# LEVEL II SCOUR ANALYSIS FOR BRIDGE 65 (MTHOTH00120065) on TOWN HIGHWAY 12, crossing FREEMAN BROOK, MOUNT HOLLY, VERMONT

Open-File Report 98-161

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 65 (MTHOTH00120065) on TOWN HIGHWAY 12, crossing FREEMAN BROOK, MOUNT HOLLY, VERMONT

By EMILY C. WILD and ERICK M. BOEHMLER

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**Pembroke, New Hampshire**

**1998**

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

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

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 65 (MTHOTH00120065) ON TOWN HIGHWAY 12, CROSSING FREEMAN BROOK, MOUNT HOLLY, VERMONT

***By*** **Emily C. Wild and Erick M. Boehmler**

## INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure MTHOTH00120065 on Town Highway 12 crossing Freeman Brook, Mount Holly, 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 (FHWA, 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 south-central Vermont. The 6.3-$mi^2$ drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover consists of forest on the upstream banks and the downstream left bank. Downstream of the bridge, the right overbank surface cover is pasture.

In the study area, Freeman Brook has an incised, sinuous channel with a slope of approximately 0.0252 ft/ft, an average channel top width of 50 ft and an average bank height of 9 ft. The channel bed material ranges from gravel to boulders with a median grain size ($D_{50}$) of 102 mm (0.335 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 3, 1995, indicated that the reach was stable.

The Town Highway 12 crossing of Freeman Brook is a 35-ft-long, one-lane bridge consisting of a 31-foot steel-stringer span (Vermont Agency of Transportation, written communication, March 21, 1995). The opening length of the structure parallel to the bridge face is 29.6 ft. The bridge is supported by vertical, concrete abutments. The channel is skewed approximately 15 degrees to the opening while the computed opening-skew-to-roadway is 35 degrees.

During the Level I assessment, it was observed that the right abutment footing was exposed 1.5 ft and the left abutment footing was exposed 0.5 ft. Scour protection measure at the site included type-2 stone fill (less than 36 inches diameter) along the upstream right bank, the left and right abutments, and the downstream left and right banks. 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 Davis, 1995) for the 100- and 500-year discharges. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.2 to 0.5 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 4.0 to 5.9 ft. Right abutment scour ranged from 11.8 to 14.1 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 46). 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.

**Plymouth, VT. Quadrangle, 1:24,000, 1966**
**Photoinspected 1983**

**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*** MTHOTH00120065 ***Stream*** Freeman Brook

***County*** Rutland ***Road*** TH 12 ***District*** 3

## Description of Bridge

***Bridge length*** 35 ***ft*** ***Bridge width*** 15.3 ***ft*** ***Max span length*** 31 ***ft***

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

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

***Stone fill on abutment?*** Yes ***Date of inspection*** 10/3/95

***Description of stone fill*** Type-2 stone fill extended along the left and right abutments .

Abutments are concrete. The right abutment footing is is exposed 1.5 feet. The left abutment footing is exposed 0.5 feet.

Yes 15

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

There is a moderate channel bend in the upstream reach.

***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*** | 10/3/95 | 0 | 0 |
| ***Level II*** | 10/3/95 | 0 | 0 |

***Potential for debris*** Moderate.

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

During the site visit on October 3, 1995, no features were observed near or at the bridge that may affect flow.

## Description of the Geomorphic Setting

***General topography*** The channel is located within a moderate relief valley.

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

***Date of inspection*** 10/3/95

***DS left:*** There is a steep channel bank with little to no flood plain.

***DS right:*** There is a steep channel bank with a moderately sloped overbank.

***US left:*** There is a steep channel bank with little to no flood plain.

***US right:*** There is a steep channel bank with a moderately sloped overbank.

## Description of the Channel

***Average top width*** 50 ***ft*** ***Average depth*** 9 ***ft***

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

Sinuous, perennial
but flashy stream with non-alluvial channel boundaries and little to no flood plain.

10/3/95

***Vegetative co***

Trees and brush

***DS left:*** Short grass and Town Highway 15

***DS right:*** Trees and brush

***US left:*** Trees, brush, grass and Town Highway 15

***US right:***

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

During the site visit on October 3, 1995, no obstructions were observed in the channel near or at the bridge that may affect flow.

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

## Hydrology

***Drainage area*** 6.3 ***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***: None.

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

***USGS gage description*** --

***USGS gage number*** --

***Gage drainage area*** -- ***mi²***

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

### Calculated Discharges

***Q100*** 1,120 ***ft³/s*** ***Q500*** 1,500 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(6.3/2.6)exp 0.67] with flood frequency estimates available from the VTAOT database (written communication, May 1995) bridge number 25 in Shrewsbury. Bridge number 25 crosses Freeman Brook upstream of this site and the drainage area above bridge number 25 is 2.6 square miles. These area adjusted values were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). The curves were extended graphically to the 500-year event.

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

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

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

***Description of reference marks used to determine USGS datum.*** RM1 is a chiseled X on top of the downstream end of the right abutment (elev. 498.98 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the left abutment (elev. 497.12 ft, arbitrary survey datum). RM3 is a nail (2.5 ft above the ground) in a telephone pole on the upstream right overbank, 95 ft from the right abutment (elev. 502.53 ft, arbitrary survey datum). RM4 is a nail in a pole, approximately 60 ft upstream and 20 ft downstream of the right abutment (elev. 504.93 arbitrary survey datum).

| [1]*Cross-section* | *Section Reference Distance (SRD) in feet* | [2]*Cross-section development* | *Comments* |
|---|---|---|---|
| EXIT1 | -25 | 1 | Exit section |
| FULLV | 0 | 2 | Downstream Full-valley section (Templated from EXIT1) |
| BRIDG | 0 | 1 | Bridge section |
| RDWAY | 10 | 1 | Road Grade section |
| APPR1 | 45 | 2 | Modelled Approach section (Templated from APTEM) |
| APTEM | 50 | 1 | Approach section as surveyed (Used as a template) |

[1] For location of cross-sections see plan-view sketch included with Level I field form, Appendix E.
For more detail on how cross-sections were developed see WSPRO input file.

## Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.060, and overbank "n" values ranged from 0.045 to 0.065.

Normal depth at the exit section (EXIT1) 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 0.0252 ft/ft, which was calculated from thalweg points surveyed downstream.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0798 ft/ft) to establish the modelled approach section (APPR1), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

For the 100- and 500-year discharges, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. After analyzing the supercritical and subcritical profiles for each discharge, it was assumed that the water surface profile passes through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satisfactory solutions.

