LEVEL II SCOUR ANALYSIS FOR BRIDGE 3 (BRIDTH00010003) on TOWN HIGHWAY 1, crossing DAILEY HOLLOW BRANCH, BRIDGEWATER, VERMONT

U.S. Geological Survey
Open-File Report 96-237

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

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By SCOTT A. OLSON and DONALD L. SONG

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Pembroke, New Hampshire

1996

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

U.S. GEOLOGICAL SURVEY
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

In this report, the words “right” and “left” refer to directions that would be reported by an observer facing downstream.

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929-- a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

In the appendices, the above abbreviations may be combined. For example, USLB would represent upstream left bank.

LEVEL II SCOUR ANALYSIS FOR BRIDGE 3 (BRIDTH00010003) ON TOWN HIGHWAY 1, CROSSING DAILEY HOLLOW BRANCH, BRIDGEWATER, VERMONT

By **Scott A. Olson and Donald L. Song**

INTRODUCTION

This report provides the results of a detailed Level II analysis of scour potential at structure BRIDTH00010003 on town highway 1 crossing Dailey Hollow Branch, Bridgewater, 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). A Level I study is included in Appendix E of this report. A Level I study provides a qualitative geomorphic characterization of the study site. Information on the bridge available from VTAOT files was compiled prior to conducting Level I and Level II analyses and can be found in Appendix D.

The site is in the Green Mountain physiographic division of central Vermont in the town of Bridgewater. The 9.88-mi^2 drainage area is in a predominantly rural, forested basin. In the vicinity of the study site, the immediate channel banks have moderate tree cover and shrubs with residential properties on the overbank.

In the study area, Dailey Hollow Branch has an incised, sinuous channel with a slope of approximately 0.009 ft/ft, an average channel top width of 46 ft and an average channel depth of 4 ft. The predominant channel bed materials are gravel and cobble with a median grain size (D_{50}) of 89.7 mm (0.294 ft). The geomorphic assessment at the time of the Level I and Level II site visit on October 27, 1994, indicated that the reach was vertically degrading.

The town highway 1 crossing of Dailey Hollow Branch is a 45-ft-long, two-lane bridge consisting of one 42-foot steel-beam span (Vermont Agency of Transportation, written communication, August 24, 1994). The bridge is supported by vertical, concrete abutments with wingwalls. Type-2 stone fill (less than 36 inches diameter) protects the downstream right and left wingwall. Type-3 stone fill (less than 48 inches diameter) exists on the downstream right bank. The left abutment is undermined by up to one foot. Horizontal probing under the abutment resulted in penetration up to 6 feet.

The bridge is misaligned with the channel. Higher discharges may directly impact the left wingwall. The channel is skewed approximately 20 degrees to the bridge; the opening-skew-to-roadway is also 20 degrees. Additional details describing conditions at the site are included in the Level II Summary and Appendices D
and E.

Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1993).
Total scour at a highway crossing is comprised of three components: 1) long-term aggradation or degradation; 2) contraction scour (due to reduction in flow area caused by 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 scour depths for contraction and local scour and a summary of the results follows.

Contraction scour for all modelled flows ranged from 0.6 ft to 1.3 ft and the worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 6.7 ft to 12.2 ft and the worst-case abutment scour occurred at the 500-year discharge. Scour depths and depths to armoring are summarized on p. 14 in the section titled “Scour Results”. Scour elevations, based on the calculated depths are presented in tables 1 and 2; a graph of the scour elevations is presented in figure 8 Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

For all scour presented in this report, “the scour depths adopted [by VTAOT] may differ from the equation values based on engineering judgement” (Richardson and others, 1993, p. 21, 27). It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and others, 1993, p. 48). Many factors, including historical performance during flood events, the geomorphic assessment, and the results of the hydraulic analyses, must be considered to properly assess the validity of abutment scour results.

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 BRIDTH00010003 ***Stream*** Dailey Hollow Branch

County Windsor ***Road*** TH01 ***District*** 04

Description of Bridge

Bridge length 45 ***ft*** ***Bridge width*** 21.7 ***ft*** ***Max span length*** 42 ***ft***

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

Abutment type vertical and concrete ***Embankment type*** sloping on right

Stone fill on abutment? No ***Date of inspection*** 10/27/94

Description of stone fill Type-2 at downstream wingwalls, Type-3, in slumped condition along the downstream right bank and road embankment.

