.3       10.4       12.5       14.9       17.4       20.0
  A(I)            12.5       12.7       13.3       13.1       13.4
  V(I)            5.58       5.51       5.27       5.33       5.21

X STA.       20.0       22.9       25.9       29.2       32.6       35.9
  A(I)            13.9       14.1       14.6       15.1       14.6
  V(I)            5.03       4.95       4.79       4.62       4.80

X STA.       35.9       39.9       45.4       52.5       73.0      205.9
  A(I)            16.4       18.3       19.9       43.8       78.4
  V(I)            4.27       3.83       3.51       1.60       0.89
```

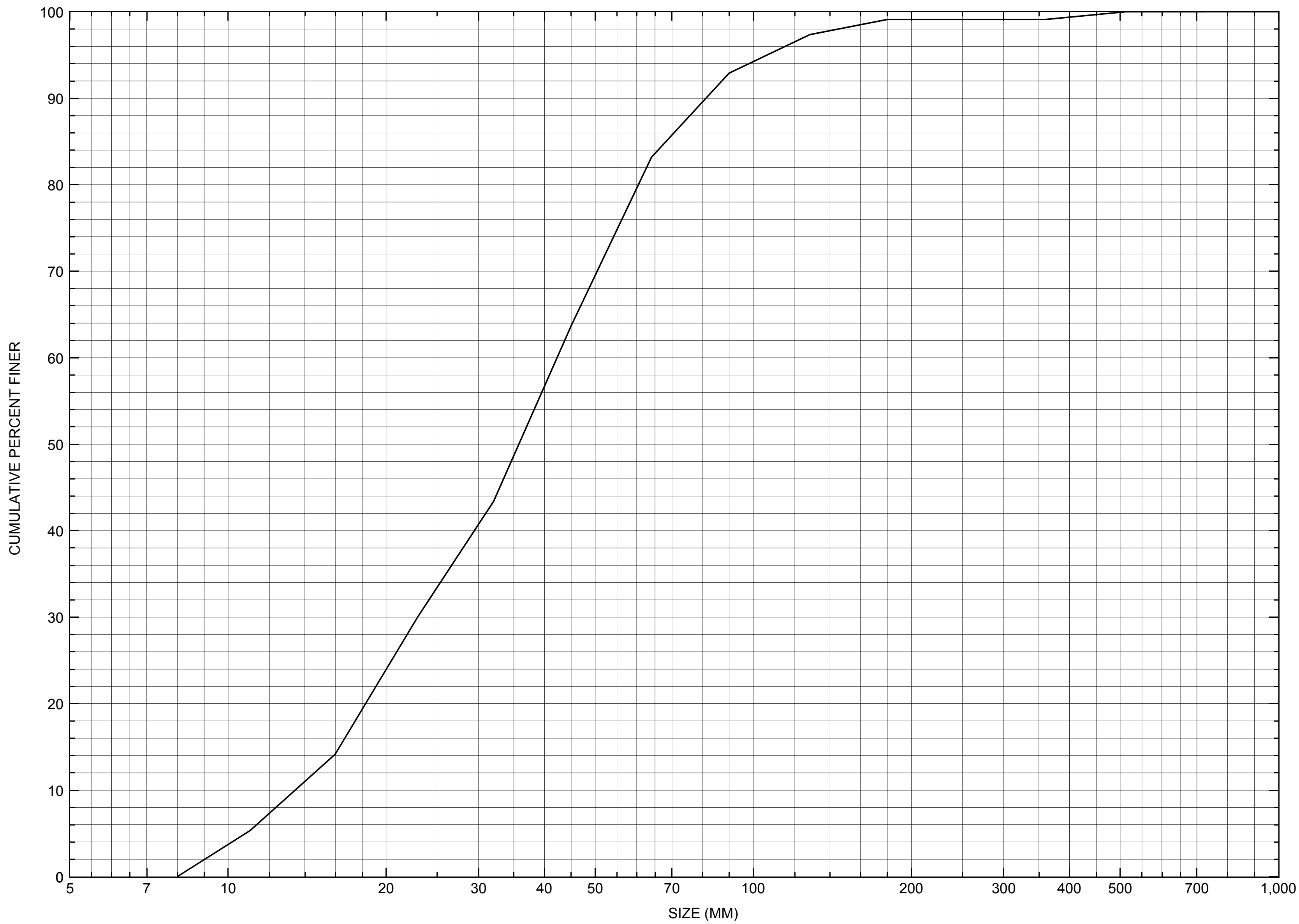
```
        U.S. Geological Survey WSPRO Input File morr005.wsp
        Hydraulic analysis for structure MORRTH00060005   Date: 11-MAR-97
        Town Highway 6 crossing Bedell Brook, Morristown, VT               EMB
           *** RUN DATE & TIME: 03-11-97  16:04