## Bridge Hydraulics Summary

*Average bridge embankment elevation* 497.6 *ft*
*Average low steel elevation* 496.3 *ft*

*100-year discharge* 1,120 *ft³/s*
*Water-surface elevation in bridge opening* 492.9 *ft*
*Road overtopping?* No *Discharge over road* -- *ft³/s*
*Area of flow in bridge opening* 97 *ft²*
*Average velocity in bridge opening* 11.5 *ft/s*
*Maximum WSPRO tube velocity at bridge* 15.1 *ft/s*

*Water-surface elevation at Approach section with bridge* 495.2
*Water-surface elevation at Approach section without bridge* 493.7
*Amount of backwater caused by bridge* 1.5 *ft*

*500-year discharge* 1,500 *ft³/s*
*Water-surface elevation in bridge opening* 493.8 *ft*
*Road overtopping?* No *Discharge over road* -- *ft³/s*
*Area of flow in bridge opening* 119 *ft²*
*Average velocity in bridge opening* 12.6 *ft/s*
*Maximum WSPRO tube velocity at bridge* 16.7 */s*

*Water-surface elevation at Approach section with bridge* 496.5
*Water-surface elevation at Approach section without bridge* 494.5
*Amount of backwater caused by bridge* 2.0 *ft*

*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 Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the 100-year and 500-year discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

Abutment scour was computed by use of the Froehlich equation (Richardson and Davis, 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 Results

| Contraction scour: | 100-year discharge | 500-year discharge | Incipient overtopping discharge |
|---|---|---|---|
| | *(Scour depths in feet)* | | |
| ***Main channel*** | | | |
| *Live-bed scour* | -- | -- | -- |
| *Clear-water scour* | 0.2 | 0.5 | -- |
| *Depth to armoring* | 12.9 | 16.5 | -- |
| ***Left overbank*** | -- | -- | -- |
| ***Right overbank*** | -- | -- | -- |

| Local scour: | 100-year discharge | 500-year discharge | Incipient overtopping discharge |
|---|---|---|---|
| ***Abutment scour*** | | | |
| *Left abutment* | 4.0 | 5.9 | -- |
| *Right abutment* | 11.8 | 14.1 | -- |
| ***Pier scour*** | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |
| *Pier 3* | -- | -- | -- |

## Riprap Sizing

| | 100-year discharge | 500-year discharge | Incipient overtopping discharge |
|---|---|---|---|
| | | *($D_{50}$ in feet)* | |
| ***Abutments:*** | | | |
| *Left abutment* | 1.7 | 2.1 | -- |
| *Right abutment* | 1.7 | 2.1 | -- |
| ***Piers:*** | | | |
| *Pier 1* | -- | -- | -- |
| *Pier 2* | -- | -- | -- |

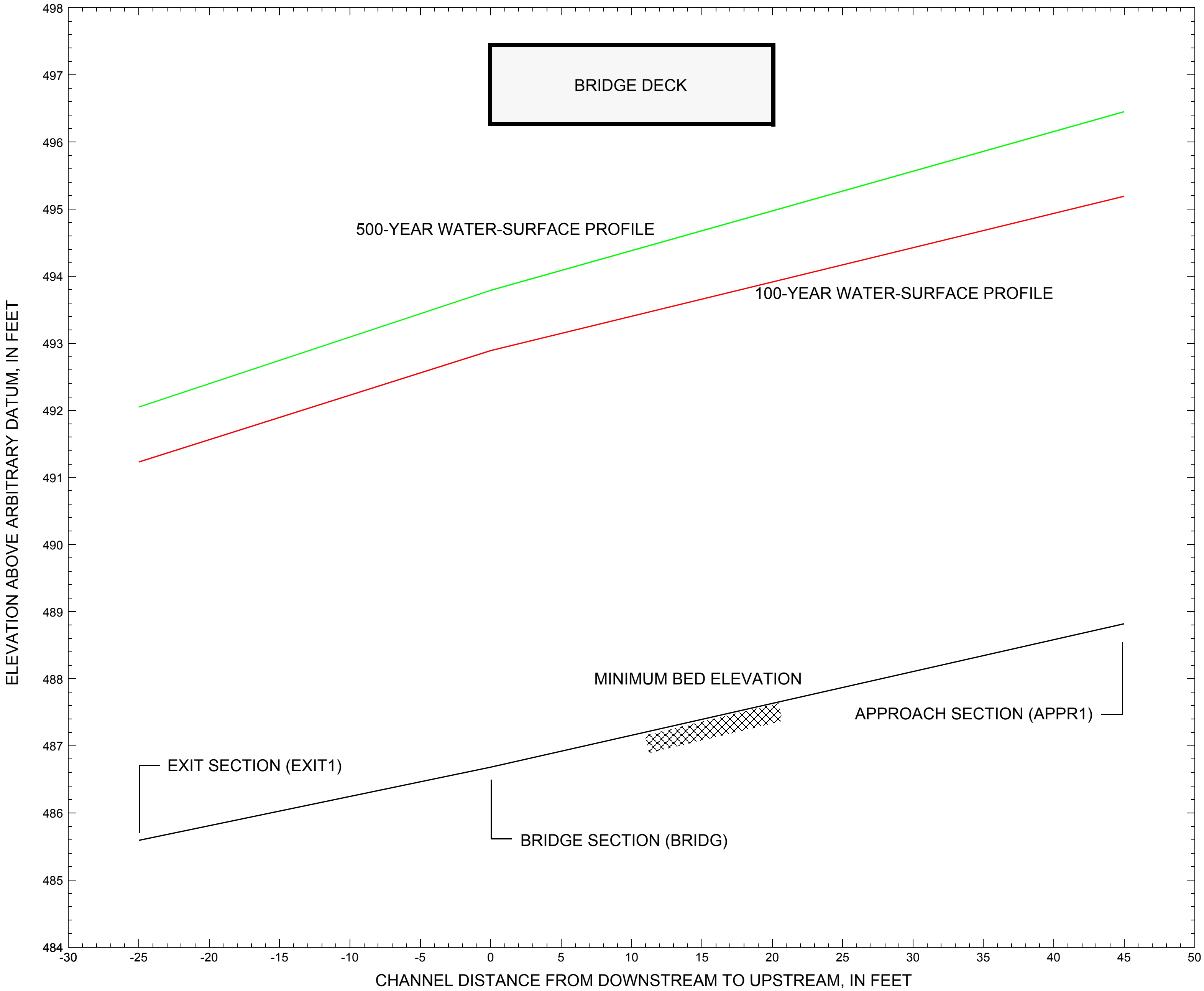


Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure MTHOTH00120065 on Town Highway 12, crossing Freeman Brook, Mount Holly, Vermont.