Brief description of piers/abutments Abutments and wingwalls are concrete. The left abutment is undermined by a maximum measurement of one foot. Maximum horizontal penetration under the abutment is six feet.

Is bridge skewed to flood flow according to N ***survey?*** Y ***Angle*** 20

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

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	10/27/94	0	0
Level II	10/27/94	-	-

Potential for debris Low

Describe any features near or at the bridge that may affect flow (include observation date) The stream joins the North Branch of the Ottauquechee 185 feet downstream of the bridge. The bridge is misaligned with the channel (10/27/95).

Description of the Geomorphic Setting

General topography The bridge crosses a high gradient incised upland stream with terraces in a moderate relief valley.

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

Date of inspection 10/27/94

DS left: Narrow flood plain to high terrace.

DS right: High terrace.

US left: High narrow terrace to valley wall.

US right: High narrow terrace to valley wall.

Description of the Channel

Average top width 46 ***ft*** ***Average depth*** 4 ***ft***

Predominant bed material gravel/cobble/boulder ***Bank material*** gravel/cobble

Straight, incised stream.

10/27/94

Vegetative co Immediate bank is densely forested with lawn on overbank.

DS left: Minor woody vegetation on immediate bank; parking lot on overbank.

DS right: Forested; gravel roadway on narrow terrace.

US left: Forested; gravel roadway on narrow terrace.

US right:

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

October 27, 1994. There is a cut bank on the downstream left and the upstream right. All banks appear to be oversteepened.

October 27, 1994 None.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 9.88 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province	***Percent of drainage area***
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 [illegible] No

Calculated Discharges

Q100 2,170 ***ft³/s*** ***Q500*** 2,920 ***ft³/s***

Discharges determined using a drainage area relationship with upstream Bridgewater bridge 43 [(9.88/9.80) to the 0.7 power]. The Q100 and Q500 discharges at bridge 43 are 2,150 and 2,900 cubic feet per second, respectively. The Q100 at bridge 43 is from the VTAOT database (VTAOT, written communication, May, 1995); the Q500 is based on a weighted average of extrapolated discharges from applicable empirical methods (Talbot, 1887; Potter, 1957a & b; Johnson and Laraway, 1971, written commun.; Johnson and Tasker, 1974; Federal Highway Administration, 1983). Bridge 43 has a drainage area of 9.8 square miles.

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 Not applicable.

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. 101.07 ft, arbitrary datum). RM2 is a chiseled X on top of the upstream end of the left abutment (elev. 100.94 ft, arbitrary datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-73	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	11	1	Road Grade section
APPRO	62	2	Modeled Approach section (Templated from SURVA)
APTEM	108	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 analysis reported herein reflects 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, Jr. and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel “n” values for the reach ranged from 0.049 to 0.057, and overbank “n” values ranged from 0.030 to 0.035.

Dailey Hollow Branch drains into the North Branch Ottauquechee River approximately 185 feet downstream of this site. The close proximity of the confluence may affect the Dailey Hollow Branch hydraulics, especially if the flow peaks are simultaneous. However an analysis of potential backwater from the North Branch Ottauquechee River is outside of the scope of this study and normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the User’s manual for WSPRO (Shearman, 1990). The slope used was 0.0092 ft/ft which was determined from surveyed thalweg points downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.031 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 100.3 *ft*
Average low steel elevation 97.6 *ft*

100-year discharge 2,170 *ft³/s*
Water-surface elevation in bridge opening 88.8 *ft*
Road overtopping? N *Discharge over road* -- *,. .s*
Area of flow in bridge opening 186 *ft²*
Average velocity in bridge opening 11.7 *ft/s*
Maximum WSPRO tube velocity at bridge 14.5 *ft/s*

Water-surface elevation at Approach section with bridge 91.2
Water-surface elevation at Approach section without bridge 89.9
Amount of backwater caused by bridge 1.3 *t*

500-year discharge 2,920 *ft³/s*
Water-surface elevation in bridge opening 89.6 *ft*
Road overtopping? N *Discharge over road* -- *,. /s*
Area of flow in bridge opening 219 *ft²*
Average velocity in bridge opening 13.3 *ft/s*
Maximum WSPRO tube velocity at bridge 16.7 */s*