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      176     17863     40     48                         2100
   490.91           176     17863     40     48  1.00      0     40     2100

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       490.91     0.0    39.8   176.1   17863.    2100.  11.93

X STA.        0.0        2.8        4.5        6.0        7.4        9.3
  A(I)           14.1        9.0        8.1        7.7        8.8
  V(I)           7.45      11.69      13.02      13.61      11.87

X STA.        9.3       10.9       12.4       14.0       15.6       17.2
  A(I)            7.8        7.5        7.6        7.7        7.6
  V(I)          13.45      14.01      13.78      13.60      13.75

X STA.       17.2       18.8       20.5       22.3       24.0       25.9
  A(I)            7.7        7.8        8.0        7.9        8.3
  V(I)          13.68      13.41      13.19      13.35      12.61

X STA.       25.9       27.9       30.0       32.4       35.2       39.8
  A(I)            8.5        8.6        9.3       10.0       14.0
  V(I)          12.29      12.18      11.28      10.53       7.51

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      66.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      387     49785     69     71                         5216
             2      494     20953    290    290                         3652
   493.62           881     70738    359    361  1.89    -14    344     5700

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      66.

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.62   -15.1   344.0   880.9   70738.    2100.   2.38

X STA.      -15.1       -1.1        2.9        6.1        9.0       12.2
  A(I)           44.0       28.7       25.4       23.9       24.3
  V(I)           2.39       3.66       4.13       4.38       4.33

X STA.       12.2       15.5       19.0       22.7       26.7       31.0
  A(I)           23.8       24.3       24.8       25.3       25.8
  V(I)           4.42       4.33       4.24       4.16       4.08

X STA.       31.0       35.2       39.8       45.8       53.0       67.2
  A(I)           25.9       26.8       29.9       32.2       55.4
  V(I)           4.05       3.92       3.52       3.26       1.90

X STA.       67.2       86.8      115.0      150.5      197.3      344.0
  A(I)           64.6       72.5       80.1       90.4      133.0
  V(I)           1.63       1.45       1.31       1.16       0.79
```

```
        U.S. Geological Survey WSPRO Input File morr005.wsp
        Hydraulic analysis for structure MORRTH00060005   Date: 11-MAR-97
        Town Highway 6 crossing Bedell Brook, Morristown, VT               EMB
           *** RUN DATE & TIME: 03-11-97  16:04

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

EXITX:XS   ******     -4      188  0.86 *****  490.95  489.52    1400  490.09
       -40 ******     60    14267  1.00 ***** *******    0.77    7.45

FULLV:FV       41     -4      222  0.62  0.31  491.25 *******    1400  490.63
         0     41     63    18132  1.00  0.00    0.00    0.62    6.31
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       66     -8      250  0.58  0.34  491.60 *******    1400  491.03
        66     66     96    20982  1.18  0.00    0.01    0.70    5.60
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<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       41      0      136  1.66  0.47  491.55  489.86    1400  489.89
         0     41     40    11898  1.00  0.13    0.00    0.99   10.33

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  495.05 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.        <<<<<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    -10      395  0.30  0.14  492.24  490.09    1400  491.94
        66     27    206    32340  1.54  0.56    0.01    0.58    3.55

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.621  0.222   25008.     0.    40.   491.86