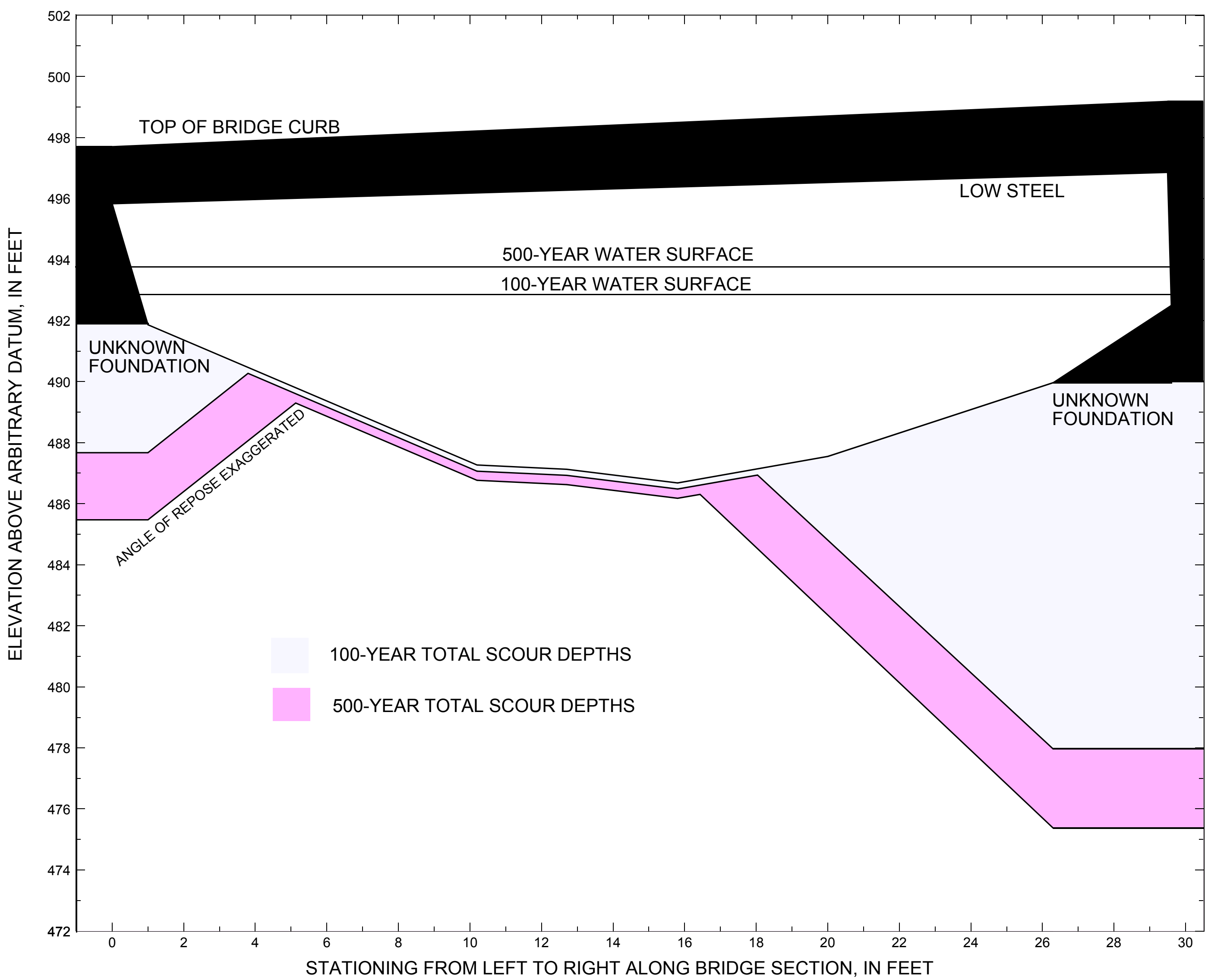


Figure 8. Scour elevations for the 100- and 500-year discharges at structure MTHOTH00120065 on Town Highway 12, crossing Freeman Brook, Mount Holly, Vermont.

**Table 1.** Remaining footing/pile depth at abutments for the 100-year discharge at structure MTHOTH00120065 on Town Highway 12, crossing Freeman Brook, Mount Holly, Vermont.

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

| Description | Station[1] | VTAOT minimum low-chord elevation (feet) | Surveyed minimum low-chord elevation[2] (feet) | Bottom of footing/pile elevation[2] (feet) | Channel elevation at abutment/ pier[2] (feet) | Contraction scour depth (feet) | Abutment scour depth (feet) | Pier scour depth (feet) | Depth of total scour (feet) | Elevation of scour[2] (feet) | Remaining footing/pile depth (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 100-year discharge is 1,120 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 495.8 | -- | 491.9 | 0.2 | 4.0 | -- | 4.2 | 487.7 | -- |
| Right abutment | 29.6 | -- | 496.9 | -- | 490.0 | 0.2 | 11.8 | -- | 12.0 | 478.0 | -- |

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 MTHOTH00120065 on Town Highway 12, crossing Freeman Brook, Mount Holly, Vermont.

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

| Description | Station[1] | VTAOT minimum low-chord elevation (feet) | Surveyed minimum low-chord elevation[2] (feet) | Bottom of footing/pile elevation[2] (feet) | Channel elevation at abutment/ pier[2] (feet) | Contraction scour depth (feet) | Abutment scour depth (feet) | Pier scour depth (feet) | Depth of total scour (feet) | Elevation of scour[2] (feet) | Remaining footing/pile depth (feet) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 500-year discharge is 1,500 cubic-feet per second | | | | | | | | | | | |
| Left abutment | 0.0 | -- | 495.8 | -- | 491.9 | 0.5 | 5.9 | -- | 6.4 | 485.5 | -- |
| Right abutment | 29.6 | -- | 496.9 | -- | 490.0 | 0.5 | 14.1 | -- | 14.6 | 475.4 | -- |

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

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# APPENDIX A:

# WSPRO INPUT FILE

# WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File mtho065.wsp
T2        Hydraulic analysis for structure MTHOTH00120065   Date: 26-FEB-98
T3        TOWN HIGHWAY 12, FREEMAN BROOK, MOUNT HOLLY, VERMONT            ECW
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1120.0   1500.0
SK          0.0252   0.0252
*
XS   EXIT1    -25           0.
GR          -72.2, 493.73    -39.0, 495.45      0.0, 496.87      7.3, 491.49
GR           14.2, 487.28     21.0, 485.96     25.5, 485.59     29.0, 486.00
GR           31.5, 487.17     40.7, 491.80     50.2, 496.87     81.1, 498.25
GR          165.3, 498.48    193.3, 511.52
*
N           0.065        0.055        0.050
SA                   0.0          50.2
*
XS   FULLV      0  * * *   0.0257
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.34      35.0
GR            0.0, 495.83      1.0, 491.87     10.2, 487.27     12.7, 487.13
GR           15.8, 486.68     20.0, 487.55     26.3, 489.97     29.5, 492.50
GR           29.6, 496.86      0.0, 495.83
*
*         BRTYPE  BRWDTH
CD           1      20.5
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     10      15.3     2
*  GR         -175.2, 499.22   -171.3, 494.24   -153.5, 495.02   -126.4, 492.15
*  GR         -113.9, 493.55    -67.9, 494.44    -43.3, 496.03
GR            0.0, 497.70
GR            2.3, 497.39      2.4, 498.07     28.6, 499.18     34.6, 499.43
GR           34.8, 498.88     75.3, 499.91    138.4, 500.40    154.5, 504.07
GR          169.9, 512.26
*
*
XT   APTEM     50           0.
GR            0.0, 497.54      7.2, 492.75     10.4, 489.85     12.8, 489.55
GR           17.4, 489.22     21.7, 489.92     26.4, 490.17     34.5, 492.00
GR           49.8, 499.15     81.7, 500.58    141.9, 500.59    177.2, 512.10
*
AS   APPR1     45    * * * 0.0798
GT
N           0.065        0.060        0.045
SA                   0.0          49.8
*
HP 1 BRIDG 492.89 1 492.89
HP 2 BRIDG 492.89 * * 1120
HP 1 APPR1 495.19 1 495.19
HP 2 APPR1 495.19 * * 1120
*
HP 1 BRIDG 493.79 1 493.79
HP 2 BRIDG 493.79 * * 1500
HP 1 APPR1 496.45 1 496.45
```

# APPENDIX B:

# WSPRO OUTPUT FILE

# WSPRO OUTPUT FILE

```
         U.S. Geological Survey WSPRO Input File mtho065.wsp
         Hydraulic analysis for structure MTHOTH00120065   Date: 26-FEB-98
         TOWN HIGHWAY 12, FREEMAN BROOK, MOUNT HOLLY, VERMONT           ECW
            *** RUN DATE & TIME: 03-06-98  08:29

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

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
              1      98.    7455.    24.    28.                         1125.
    492.89           98.    7455.    24.    28.  1.00     1.    30.   1125.