Water-surface elevation at Approach section with bridge 92.7
Water-surface elevation at Approach section without bridge 91.0
Amount of backwater caused by bridge 1.7

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 -- *t*

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, 1993). 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, 1993, p. 35, equation 18). 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 was computed by use of the Froehlich equation (Richardson and others, 1993, p. 49, equation 24). The Froehlich equation gives “excessively conservative estimates of scour depths” (Richardson and others, 1993, p. 48). 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-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.6	1.3	--
Depth to armoring	18.5	26.0	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	10.1	12.2	--
Right abutment	6.7	8.3	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Rock Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	2.0	2.4	--
Right abutment	2.0	2.4	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

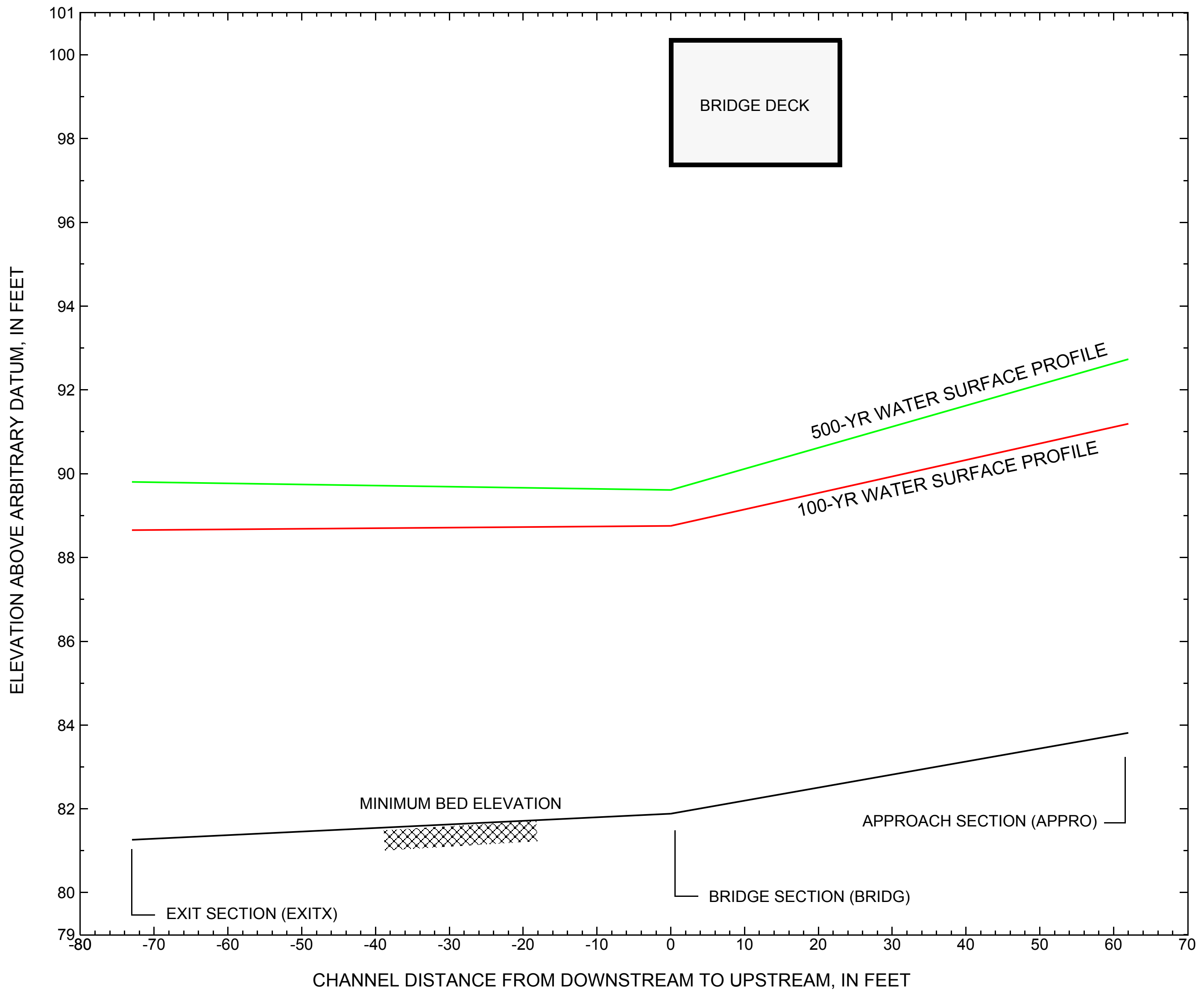

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BRIDTH00010003 on town highway 1, crossing Dailey Hollow Branch, Bridgewater, Vermont.