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXITX:XS     -41.    -5.    60.   1400.   14267.    188.    7.45  490.09
   FULLV:FV      0.     -5.    63.   1400.   18132.    222.    6.31  490.63
   BRIDG:BR      0.      0.    40.   1400.   11898.    136.   10.33  489.89
   RDWAY:RG      13.**************      0.******************    1.00********
   APPRO:AS      66.   -11.   206.   1400.   32340.    395.    3.55  491.94

    XSID:CODE   XLKQ   XRKQ      KQ
   APPRO:AS      0.     40.   25008.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    489.52    0.77  485.59  511.17************  0.86  490.95  490.09
   FULLV:FV  ********    0.62  485.64  511.22  0.31  0.00  0.62  491.25  490.63
   BRIDG:BR    489.86    0.99  485.43  495.18  0.47  0.13  1.66  491.55  489.89
   RDWAY:RG  ****************  497.43  513.78**********************************
   APPRO:AS    490.09    0.58  485.27  509.27  0.14  0.56  0.30  492.24  491.94
```

```
        U.S. Geological Survey WSPRO Input File morr005.wsp
        Hydraulic analysis for structure MORRTH00060005   Date: 11-MAR-97
        Town Highway 6 crossing Bedell Brook, Morristown, VT               EMB
           *** RUN DATE & TIME: 03-11-97  16:04

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

EXITX:XS   ******     -5      249  1.11 *****  492.08  490.43    2100  490.98
       -40 ******     66    21405  1.00 ***** *******    0.80    8.44

FULLV:FV       41     -5      289  0.82  0.32  492.39 *******    2100  491.58
         0     41     69    26553  1.00  0.00   -0.01    0.65    7.26
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       66    -11      434  0.59  0.31  492.70 *******    2100  492.11
        66     66    223    35216  1.61  0.00   -0.01    0.80    4.84
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    2100.     490.91

            <<<<<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       41      0      176  2.22 *****  493.12  490.91    2100  490.91
         0     41     40    17844  1.00 ***** *******    1.00   11.94

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  495.05 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.        <<<<<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    -14      882  0.17  0.10  493.79  490.96    2100  493.62
        66     30    344    70814  1.89  0.56    0.02    0.37    2.38

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.830  0.456   38301.     3.    43.   493.58

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -41.    -6.    66.   2100.   21405.     249.    8.44  490.98
   FULLV:FV       0.    -6.    69.   2100.   26553.     289.    7.26  491.58
   BRIDG:BR       0.     0.    40.   2100.   17844.     176.   11.94  490.91
   RDWAY:RG      13.**************      0.*****************     1.00********
   APPRO:AS      66.   -15.   344.   2100.   70814.     882.    2.38  493.62

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       3.    43.   38301.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     490.43    0.80  485.59  511.17************  1.11  492.08  490.98
   FULLV:FV   ********    0.65  485.64  511.22  0.32  0.00  0.82  492.39  491.58
   BRIDG:BR     490.91    1.00  485.43  495.18************  2.22  493.12  490.91
   RDWAY:RG   ***************  497.43  513.78**********************************
   APPRO:AS     490.96    0.37  485.27  509.27  0.10  0.56  0.17  493.79  493.62
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

# APPENDIX C:

# BED-MATERIAL PARTICLE-SIZE DISTRIBUTION




Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure MORRTH00060005, in Morristown, Vermont.

# APPENDIX D:

# HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number MORRTH00060005

## General Location Descriptive

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

Date *(MM/DD/YY)* 10 / 26 / 95

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

County *(FIPS county code; I - 3; nnn)* 015

Town *(FIPS place code; I - 4; nnnnn)* 46675

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

Waterway *(I - 6)* Bedell Brook

Road Name *(I - 7):* -

Route Number C2006

Vicinity *(I - 9)* 0.5 MI TO JCT W CL3 TH72

Topographic Map Morrisville

Hydrologic Unit Code: 2010003

Latitude *(I - 16; nnnn.n)* 44306

Longitude *(i - 17; nnnnn.n)* 72359

## Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10080700050807

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

Maximum span length *(I - 48; nnnn)* 0042

Year built *(I - 27; YYYY)* 1929

Structure length *(I - 49; nnnnnn)* 000044

Average daily traffic, ADT *(I - 29; nnnnnn)* 000340

Deck Width *(I - 52; nn.n)* 238

Year of ADT *(I - 30; YY)* 91

Channel & Protection *(I - 61; n)* 5

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

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

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*) 42

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

Vertical clearance from streambed (*nnn.n ft*) 8.74

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

Waterway of full opening (*nnn.n ft*$^2$) 367.2

Comments:

**According to the structural inspection report dated 6/20/95, the structure is a concrete T-beam with an asphalt road surface. The footing concrete is spalled, with some section loss. The end of the right wingwall has alligator cracks and leaks, with spalling and section loss. The right abutment has a few fine cracks and surface spalls along the bottom, with a small spall in the top left corner. The left abutment footing is several feet wide, and the concrete has areas of deep spalling and delamination along its top and front edge. The left abutment wall and the downstream left wingwall have minor cracks and surface spalls. The upstream left wingwall has a few alligator cracks and small leaks, and has broken** **(Continued, page 31)**

## 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:

**vertically from the left abutment wall. The crack is one half inch wide at the bottom and 1.5 inches wide at the top. A large, partially vegetated, coarse gravel bar is noted in the channel under the structure. The bar splits the flow. The US and DS channel embankments are covered with vegetation, with a few boulders and areas of erosion showing. The US channel flows toward the bridge at a 90 degree angle. Many scour problems in the past were noted, with about 1-1.5 feet of scour along the front edge of the left abutment footing.**

## USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **6.28** $mi^2$  Lake and pond area **0.033** $mi^2$
Watershed storage *(ST)* **0.5** %
Bridge site elevation **758** ft  Headwater elevation **2730** ft
Main channel length **4.46** mi
10% channel length elevation **778** ft  85% channel length elevation **1960** ft
Main channel slope *(S)* **353.83** 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 BENCKMARK 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 DRILL BORING INFORMATION**

Comments:

-

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

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

Comments: -
-

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

# APPENDIX E:

# LEVEL I DATA FORM

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

Qa/Qc Check by: **EW** Date: **10/31/96**
Computerized by: **EW** Date: **10/31/96**
Reviewd by: **EB** Date: **3/21/97**

Structure Number **MORRTH00060005**

## A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **J. DEGNAN** Date *(MM/DD/YY)* **07** / **16** / 19**96**
2. Highway District Number **06** Mile marker **000000**
   County **LAMOILLE (015)** Town **MORRISTOWN (46675)**
   Waterway *(I - 6)* **Bedell Brook** Road Name **-**
   Route Number **TH 6** Hydrologic Unit Code: **02010003**
3. Descriptive comments:
**This structure is a concrete T-beam type bridge with an asphalt roadway surface and concrete guard-rail posts with cable stretched between the posts. This site is located one-half mile from the intersection of TH 6 with TH 72.**

## B. Bridge Deck Observations

4. Surface cover... LBUS **4** RBUS **5** LBDS **5** RBDS **4** Overall **4**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US **2** UB **2** 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 **44** *(feet)* Span length **42** *(feet)* Bridge width **23.8** *(feet)*

### Road approach to bridge:

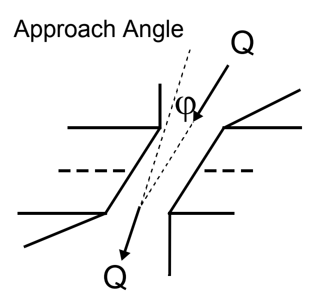
8. LB **2** RB **0** *( **0** even, **1**- lower, **2**- higher)*
9. LB **1** RB **1** *( **1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left **0.0:1** US right **0.0:1**

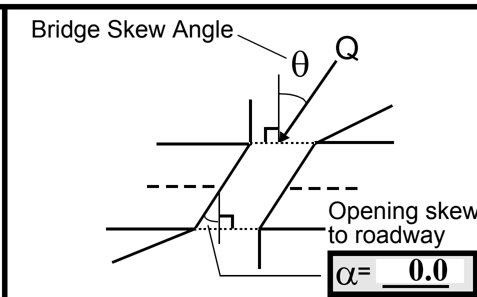
| | Protection | | 13.Erosion | 14.Severity |
|---|---|---|---|---|
| | 11.Type | 12.Cond. | | |
| LBUS | 0 | - | 2 | 1 |
| RBUS | 0 | - | 0 | - |
| RBDS | 0 | - | 0 | - |
| LBDS | 0 | - | 2 | 2 |