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        492.89     0.7    29.5    97.5    7455.    1120.  11.49

X STA.         0.7        7.3        8.5        9.6       10.4       11.3
  A(I)           13.4        4.5        4.3        4.0        3.8
  V(I)           4.16      12.39      13.03      14.14      14.83

X STA.        11.3       12.1       12.9       13.7       14.4       15.2
  A(I)            3.7        3.8        3.8        3.7        3.8
  V(I)          15.03      14.74      14.66      15.06      14.79

X STA.        15.2       15.9       16.7       17.5       18.3       19.1
  A(I)            3.8        3.8        3.8        3.8        3.8
  V(I)          14.69      14.85      14.56      14.82      14.72

X STA.        19.1       20.0       20.9       22.0       23.3       29.5
  A(I)            3.8        4.1        4.3        4.5       12.9
  V(I)          14.63      13.70      13.07      12.49       4.33

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      45.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
              2     165.   10115.    39.    42.                         1914.
    495.19          165.   10115.    39.    42.  1.00     3.    42.   1914.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      45.

          WSEL     LEW     REW    AREA        K        Q    VEL
        495.19     2.9    42.2   164.7   10115.    1120.   6.80

X STA.         2.9       10.5       11.7       12.8       13.8       14.9
  A(I)           20.6        6.6        6.5        6.3        6.6
  V(I)           2.72       8.52       8.57       8.86       8.53

X STA.        14.9       15.9       16.9       18.0       19.0       20.2
  A(I)            6.4        6.5        6.5        6.7        6.7
  V(I)           8.70       8.62       8.55       8.38       8.37

X STA.        20.2       21.3       22.4       23.6       24.9       26.1
  A(I)            6.5        6.7        6.7        6.7        6.7
  V(I)           8.68       8.38       8.36       8.36       8.36

X STA.        26.1       27.3       28.8       30.3       32.1       42.2
  A(I)            6.7        7.1        7.5        7.7       23.0
  V(I)           8.31       7.87       7.48       7.29       2.44
```

```
        U.S. Geological Survey WSPRO Input File mtho065.wsp
        Hydraulic analysis for structure MTHOTH00120065   Date: 26-FEB-98
        TOWN HIGHWAY 12, FREEMAN BROOK, MOUNT HOLLY, VERMONT            ECW
           *** RUN DATE & TIME: 03-06-98  08:29

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     119.     9934.    24.    30.                        1507.
   493.79          119.     9934.    24.    30.  1.00     1.    30.   1507.


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.79     0.5    29.5   118.8    9934.    1500.  12.63

X STA.        0.5        6.8        8.1        9.2       10.2       11.0
  A(I)           16.2        5.7        5.2        5.0        4.5
  V(I)           4.62      13.22      14.41      14.92      16.70

X STA.       11.0       11.9       12.7       13.5       14.4       15.2
  A(I)            4.6        4.6        4.6        4.6        4.7
  V(I)          16.48      16.43      16.43      16.34      16.06

X STA.       15.2       16.0       16.8       17.6       18.5       19.3
  A(I)            4.6        4.6        4.7        4.6        4.6
  V(I)          16.20      16.39      16.03      16.28      16.13

X STA.       19.3       20.2       21.3       22.4       23.7       29.5
  A(I)            4.7        5.0        5.1        5.4       15.9
  V(I)          16.01      15.04      14.66      13.92       4.71

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      45.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     217.    14822.    44.    48.                        2740.
   496.45          217.    14822.    44.    48.  1.00     1.    45.   2740.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      45.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.45     1.0    44.9   217.0   14822.    1500.   6.91

X STA.        1.0       10.1       11.3       12.5       13.7       14.8
  A(I)           28.1        8.9        8.5        8.3        8.6
  V(I)           2.67       8.44       8.79       9.08       8.75

X STA.       14.8       15.9       17.1       18.2       19.3       20.5
  A(I)            8.4        8.5        8.5        8.7        8.7
  V(I)           8.94       8.87       8.83       8.65       8.61

X STA.       20.5       21.8       23.0       24.3       25.6       26.9
  A(I)            8.6        8.7        8.6        8.8        8.6
  V(I)           8.73       8.62       8.74       8.53       8.74