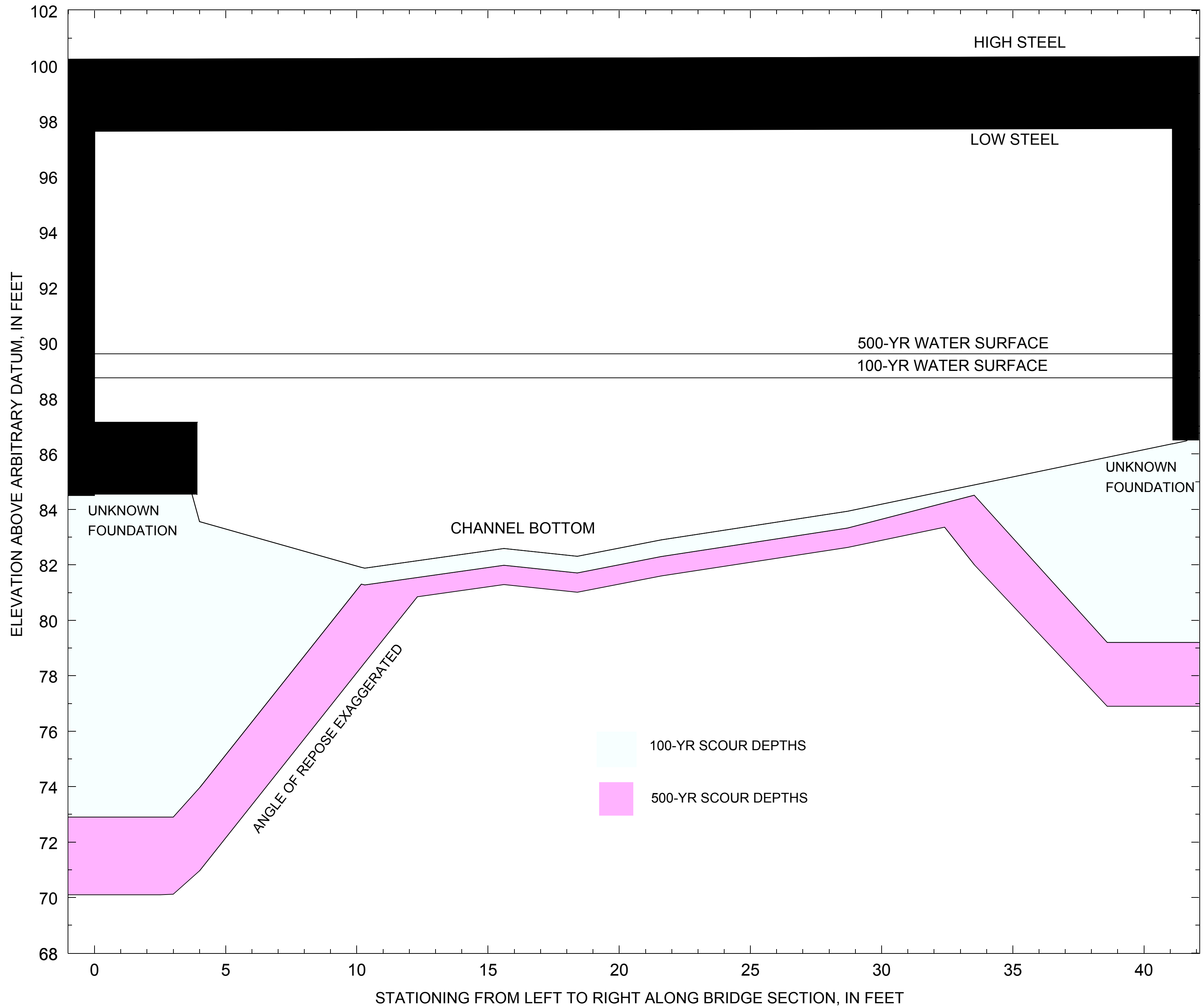

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BRIDTH00010003 on town highway 1, crossing Dailey Hollow Branch, Bridgewater, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BRIDTH00010003 on Town Highway 1, crossing Dailey Hollow Branch, Bridgewater, 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 2,170 cubic-feet per second											
Left abutment	0.0	--	97.64	--	83.6	0.6	10.1	--	10.7	72.9	--
Right abutment	41.1	--	97.66	--	86.5	0.6	6.7	--	7.3	79.2	--

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 BRIDTH00010003 on Town Highway 1, crossing Dailey Hollow Branch, Bridgewater, 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 2,920 cubic-feet per second											
Left abutment	0.0	--	97.64	--	83.6	1.3	12.2	--	13.5	70.1	--
Right abutment	41.1	--	97.66	--	86.5	1.3	8.3	--	9.6	76.9	--

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, 1966, Plymouth, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brid003.wsp
T2        CREATED ON 26-APR-95 FOR BRIDGE BRIDTH00010003 USING FILE brid003.dca
T3        Dailey Hollow Branch, Town Highway 1, Town of Bridgewater
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q          2170 2920
SK         0.0092 0.0092
*
*
XS   EXITX    -73
GR         -119.9,  92.44    -30.7,  94.16    -21.0,  89.95     -4.2,  85.64
GR           -3.6,  83.31      0.0,  82.31      5.3,  81.33      9.5,  81.92
GR           16.6,  81.26     22.4,  82.25     32.6,  82.89     38.9,  86.93
GR           52.2,  96.88    176.4,  96.82
N            0.035        0.052        0.035
SA                  -30.7        52.2
*
XS   FULLV   0 * * * 0.009
*
BR   BRIDG   0 97.65 20