*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: **40** 16. Bridge skew: **45**




17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **3**
Range? **90** feet **US** *(US, UB, DS)* to **0** feet **DS**
Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **90** feet **DS** *(US, UB, DS)* to **200** feet **DS**

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

18. Bridge Type: **1a**

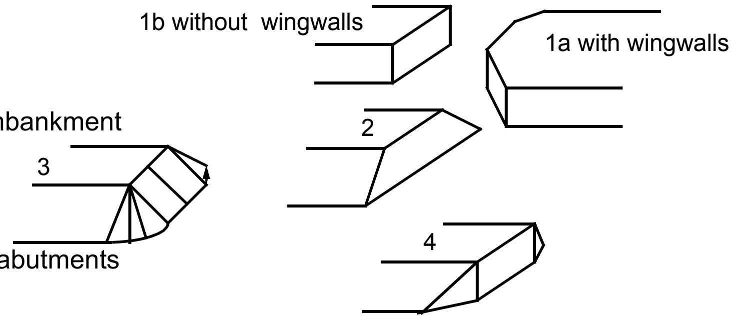
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular 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.)

**The wingwalls are parallel with abutments, except the upstream right wingwall, which is about 65 degrees from parallel with the abutment wall.**

**Although there are a few trees in the area, the upstream right bank surface cover consists of mainly brush. Additionally, the right bank upstream runs parallel to the road and there is not much area between the TH 6 roadway embankment and the upstream right bank.**

**The bar discussed in the historical form was vegetated and located in the middle of the stream underneath the bridge. At the time of this assessment the bar was against the RABUT, unvegetated and directing flow towards the LABUT.**

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| **45.5** | **7.5** | | | **1.5** | **2** | **3** | **123** | **123** | **2** | **1** |

23. Bank width **25.0** 24. Channel width **10.0** 25. Thalweg depth **59.5** 29. Bed Material **342**

30 .Bank protection type: LB **4** 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.):

**There is a concrete slab protecting the left bank, extending from 24 feet upstream to 10 feet upstream. There is also a boulder 4 feet long at the upstream end.**

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 35 35. Mid-bar width: 25
36. Point bar extent: 70 feet US (US, UB) to 0 feet DS (US, UB, DS) positioned 50 %LB to 100 %RB
37. Material: 342
38. Point or side bar comments (Circle Point or Side; Note additional bars, material variation, status, etc.):
**The point bar has developed along the right bank and its material is loosely deposited.**

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: 65 42. Cut bank extent: 120 feet US (US, UB) to 60 feet US (US, UB, DS)
43. Bank damage: 2 ( 1- eroded and/or creep; 2- slip failure; 3- block failure)
44. Cut bank comments (eg. additional cut banks, protection condition, etc.):
-

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 19
47. Scour dimensions: Length 60 Width 11 Depth : 2 Position 0 %LB to 40 %RB
48. Scour comments (eg. additional scour areas, local scouring process, etc.):
**Scour depth is 2 feet using a 0.5 foot average thalweg depth measured elsewhere in the reach.**

49. Are there major confluences? Y (Y or if N type ctrl-n mc) 50. How many? 1
51. Confluence 1: Distance 46 52. Enters on LB (LB or RB) 53. Type 2 ( 1- perennial; 2- ephemeral)
Confluence 2: Distance _____ Enters on _____ (LB or RB) Type _____ ( 1- perennial; 2- ephemeral)
54. Confluence comments (eg. confluence name):
**The confluence is not presently flowing. The bed material is boulder and it enters the channel off the left bank at a steep slope.**