X STA.       26.9       28.3       29.8       31.4       33.3       44.9
  A(I)            8.9        9.2        9.5        9.8       31.2
  V(I)           8.43       8.14       7.89       7.64       2.40
```

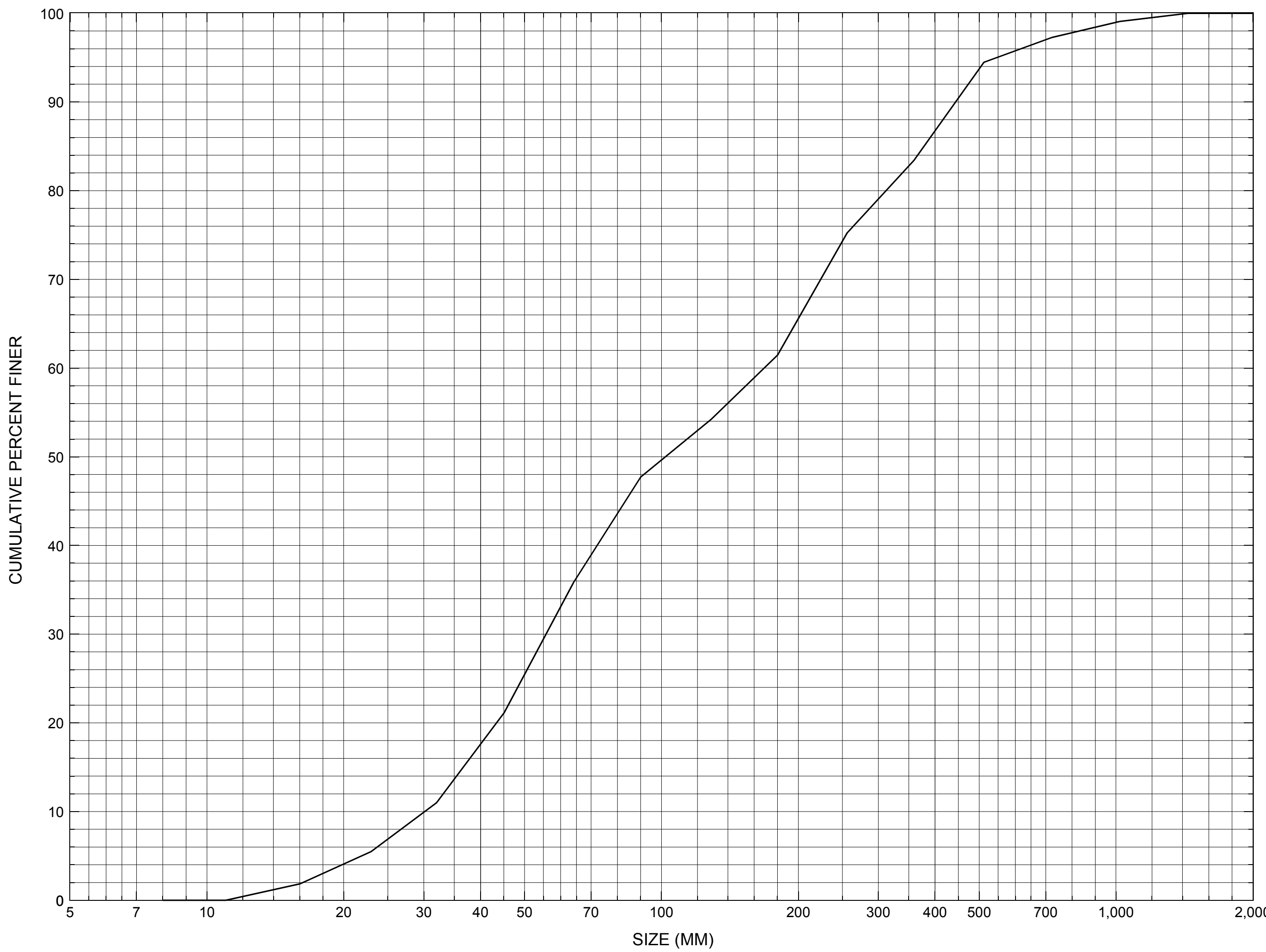
```
        U.S. Geological Survey WSPRO Input File mtho065.wsp
        Hydraulic analysis for structure MTHOTH00120065   Date: 26-FEB-98
        TOWN HIGHWAY 12, FREEMAN BROOK, MOUNT HOLLY, VERMONT           ECW
           *** RUN DATE & TIME: 03-06-98  08:29
 XSID:CODE   SRDL    LEW     AREA    VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXIT1:XS   ******     8.     116.  1.45 *****  492.69  490.91   1120.  491.23
      -25. ******    40.    7052.  1.00 ***** *******    0.89    9.67
 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.90     491.87     491.55
 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   490.73     512.16    0.50
 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   490.73     512.16     491.55
FULLV:FV      25.     8.     116.  1.45  0.63  493.33  491.55   1120.  491.88
        0.    25.    40.    7054.  1.00  0.00    0.01    0.89    9.67
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID “APPR1”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.21     493.23     493.67
 ===110 WSEL NOT FOUND AT SECID “APPR1”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.38     511.70    0.50
 ===115 WSEL NOT FOUND AT SECID “APPR1”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.38     511.70     493.67
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID “APPR1”
                  WSBEG,WSEND,CRWS =   493.67     511.70     493.67
APPR1:AS      45.     5.     109.  1.63 *****  495.31  493.67   1120.  493.67
       45.    45.    39.    5692.  1.00 ***** *******    1.00   10.25
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID “BRIDG”     Q,CRWS =    1120.     492.89
            <<<<<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      25.     1.      97.  2.05 *****  494.94  492.89   1120.  492.89
        0.    25.    30.    7450.  1.00 ***** *******    1.00   11.49
     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.34 ****** ****** ******
    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      10.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>
 XSID:CODE   SRDL    LEW     AREA    VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPR1:AS      25.     3.     165.  0.72  0.50  495.91  493.67   1120.  495.19
       45.    30.    42.   10109.  1.00  0.46   -0.02    0.59    6.80
       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.178  0.000   10409.     5.    34.   494.83
                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXIT1:XS     -25.     8.    40.   1120.    7052.     116.    9.67  491.23
    FULLV:FV       0.     8.    40.   1120.    7054.     116.    9.67  491.88
    BRIDG:BR       0.     1.    30.   1120.    7450.      97.   11.49  492.89
    RDWAY:RG      10.**************      0.*****************    2.00********
    APPR1:AS      45.     3.    42.   1120.   10109.     165.    6.80  495.19
    XSID:CODE   XLKQ   XRKQ       KQ
    APPR1:AS       5.    34.   10409.
 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXIT1:XS    490.91    0.89  485.59  511.52************  1.45  492.69  491.23
    FULLV:FV    491.55    0.89  486.23  512.16  0.63  0.00  1.45  493.33  491.88
    BRIDG:BR    492.89    1.00  486.68  496.86************  2.05  494.94  492.89
    RDWAY:RG  ****************  497.39  512.26**********************************
    APPR1:AS    493.67    0.59  488.82  511.70  0.50  0.46  0.72  495.91  495.19
```

# WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File mtho065.wsp
        Hydraulic analysis for structure MTHOTH00120065   Date: 26-FEB-98
        TOWN HIGHWAY 12, FREEMAN BROOK, MOUNT HOLLY, VERMONT            ECW
           *** RUN DATE & TIME: 03-06-98  08:29
 XSID:CODE   SRDL    LEW     AREA    VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXIT1:XS   ******     7.     143.  1.71 *****  493.76  491.76   1500.  492.05
     -25. ******    41.    9449.  1.00 ***** *******    0.91   10.48
 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.91     492.69     492.40
 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.55     512.16    0.50
 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.55     512.16     492.40
FULLV:FV      25.     7.     143.  1.71  0.63  494.41  492.40   1500.  492.70
        0.    25.    41.    9462.  1.00  0.00    0.01    0.91   10.47
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID “APPR1”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.20     493.97     494.46
 ===110 WSEL NOT FOUND AT SECID “APPR1”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.20     511.70    0.50
 ===115 WSEL NOT FOUND AT SECID “APPR1”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.20     511.70     494.46
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID “APPR1”
                  WSBEG,WSEND,CRWS =   494.46     511.70     494.46
APPR1:AS      45.     4.     137.  1.86 *****  496.33  494.46   1500.  494.46
       45.    45.    41.    7835.  1.00 ***** *******    1.00   10.94
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID “BRIDG”     Q,CRWS =    1500.     493.79
            <<<<<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      25.     1.     119.  2.48 *****  496.27  493.79   1500.  493.79
        0.    25.    30.    9922.  1.00 ***** *******    1.00   12.64
     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.34 ****** ****** ******
    XSID:CODE    SRD   FLEN    HF    VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      10.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>
 XSID:CODE   SRDL    LEW     AREA    VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPR1:AS      25.     1.     217.  0.74  0.45  497.19  494.46   1500.  496.45
       45.    30.    45.   14821.  1.00  0.47   -0.01    0.55    6.91
       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.216  0.000   15169.     5.    34.   496.15
                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -25.     7.    41.   1500.    9449.     143.   10.48  492.05
   FULLV:FV       0.     7.    41.   1500.    9462.     143.   10.47  492.70
   BRIDG:BR       0.     1.    30.   1500.    9922.     119.   12.64  493.79
   RDWAY:RG      10.**************       0.******************    2.00********
   APPR1:AS      45.     1.    45.   1500.   14821.     217.    6.91  496.45
    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS       5.    34.   15169.
 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    491.76    0.91  485.59  511.52************  1.71  493.76  492.05
   FULLV:FV    492.40    0.91  486.23  512.16  0.63  0.00  1.71  494.41  492.70
   BRIDG:BR    493.79    1.00  486.68  496.86************  2.48  496.27  493.79
   RDWAY:RG  ****************  497.39  512.26**********************************
   APPR1:AS    494.46    0.55  488.82  511.70  0.45  0.47  0.74  497.19  496.45
```

# APPENDIX C:

# BED-MATERIAL PARTICLE-SIZE DISTRIBUTION




Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure MTHOTH00120065, in Mount Holly, Vermont.