GR            0.0,  97.64      0.6,  87.00      3.8,  87.00      4.0,  83.56
GR            6.5,  82.87     10.3,  81.88     15.6,  82.59     18.4,  82.31
GR           21.6,  82.90     28.7,  83.93     41.1,  86.47     41.1,  97.66
GR            0.0,  97.64
N            0.049
CD           1 36.5 * * 62.5 7.2
*
XR   RDWAY   11 21.7 1
GR         -121.5,  96.60    -71.5,  97.49    -34.7,  98.85      0.0, 100.19
GR            0.1, 100.95      1.6, 100.95      2.0, 101.69     41.9, 101.83
GR           42.0, 101.06     44.1, 101.07     45.3, 100.39     76.4, 100.42
GR           101.0, 110.88
BP           0
*
XT   APTEM   108
GR           -102.5, 105.83    -72.0, 104.05    -57.4,  98.61    -19.4,  98.11
GR          -7.4,  89.75     -5.7,  88.71      2.1,  87.12      5.0,  85.74
GR           13.2,  85.24     20.9,  85.71     26.8,  86.21     37.1,  88.72
GR           38.7,  90.29     42.8,  91.99     57.3,  99.83     83.5, 101.43
GR           96.3, 109.49
*
AS   APPRO   62
GT           -1.43
N            0.030        0.057        0.030
SA                 -19.4         57.3
BP           0
*
HP 1 BRIDG    88.75 1 88.75
HP 2 BRIDG    88.75 * * 2170
HP 1 APPRO    91.19 1 91.19
HP 2 APPRO    91.19 * * 2170
*
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brid003.wsp
       CREATED ON 26-APR-95 FOR BRIDGE BRIDTH00010003 USING FILE brid003.dca
       Dailey Hollow Branch, Town Highway 1, Town of Bridgewater
          *** RUN DATE & TIME: 09-20-95  14:08
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      186.   14372.    38.    46.                      2335.
   88.75           186.   14372.    38.    46.  1.00     1.    41.   2335.