## 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 |
|---|---|---|---|---|---|---|---|
| 35.0 | | 1.5 | | 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.):
**324**
**There is a concrete slab 17 feet long and 2.5 feet wide. It is parallel to flow and starts at the downstream bridge face. It directs flow into the downstream left wingwall. The concrete slab is not flat on the bed, but appears displaced.**

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**

**The debris is on the point bar at the upstream bridge face.**

| 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 | | **35** | **90** | **2** | **2** | **0.5** | **1** | **90.0** |
| RABUT | **1** | **-** | **90** | | | **2** | **1** | **40.0** |

*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.):

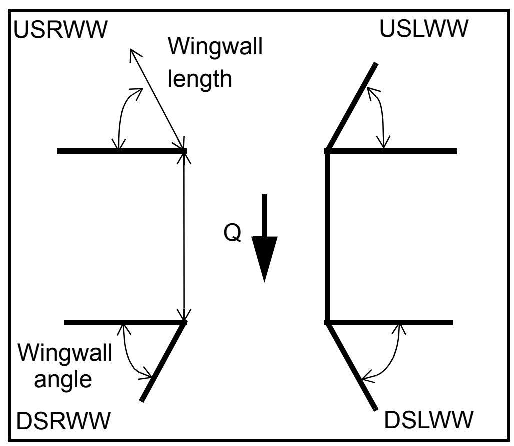
**0**
**0**
**1**

**The exposed part of the left abutment footing is a 5 ft. extension from the footing, which is a concrete slab extending out from under the protection at the downstream bridge face. It has been eroded but not displaced. There is a total of 6 feet of solid material extending horizontally from the abutment at the same elevation as the footing.**

**Scour is evident at the RABUT by extremely loose, soft bed material at the base of the wall.**

80. **Wingwalls**:

| | Exist? | Material? | Scour Condition? | Scour depth? | Exposure depth? | 81. Angle? | Length? |
|---|---|---|---|---|---|---|---|
| USLWW: | | | | | | **40.0** | |
| USRWW: | **Y** | | **1** | | **2** | **1.5** | |
| DSLWW: | **0.5** | | **1** | | **Y** | **25.5** | |
| DSRWW: | **1** | | **0** | | **-** | **25.5** | |




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

82. **Bank / Bridge Protection**:

| Location | USLWW | USRWW | LABUT | RABUT | LB | RB | DSLWW | DSRWW |
|---|---|---|---|---|---|---|---|---|
| Type | **-** | **2** | **Y** | **-** | **2** | **-** | **1** | **-** |
| Condition | **Y** | **1.5** | **1** | **-** | **2** | **-** | **1** | **-** |
| Extent | **1** | **1.5** | **0** | **4** | **0** | **4** | **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*

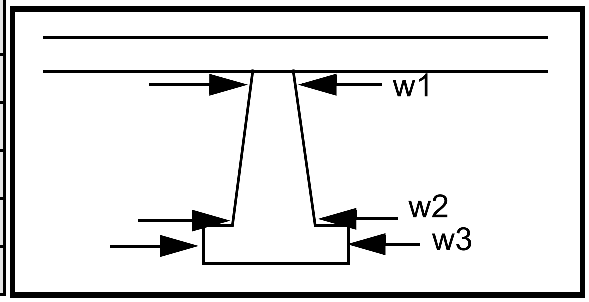
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
**4**
**2**
**1**
**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 | | | | **90.0** | **18.5** | **25.0** |
| Pier 2 | | | | **29.0** | **90.0** | **12.0** |
| Pier 3 | | | - | **90.0** | **12.0** | - |
| Pier 4 | - | - | - | - | - | - |