# APPENDIX D:

# HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number MTHOTH00120065

## General Location Descriptive

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

Date (MM/DD/YY) 03 / 21 / 95

Highway District Number (I - 2; nn) 03

County (FIPS county code; I - 3; nnn) 021

Town (FIPS place code; I - 4; nnnnn) 47200

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

Waterway (I - 6) FREEMAN BROOK

Road Name (I - 7): -

Route Number TH012

Vicinity (I - 9) 0.08 MI TO JCT W C3 TH15

Topographic Map Mount Holly

Hydrologic Unit Code: 02010002

Latitude (I - 16; nnnn.n) 43288

Longitude (i - 17; nnnnn.n) 72513

## Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10111200651112

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0031

Year built (I - 27; YYYY) 1934

Structure length (I - 49; nnnnnn) 000035

Average daily traffic, ADT (I - 29; nnnnnn) 000020

Deck Width (I - 52; nn.n) 153

Year of ADT (I - 30; YY) 92

Channel & Protection (I - 61; n) 4

Opening skew to Roadway (I - 34; nn) 30

Waterway adequacy (I - 71; n) 6

Operational status (I - 41; X) B

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

Structure type (I - 43; nnn) 302

Year Reconstructed (I - 106) 0000

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

Clear span (nnn.n ft) 024.9

Number of spans (I - 45; nnn) 001

Vertical clearance from streambed (nnn.n ft) 008.1

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

Waterway of full opening (nnn.n $ft^2$) 202.0

Comments:

**The structural inspection report of 6/24/94 indicates the structure is a steel stringer type bridge with a concrete deck. The right abutment is concrete with areas of cracks with leaks and overall scaling. This abutment is reported to have moved and settled, particularly on the upstream end. The footing is undermined by about 4 to 5 inches and extends several feet along the footing. The left abutment is concrete and has some concrete spalls reported. This abutment is noted as having shifted toward the channel and settled on the upstream end. The abutment is displaced to the extent that the curtain wall area of the superstructure is no longer bearing on the abutment. There is a gap reported** **(continued, page 31)**

## 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:

**between the left abutment and the curtain walls, exposing the backfill. The curtain walls have extensive cracks and breaks. The deck has separated from two of the steel beams near the left abutment side of the bridge. There are no wingwalls. Heavy stone fill riprap is noted along the right abutment and some light stone fill riprap along the left abutment. The channel bed is mainly gravel, cobbles, and boulders. There is some debris noted in the channel downstream of the bridge consisting of some small branches and a log.**

## USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **6.25** $mi^2$  Lake/pond/swamp area **0.02** $mi^2$

Watershed storage *(ST)* **0.3** %

Bridge site elevation **1270** ft  Headwater elevation **3286** ft

Main channel length **5.49** mi

10% channel length elevation **1427** ft  85% channel length elevation **2320** ft

Main channel slope *(S)* **216.88** ft / mi

Watershed Precipitation Data

Average site precipitation - in  Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

## Bridge Plan Data

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

Project Number -  Minimum channel bed elevation: -

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

Benchmark location description:
**NO BENCHMARK INFORMATION**

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

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:
**NO FOUNDATION MATERIAL INFORMATION**

Comments:
**NO PLANS.**

## Cross-sectional Data

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

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

Comments: **This section was created from a sketch dated 8/19/92, that was attached to a bridge inspection report. The sketch included low chord to bed, and station distances. The low chord elevations were created from the coordinate system in this report, so a comparison can be made.**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Station | 0 | 8.50 | 11.83 | 17.33 | 21.33 | 28.75 | - | - | - | - | - |
| Feature | LAB | - | - | - | - | RAB | - | - | - | - | - |
| Low chord elevation | 495.80 | 496.10 | 496.21 | 496.40 | 496.54 | 496.80 | - | - | - | - | - |
| Bed elevation | 491.72 | 488.35 | 488.04 | 487.90 | 488.79 | 490.13 | - | - | - | - | - |
| Low chord to bed | 4.08 | 7.75 | 8.17 | 8.50 | 7.75 | 6.67 | - | - | - | - | - |
| 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: **CG** Date: **2/9/96**
Computerized by: **CG** Date: **2/9/96**
Reviewd by: **EW** Date: **3/9/98**

# Structure Number **MTHOTH00120065**

## A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E**. **Boehlmer** Date *(MM/DD/YY)* **10** / **03** / 19**96**
2. Highway District Number **03** Mile marker **0**
County **Rutland (021)** Town **Mount Holly (47200)**
Waterway *(I - 6)* **Freeman Brook** Road Name **-**
Route Number **TH 012** Hydrologic Unit Code: **02010002**
3. Descriptive comments:
**The bridge is located 0.08 miles from the intersection of TH 12 with TH 15.**

## B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **6** LBDS **6** RBDS **4** Overall **6**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US **2** UB **1** DS **1** *(**1**- pool; **2**- riffle)*
6. Bridge structure type **1** *( **1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length **35** *(feet)* Span length **31** *(feet)* Bridge width **15.3** *(feet)*

### Road approach to bridge:

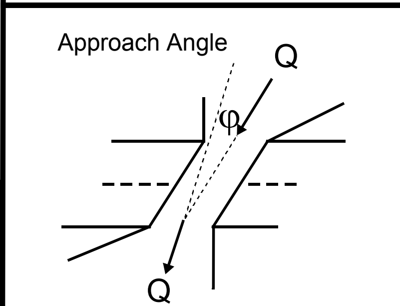
8. LB **1** RB **0** *( **0** even, **1**- lower, **2**- higher)*
9. LB **2** RB **2** *( **1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

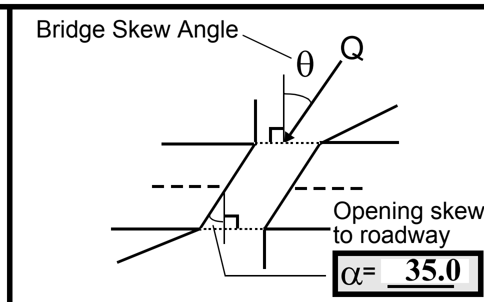
| | Protection | | 13.Erosion | 14.Severity |
|---|---|---|---|---|
| | 11.Type | 12.Cond. | | |
| LBUS | 1 | 1 | 2 | 3 |
| RBUS | 2 | 1 | 0 | 0 |
| RBDS | 2 | 1 | 0 | 0 |
| LBDS | 0 | - | 0 | 0 |

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

### Channel approach to bridge (BF):

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



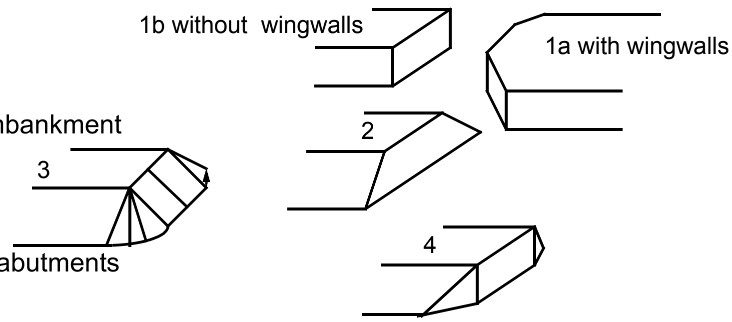




17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **140** feet **US** *(US, UB, DS)* to **90** feet **US**
Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **15** feet **US** *(US, UB, DS)* to **0** feet **DS**

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

18. Bridge Type: **1b**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls parallel to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.