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
       88.75     0.5    41.1   186.2   14372.    2170.  11.65

X STA.         0.5        6.3        8.1        9.6       10.9       12.2
  A(I)            17.8       10.4        9.0        8.5        7.9
  V(I)            6.09      10.45      12.10      12.73      13.72

X STA.        12.2       13.4       14.7       16.0       17.3       18.6
  A(I)             7.7        7.7        7.7        7.6        7.5
  V(I)           14.14      14.10      14.02      14.33      14.49

X STA.        18.6       19.8       21.2       22.7       24.2       25.9
  A(I)             7.6        7.8        7.9        8.2        8.3
  V(I)           14.27      13.94      13.82      13.16      13.00

X STA.        25.9       27.7       29.8       32.2       35.4       41.1
  A(I)             8.7        9.3       10.0       11.2       15.4
  V(I)           12.43      11.70      10.81       9.70       7.04

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      62.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            2      284.   21203.    55.    59.                      3639.
   91.19           284.   21203.    55.    59.  1.00   -12.    44.   3639.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      62.
        WSEL     LEW     REW    AREA        K        Q    VEL
       91.19   -11.5    44.0   283.6   21203.    2170.   7.65

X STA.       -11.5       -2.9        0.5        3.3        5.3        7.1
  A(I)            23.3       16.5       15.3       13.5       12.5
  V(I)            4.66       6.58       7.08       8.03       8.71

X STA.         7.1        8.9       10.5       12.1       13.7       15.3
  A(I)            12.4       11.9       11.6       11.6       11.5
  V(I)            8.75       9.15       9.33       9.33       9.40

X STA.        15.3       16.9       18.6       20.3       22.1       23.9
  A(I)            11.8       11.6       12.0       12.2       12.5
  V(I)            9.19       9.32       9.03       8.90       8.71

X STA.        23.9       25.9       28.0       30.6       33.9       44.0
  A(I)            13.1       13.6       14.9       16.6       25.2
  V(I)            8.31       8.00       7.28       6.54       4.31

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      219.   18383.    38.    48.                      2977.
   89.61           219.   18383.    38.    48.  1.00     0.    41.   2977.

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
       89.61     0.5    41.1   219.1   18383.    2920.  13.33

X STA.         0.5        6.1        8.0        9.5       10.9       12.2
  A(I)            21.1       12.3       10.9       10.0        9.3
  V(I)            6.91      11.89      13.45      14.65      15.77

X STA.        12.2       13.6       14.9       16.3       17.6       18.9
  A(I)             9.4        9.0        9.1        8.9        8.7
  V(I)           15.60      16.31      16.13      16.42      16.70

X STA.        18.9       20.2       21.6       23.1       24.7       26.4
  A(I)             8.9        9.2        9.3        9.4        9.9
  V(I)           16.35      15.93      15.70      15.48      14.80

X STA.        26.4       28.3       30.4       32.8       35.8       41.1
  A(I)            10.4       10.8       11.4       13.0       18.3
  V(I)           14.07      13.55      12.78      11.26       7.97