| Level 1 Pier Descr. | 1 | 2 | 3 | 4 | |
|---|---|---|---|---|---|
| 86. Location (BF) | **e** | **nds** | **and** | **of** | *LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP* |
| 87. Type | **slab** | **to** | **the** | **the** | ***1**- Solid pier, **2**- column, **3**- bent* |
| 88. Material | **men-** | **the** | **wing** | **wing** | ***1**- Wood; **2**- concrete; **3**- metal; **4**- stone* |
| 89. Shape | **tione** | **USL** | **wall** | **wall** | ***1**- Round; **2**- Square; **3**- Pointed* |
| 90. Inclined? | **d in** | **WW.** | **foot-** | **and** | *Y- yes; N- no* |
| 91. Attack ∠ (BF) | **the** | **The** | **ing is** | **the** | |
| 92. Pushed | **abut** | **slab** | **expo** | **abut** | *LB or RB* |
| 93. Length (feet) | - | - | - | - | |
| 94. # of piles | **ment** | **pro-** | **sed** | **ment** | |
| 95. Cross-members | **sec-** | **tects** | **only** | **. The** | ***0**- none; **1**- laterals; **2**- diagonals; **3**- both* |
| 96. Scour Condition | **tion** | **the** | **near** | **USL** | ***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed* |
| 97. Scour depth | **also** | **wing** | **the** | **WW** | |
| 98. Exposure depth | **exte** | **wall** | **joint** | **has** | |

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

**seperated from the abutment wall along a one inch wide vertical crack at the joint between the two walls. The same footing extension is 0.5 foot lower at the downstream left wingwall than at the LABUT and USLWW. Scour is deepest at the joint between the left abutment and the DSLWW. The bank/ bridge protection primarily consists of concrete slabs.**

**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.):

-
-
-
-

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

Cut bank extent: RS 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? _____ (Y or if N type ctrl-n cs) Mid-scour distance: 2

Scour dimensions: Length 2 Width 123 Depth: 123 Positioned 1 %LB to 2 %RB

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

**324**
**0**
**0**
-

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 _____ Enters on _____ (LB or RB) Type _____ ( **1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

## 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

- Y

| | | | |
|---|---|---|---|
| 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: | MORRTH00060005 | Town: | Morristown |
| Road Number: | TH 6 | County: | Lamoille |
| Stream: | Bedell Brook | | |

Initials EMB      Date:    3/21/97  Checked: LKS     4/1/97

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 | 1400 | 2100 | 0 |
| Main Channel Area, ft2 | 275 | 387 | 0 |
| Left overbank area, ft2 | 0 | 0 | 0 |
| Right overbank area, ft2 | 120 | 494 | 0 |
| Top width main channel, ft | 65 | 69 | 0 |
| Top width L overbank, ft | 0 | 0 | 0 |
| Top width R overbank, ft | 152 | 290 | 0 |
| D50 of channel, ft | 0.1173 | 0.1173 | 0 |
| D50 left overbank, ft | -- | -- | -- |
| D50 right overbank, ft | -- | -- | -- |
| y1, average depth, MC, ft | 4.2 | 5.6 | ERR |
| y1, average depth, LOB, ft | ERR | ERR | ERR |
| y1, average depth, ROB, ft | 0.8 | 1.7 | ERR |
| Total conveyance, approach | 32315 | 70738 | 0 |
| Conveyance, main channel | 29283 | 49785 | 0 |
| Conveyance, LOB | 0 | 0 | 0 |
| Conveyance, ROB | 3031 | 20953 | 0 |
| Percent discrepancy, conveyance | 0.0031 | 0.0000 | ERR |
| Qm, discharge, MC, cfs | 1268.6 | 1478.0 | ERR |
| Ql, discharge, LOB, cfs | 0.0 | 0.0 | ERR |
| Qr, discharge, ROB, cfs | 131.3 | 622.0 | ERR |
| Vm, mean velocity MC, ft/s | 4.6 | 3.8 | ERR |
| Vl, mean velocity, LOB, ft/s | ERR | ERR | ERR |
| Vr, mean velocity, ROB, ft/s | 1.1 | 1.3 | ERR |
| Vc-m, crit. velocity, MC, ft/s | 7.0 | 7.3 | N/A |
| 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 | N/A |

| ARMORING | | | |
|---|---|---|---|
| D90 | 0.2666 | 0.2666 | 0 |
| D95 | 0.3484 | 0.3484 | 0 |
| Critical grain size,Dc, ft | 0.4231 | 0.5085 | ERR |
| Decimal-percent coarser than Dc | 0.0261 | 0.0166 | 0 |
| Depth to armoring,ft | N/A | N/A | ERR |