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

**4: The upstream surface cover is all forest. The downstream right bank cover is a lawn in front of a home, but then forest is the predominate surface cover further downstream. The surface cover on the downstream left bank is forest, which is bisected by the gravel roadway**

**7: Values are from the VTAOT database. During the site visit, the measured bridge length equaled 35 feet, the span length equaled 32 feet and the width equaled 15.2 feet.**

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| **32.0** | **7.5** | | | **9.0** | **4** | **2** | **453** | **7** | **2** | **1** |

23. Bank width **35.0**  24. Channel width **20.0**  25. Thalweg depth **48.5**  29. Bed Material **453**

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

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

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

**The upstream channel bends moderately and then straightens out in its approach to the bridge. It impacts the right bank slightly before passing under the bridge. The water surface is constant riffle with only small, minor pooled areas between riffle areas. The slope is steep riffle around a bend far upstream, then a shallower slope riffle, then a steep riffle between 15 feet upstream and 5 feet under the bridge where the slope flattens again. From about 135 feet upstream to 95 feet upstream, there is one significant pooled area between the steep riffle at the bend and the steep riffle on the straight section approaching the bridge. The right bank material is probably the same as the left bank but it was covered by stone fill from the bridge to more than 130 feet upstream. The fill protects the right bank wall. Some of the fill is new and some is older.**

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **65** 35. Mid-bar width: **11.0**

36. Point bar extent: **95** feet **US** (US, UB) to **15** feet **US** (US, UB, DS) positioned **30** %LB to **100** %RB

37. Material: **543**

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

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: **100** 42. Cut bank extent: **140** feet **US** (US, UB) to **90** 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.):

**The most remarkable erosion at this cut-bank is around 100 feet upstream. The fine material has washed out from between the cobble and boulder bank material.**

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

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

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

**NO CHANNEL SCOUR**

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

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

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

54. Confluence comments (eg. confluence name):

**NO MAJOR CONFLUENCES**

## D. Under Bridge Channel Assessment

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

| 56. Height (BF) 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 |
|---|---|---|---|---|---|---|---|
| **16.0** | | **1.0** | | **2** | **7** | **7** | **-** |

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

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

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

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

**435**

**The under bridge channel is flatter and a “handmade” small rock dam downstream currently pools water back to about 10 feet under the bridge from the upstream bridge face.**

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

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

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

70. Debris and Ice Comments:

**2**

**There are lots of trees on the banks upstream but the channel is only slightly sinuous with some minor cut banks. The bend in the channel near 130 feet upstream is a likely spot for debris and ice buildup. The bridge may also collect ice and debris with a minor bend under the bridge and stone fill and abutment constriction.**

| 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 | | - | 90 | 0 | 2 | 0 | 0.5 | 90.0 |
| RABUT | 1 | 10 | 90 | | | 2 | 5 | 24.0 |

*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.):

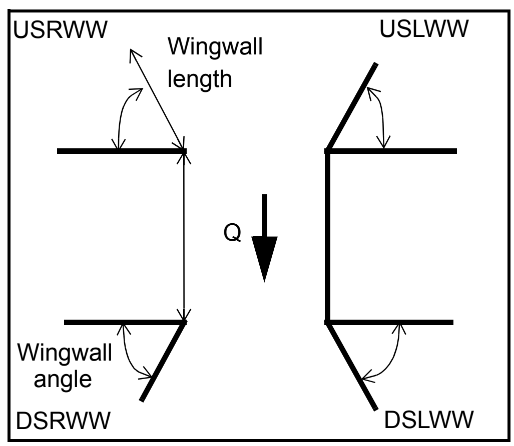
**2.0**
**1.5**
**1**

**The left abutment footing is currently only exposed at the very top from 0 to 0.5 feet at the most. Some new type I stone fill has been sloped up from the channel to the top of the footing. The deepest point of the under bridge channel bed is about 5 feet below the top of the footing. The right abutment is in very poor condition. The right abutment footing dips upstream and is pitched into the right bank (i.e. the footing slants down in an upstream direction and slants down into the right bank) probably from scour of the bed at the upstream end and behind the wall at one time. The bottom of the footing is visible from the centerline of the roadway under the bridge to the downstream bridge face. The stream bed is about 2 feet below the bottom of the footing at**

80. **Wingwalls**:

| | Exist? | Material? | Scour Condition? | Scour depth? | Exposure depth? | 81. Angle? | Length? |
|---|---|---|---|---|---|---|---|
| USLWW: | the | | deep | | est | 24.0 | |
| USRWW: | point | | . | | Ther | 0.5 | |
| DSLWW: | e is | | some | | stone | 21.5 | |
| DSRWW: | fill at | | the | | bot- | 19.5 | |

*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 | tom | righ | men | ng | fro | stre | at | nnel |
| Condition | of | t | t | slop | m | amb | the | edge |
| Extent | the | abut | footi | ing | the | ed | cha | up |

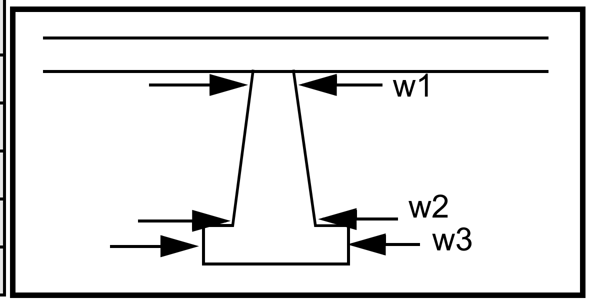
*Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee*
*Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed*
*Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other*

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
**to the bottom of the footing at the downstream end, and to a point about 0.75 feet up on the footing at the upstream end.**
**N**
**-**
**-**
**-**
**-**
**N**
**-**
**-**
**-**

## Piers:

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

| 85. Pier no. | width (w) feet | | | elevation (e) feet | | |
|---|---|---|---|---|---|---|
| | w1 | w2 | w3 | e@w1 | e@w2 | e@w3 |
| Pier 1 | - | - | - | - | - | - |
| Pier 2 | - | - | - | - | - | - |
| Pier 3 | - | - | - | - | - | - |
| Pier 4 | - | - | - | - | - | - |




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

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

**where wingwalls would be on the upstream and downstream ends of the right abutment. Protection on the left abutment consists of a native boulder at the upstream end with some type 3 stone fill just downstream of the boulder, then newer type 1 stone fill from the centerline of the roadway under the bridge to the downstream end of the left abutment.**

## 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| - | - | | | - | | N | - | - | - | - |

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

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

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

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

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

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? - (Y or if N type ctrl-n cb) Where? - (LB or RB) Mid-bank distance: **NO**

Cut bank extent: **PIE** feet **RS** (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: _______

Scour dimensions: Length **2** Width **1** Depth: **453** Positioned **7** %LB to **2** %RB

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

**1**
**453**
**2**
**2**

Are there major confluences? **1** (Y or if N type ctrl-n mc) How many? **1**

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

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

Confluence comments (eg. confluence name):

**is pooled down to a rock dam about 35 feet downstream. The dam backs water up to about the road center-line under the bridge. The channel gradient downstream of the bridge is lower than upstream and the chan-**