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      62.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            2      373.   31384.    61.    65.                      5253.
   92.73           373.   31384.    61.    65.  1.00   -14.    47.   5253.
```

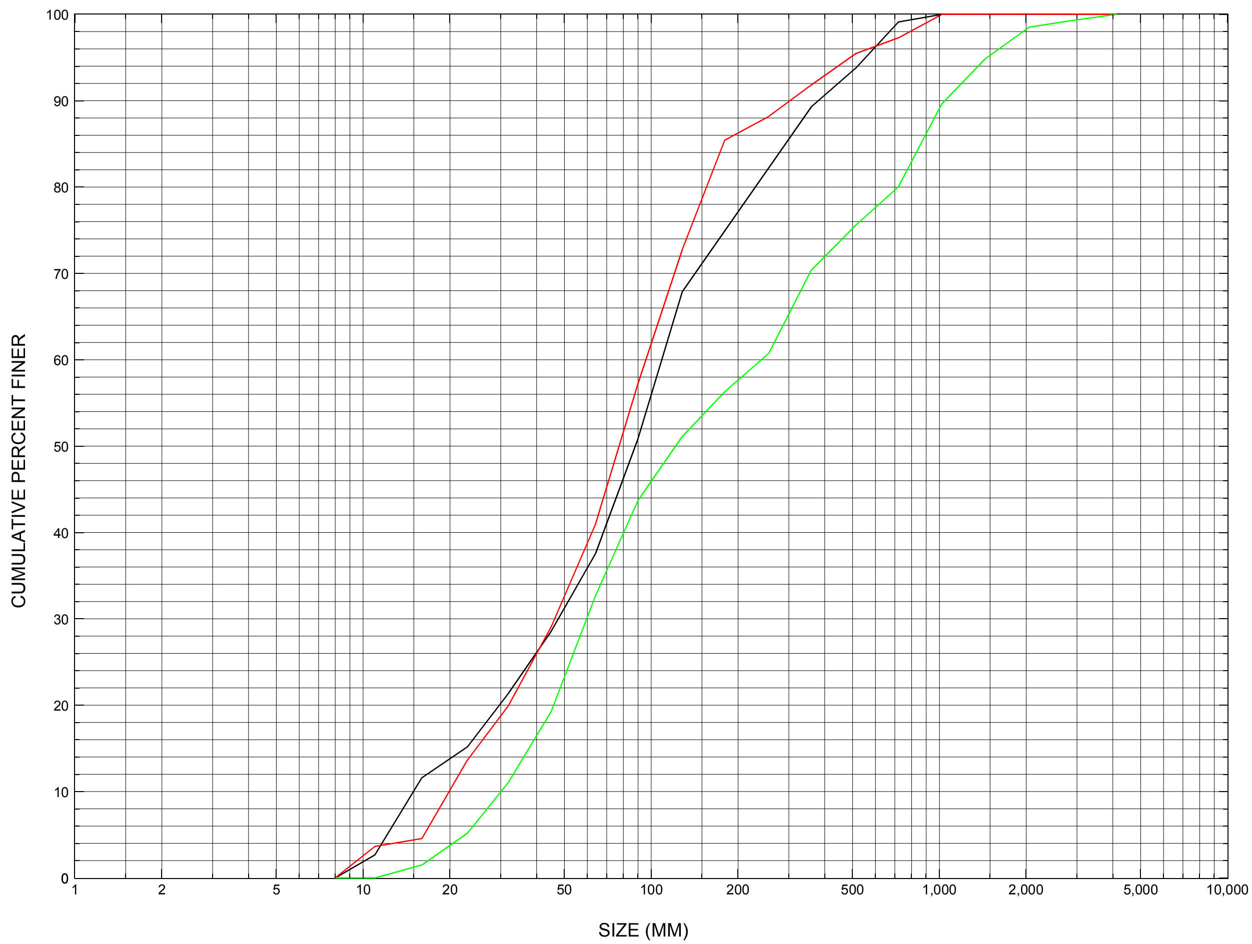
```
    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      62.
         WSEL     LEW     REW    AREA        K        Q    VEL
        92.73   -13.7    46.8   373.0   31384.    2920.   7.83
X STA.       -13.7       -4.1       -0.6        2.3        4.7        6.6
  A(I)            31.6       21.5       19.5       18.1       16.3
  V(I)            4.62       6.79       7.49       8.05       8.95

X STA.         6.6        8.5       10.3       12.0       13.7       15.4
  A(I)            15.9       15.6       15.3       15.2       15.1
  V(I)            9.16       9.37       9.57       9.58       9.64

X STA.        15.4       17.2       18.9       20.8       22.7       24.7
  A(I)            15.4       15.2       15.7       15.7       16.7
  V(I)            9.47       9.59       9.27       9.32       8.76

X STA.        24.7       26.8       29.1       31.9       35.5       46.8
  A(I)            16.8       18.1       19.5       22.6       33.0
  V(I)            8.70       8.07       7.48       6.45       4.42

        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brid003.wsp
        CREATED ON 26-APR-95 FOR BRIDGE BRIDTH00010003 USING FILE brid003.dca
        Dailey Hollow Branch, Town Highway 1, Town of Bridgewater
           *** RUN DATE & TIME: 09-20-95  14:08

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

EXITX:XS   ******   -16.     284.  0.91 *****   89.55   86.87   2170.   88.65
      -73. ******    41.   22618.  1.00 ***** *******    0.60    7.63

FULLV:FV      73.   -16.     286.  0.89  0.67   90.23 *******   2170.   89.34
        0.    73.    41.   22853.  1.00  0.00    0.02    0.60    7.58
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.87      89.89      89.47

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =    88.84     108.06    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =    88.84     108.06      89.47