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)

| Approach Section | Q100 | Q500 | Qother |
|---|---|---|---|
| Main channel Area, ft2 | 275 | 387 | 0 |
| Main channel width, ft | 65 | 69 | 0 |
| y1, main channel depth, ft | 4.23 | 5.61 | ERR |

| Bridge Section | | | |
|---|---|---|---|
| (Q) total discharge, cfs | 1400 | 2100 | 0 |
| (Q) discharge thru bridge, cfs | 1400 | 2100 | 0 |
| Main channel conveyance | 11876 | 17863 | 0 |
| Total conveyance | 11876 | 17863 | 0 |
| Q2, bridge MC discharge,cfs | 1400 | 2100 | ERR |
| Main channel area, ft2 | 135 | 176 | 0 |
| Main channel width (skewed), ft | 39.8 | 39.8 | 0.0 |
| Cum. width of piers in MC, ft | 0.0 | 0.0 | 0.0 |
| W, adjusted width, ft | 39.8 | 39.8 | 0 |
| y_bridge (avg. depth at br.), ft | 3.40 | 4.42 | ERR |
| Dm, median (1.25*D50), ft | 0.146625 | 0.146625 | 0 |
| y2, depth in contraction,ft | 4.53 | 6.41 | ERR |
| ys, scour depth (y2-ybridge), ft | 1.13 | 1.99 | N/A |

Abutment Scour

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

| Characteristic | Left Abutment 100 yr Q | 500 yr Q | Other Q | Right Abutment 100 yr Q | 500 yr Q | Other Q |
|---|---|---|---|---|---|---|
| (Qt), total discharge, cfs | 1400 | 2100 | 0 | 1400 | 2100 | 0 |
| a', abut.length blocking flow, ft | 11.4 | 15.1 | 0 | 166.1 | 304.2 | 0 |
| Ae, area of blocked flow ft2 | 29.1 | 51.9 | 0 | 160.8 | 558.1 | 0 |
| Qe, discharge blocked abut.,cfs | 91 | 133.9 | 0 | 281.8 | 840 | 0 |
| (If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually) | | | | | | |
| Ve, (Qe/Ae), ft/s | 3.13 | 2.58 | ERR | 1.75 | 1.51 | ERR |
| ya, depth of f/p flow, ft | 2.55 | 3.44 | ERR | 0.97 | 1.83 | ERR |
| --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 | 0.345 | 0.245 | ERR | 0.314 | 0.196 | ERR |
| ys, scour depth, ft | 7.28 | 8.57 | N/A | 9.09 | 13.21 | N/A |

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) | 11.4 | 15.1 | 0 | 166.1 | 304.2 | 0 |
| y1 (depth f/p flow, ft) | 2.55 | 3.44 | ERR | 0.97 | 1.83 | ERR |
| a'/y1 | 4.47 | 4.39 | ERR | 171.57 | 165.81 | ERR |
| Skew correction (p. 49, fig. 16) | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Froude no. f/p flow | 0.34 | 0.25 | N/A | 0.31 | 0.20 | N/A |
| Ys w/ corr. factor K1/0.55: | | | | | | |
| vertical | ERR | ERR | ERR | 4.80 | 7.79 | ERR |
| vertical w/ ww's | ERR | ERR | ERR | 3.94 | 6.39 | ERR |
| spill-through | ERR | ERR | ERR | 2.64 | 4.28 | 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 | Qother | | | |
|---|---|---|---|---|---|---|
| Fr, Froude Number | 0.99 | 1 | 0 | 0.99 | 1 | 0 |
| (Fr from the characteristic V and y in contracted section--mc, bridge section) | | | | | | |
| y, depth of flow in bridge, ft | 3.40 | 4.42 | 0.00 | 3.40 | 4.42 | 0.00 |
| Median Stone Diameter for riprap at: | left abutment | | | right abutment, ft | | |
| Fr<=0.8 (vertical abut.) | ERR | ERR | 0.00 | ERR | ERR | 0.00 |
| Fr>0.8 (vertical abut.) | 1.42 | 1.85 | ERR | 1.42 | 1.85 | ERR |