## F. Geomorphic Channel Assessment

107. Stage of reach evolution **nel**

**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)*:

**is a bit wider than upstream. The channel is fairly straight and then begins to bend moderately to the left about 120 feet downstream. Only the toe of the left bank is protected from 0 feet to about 35 feet downstream. The right bank is heavily covered by stone fill from 0 feet downstream to 105 feet downstream. The left bank is protected only at the toe of it from 0 feet to approximately 35 feet downstream. The stone fill completely covers the bank material in the area of 0 feet downstream to 105 feet downstream. There is a roadway atop the right embankment here and may have been filled also with stone (non native bank material). Further downstream the bank material is probably native consisting of mainly cobbles and boulders with some gravel and sand.**

## 109. G. Plan View Sketch

N

| | | | |
|---|---|---|---|
| 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: MTHOTH00120065 Town: MOUNT HOLLY
Road Number: TH 12 County: RUTLAND
Stream: FREEMAN BROOK

Initials ECW Date: 3-6-98 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 Davis, 1995, p. 28, eq. 16)

Approach Section

| Characteristic | 100 yr | 500 yr | other Q |
|---|---|---|---|
| Total discharge, cfs | 1120 | 1500 | 0 |
| Main Channel Area, ft2 | 165 | 217 | 0 |
| Left overbank area, ft2 | 0 | 0 | 0 |
| Right overbank area, ft2 | 0 | 0 | 0 |
| Top width main channel, ft | 39 | 44 | 0 |
| Top width L overbank, ft | 0 | 0 | 0 |
| Top width R overbank, ft | 0 | 0 | 0 |
| D50 of channel, ft | 0.335 | 0.335 | 0 |
| D50 left overbank, ft | -- | -- | -- |
| D50 right overbank, ft | -- | -- | -- |
| y1, average depth, MC, ft | 4.2 | 4.9 | ERR |
| y1, average depth, LOB, ft | ERR | ERR | ERR |
| y1, average depth, ROB, ft | ERR | ERR | ERR |
| Total conveyance, approach | 10115 | 14822 | 0 |
| Conveyance, main channel | 10115 | 14822 | 0 |
| Conveyance, LOB | 0 | 0 | 0 |
| Conveyance, ROB | 0 | 0 | 0 |
| Percent discrepancy, conveyance | 0.0000 | 0.0000 | ERR |
| Qm, discharge, MC, cfs | 1120.0 | 1500.0 | ERR |
| Ql, discharge, LOB, cfs | 0.0 | 0.0 | ERR |
| Qr, discharge, ROB, cfs | 0.0 | 0.0 | ERR |
| Vm, mean velocity MC, ft/s | 6.8 | 6.9 | ERR |
| Vl, mean velocity, LOB, ft/s | ERR | ERR | ERR |
| Vr, mean velocity, ROB, ft/s | ERR | ERR | ERR |
| Vc-m, crit. velocity, MC, ft/s | 9.9 | 10.2 | 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 |
| 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 Davis, 1995, p. 32, eq. 20, 20a)

 Bridge Section                      Q100     Q500     Other Q

   (Q) total discharge, cfs          1120     1500     0
   (Q) discharge thru bridge, cfs    1120     1500     0
   Main channel conveyance           7455     9934     0
   Total conveyance                  7455     9934     0
 Q2, bridge MC discharge,cfs         1120     1500     ERR
   Main channel area, ft2            98       119      0
   Main channel width (normal), ft   23.6     23.8     0.0
   Cum. width of piers in MC, ft     0.0      0.0      0.0
 W, adjusted width, ft               23.6     23.8     0
 y_bridge (avg. depth at br.), ft    4.15     5.00     ERR
 Dm, median (1.25*D50), ft           0.41875  0.41875  0
 y2, depth in contraction,ft           4.34     5.53   ERR

 ys, scour depth (y2-ybridge), ft    0.19     0.53     N/A
```

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  1120     1500     N/A
   Main channel area (DS), ft2       98       119      0
   Main channel width (normal), ft   23.6     23.8     0.0
   Cum. width of piers, ft           0.0      0.0      0.0
   Adj. main channel width, ft       23.6     23.8     0.0
 D90, ft                             1.4548   1.4548   0.0000
 D95, ft                             1.7881   1.7881   0.0000
 Dc, critical grain size, ft         1.0440   1.1470   ERR
 Pc, Decimal percent coarser than Dc 0.195    0.172    0.000

 Depth to armoring, ft               12.93    16.54    ERR
```

Abutment Scour

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

| Characteristic | Left Abutment 100 yr Q | Left Abutment 500 yr Q | Left Abutment Other Q | Right Abutment 100 yr Q | Right Abutment 500 yr Q | Right Abutment Other Q |
|---|---|---|---|---|---|---|
| (Qt), total discharge, cfs | 1120 | 1500 | 0 | 1120 | 1500 | 0 |
| a', abut.length blocking flow, ft | 0.4 | 2.1 | 0 | 15.3 | 18 | 0 |
| Ae, area of blocked flow ft2 | 1.08 | 6.48 | 0 | 47.53 | 68.6 | 0 |
| Qe, discharge blocked abut.,cfs | 2.95 | 17.31 | 0 | 242.67 | 375 | 0 |
| (If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually) | | | | | | |
| Ve, (Qe/Ae), ft/s | 2.72 | 2.67 | ERR | 5.11 | 5.47 | ERR |
| ya, depth of f/p flow, ft | 2.70 | 3.09 | ERR | 3.11 | 3.81 | ERR |
| --Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru) | | | | | | |
| K1 | 1 | 1 | 1 | 1 | 1 | 1 |
| --Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US) | | | | | | |
| theta | 125 | 125 | 125 | 55 | 55 | 55 |
| K2 | 1.04 | 1.04 | 1.04 | 0.94 | 0.94 | 0.94 |
| Fr, froude number f/p flow | 0.292 | 0.268 | ERR | 0.510 | 0.493 | ERR |
| ys, scour depth, ft | 4.03 | 5.86 | N/A | 11.82 | 14.09 | N/A |

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

| | | | | | | |
|---|---|---|---|---|---|---|
| a'(abut length blocked, ft) | 0.4 | 2.1 | 0 | 15.3 | 18 | 0 |
| y1 (depth f/p flow, ft) | 2.70 | 3.09 | ERR | 3.11 | 3.81 | ERR |
| a'/y1 | 0.15 | 0.68 | ERR | 4.93 | 4.72 | ERR |
| Skew correction (p. 49, fig. 16) | 1.08 | 1.08 | 1.08 | 0.87 | 0.87 | 0.87 |
| Froude no. f/p flow | 0.29 | 0.27 | N/A | 0.51 | 0.49 | N/A |
| Ys w/ corr. factor K1/0.55: | | | | | | |
| vertical | ERR | ERR | ERR | ERR | ERR | ERR |
| vertical w/ ww's | ERR | ERR | ERR | ERR | ERR | ERR |
| spill-through | ERR | ERR | ERR | ERR | ERR | ERR |

Abutment riprap Sizing

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

| Characteristic | Q100 | Q500 | Other Q | Q100 | Q500 | Other Q |
|---|---|---|---|---|---|---|
| Fr, Froude Number | 1 | 1 | 0 | 1 | 1 | 0 |
| y, depth of flow in bridge, ft | 4.15 | 5.00 | 0.00 | 4.15 | 5.00 | 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.) | 1.74 | 2.09 | ERR | 1.74 | 2.09 | ERR |