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  0.62

APPRO:AS      62.   -10.     214.  1.59  0.90   91.48   89.47   2170.   89.89
       62.    62.    41.   14173.  1.00  0.35    0.00    0.87   10.12
         <<<<<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      73.     1.     186.  2.11  1.06   90.86   88.51   2170.   88.75
        0.    73.    41.   14364.  1.00  0.25    0.00    0.93   11.66

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******   97.65 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      11.        <<<<<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      26.   -12.     283.  0.91  0.41   92.10   89.47   2170.   91.19
       62.    26.    44.   21186.  1.00  0.83    0.02    0.60    7.66

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.201  0.000   21643.    -3.    38.    90.76

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -73.   -16.    41.   2170.   22618.     284.    7.63   88.65
   FULLV:FV       0.   -16.    41.   2170.   22853.     286.    7.58   89.34
   BRIDG:BR       0.     1.    41.   2170.   14364.     186.   11.66   88.75
   RDWAY:RG      11.**************       0.*****************    1.00********
   APPRO:AS      62.   -12.    44.   2170.   21186.     283.    7.66   91.19

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -3.    38.   21643.
```

WSPRO OUTPUT FILE (continued)

```
  SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     86.87    0.60   81.26   96.88************  0.91   89.55   88.65
   FULLV:FV  ********    0.60   81.92   97.54  0.67  0.00  0.89   90.23   89.34
   BRIDG:BR     88.51    0.93   81.88   97.66  1.06  0.25  2.11   90.86   88.75
   RDWAY:RG  ****************   96.60  110.88**********************************
   APPRO:AS     89.47    0.60   83.81  108.06  0.41  0.83  0.91   92.10   91.19

         U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE brid003.wsp
         CREATED ON 26-APR-95 FOR BRIDGE BRIDTH00010003 USING FILE brid003.dca
         Dailey Hollow Branch, Town Highway 1, Town of Bridgewater
            *** RUN DATE & TIME: 09-20-95  14:08

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

EXITX:XS   ******   -20.     354.  1.06 *****   90.86   87.87   2920.   89.80
      -73. ******    43.   30422.  1.00 ***** *******    0.61    8.25

FULLV:FV      73.   -21.     356.  1.04  0.67   91.54 *******   2920.   90.50
        0.    73.    43.   30714.  1.00  0.00    0.02    0.61    8.20
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.85      91.00      90.41

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =    90.00     108.06    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =    90.00     108.06      90.41

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.65

APPRO:AS      62.   -11.     272.  1.79  0.86   92.77   90.41   2920.   90.98
       62.    62.    44.   19990.  1.00  0.37    0.00    0.85   10.72
         <<<<<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      73.     0.     219.  2.76  1.11   92.37   89.54   2920.   89.61
        0.    73.    41.   18383.  1.00  0.40    0.00    0.98   13.33

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******   97.65 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      11.        <<<<<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      26.   -14.     373.  0.95  0.39   93.68   90.41   2920.   92.73
       62.    27.    47.   31386.  1.00  0.92    0.01    0.56    7.83

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.257  0.000   31613.    -3.    37.    92.38

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -73.   -20.    43.   2920.   30422.     354.    8.25   89.80
   FULLV:FV       0.   -21.    43.   2920.   30714.     356.    8.20   90.50
   BRIDG:BR       0.     0.    41.   2920.   18383.     219.   13.33   89.61
   RDWAY:RG      11.**************      0.******************    1.00********
   APPRO:AS      62.   -14.    47.   2920.   31386.     373.    7.83   92.73

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -3.    37.   31613.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     87.87    0.61   81.26   96.88************  1.06   90.86   89.80
   FULLV:FV  ********    0.61   81.92   97.54  0.67  0.00  1.04   91.54   90.50
   BRIDG:BR     89.54    0.98   81.88   97.66  1.11  0.40  2.76   92.37   89.61
   RDWAY:RG  ****************   96.60  110.88**********************************
   APPRO:AS     90.41    0.56   83.81  108.06  0.39  0.92  0.95   93.68   92.73
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distributions for three pebble count transects at the approach cross-section for structure BRIDTH00010003, in Bridgewater, Vermont.

APPENDIX D:

HISTORICAL DATA FORM