LEVEL II SCOUR ANALYSIS FOR BRIDGE 29 (HARDTH00310029) on TOWN HIGHWAY 31, crossing the LAMOILLE RIVER, HARDWICK, VERMONT

U.S. Geological Survey
Open-File Report 97-340

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

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By SCOTT A. OLSON

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Pembroke, New Hampshire

1997

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

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

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 29 (HARDTH00310029) ON TOWN HIGHWAY 31, CROSSING THE LAMOILLE RIVER, HARDWICK, VERMONT

By **Scott A. Olson**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure HARDTH00310029 on town highway 31 crossing the Lamoille River, Hardwick, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province of north-central Vermont. The 64.4-mi^2 drainage area is in a predominantly rural basin. In the vicinity of the study site, the surface cover is pasture except for the immediate downstream channel banks and the downstream left overbank which are brush covered.

In the study area, the Lamoille River has a sinuous channel with a slope of approximately 0.001 ft/ft, an average channel top width of 84 ft and an average channel depth of 4 ft. The predominant channel bed materials are cobble and gravel with a median grain size (D_{50}) of 36.1 mm (0.119 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 26, 1995, indicated that the reach was stable.

The town highway 31 crossing of the Lamoille River is a 65-ft-long, one-lane bridge consisting of one 61-foot steel-beam span (Vermont Agency of Transportation, written communication, March 27, 1995). The bridge is supported by vertical, stone abutments with wingwalls. The right abutment has a concrete facing and a concrete subfooter. The channel is skewed approximately 5 degrees to the opening while the opening-skew-to-roadway is 0 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, 1995). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 2.7 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 10.3 to 18.6 ft. The worst-case abutment scour occurred at the 100-year discharge at the right abutment. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Caspian Lake, VT. Quadrangle, 1:24,000, 1986

NORTH

Figure 1. Location of study area on USGS 1:24,000 scale map.

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

LEVEL II SUMMARY

Structure Number HARDTH00310029 ***Stream*** Lamoille River

County Caledonia ***Road*** TH31 ***District*** 7

Description of Bridge

Bridge length 65 ***ft*** ***Bridge width*** 13.9 ***ft*** ***Max span length*** 61 ***ft***

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

Abutment type Vertical, stone ***Embankment type*** Sloping

Stone fill on abutment? No ***Date of inspection*** 7/26/95

Description of stone fill --

Abutments and wingwalls are stone. The right abutment is faced with concrete and has a concrete subfooter.

Is bridge skewed to flood flow according to Y ***survey?*** ***Angle*** 5

N

The immediate reach is straight. There are moderate bends further upstream and downstream of the structure (see Figures 4 and 5).

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	7/26/95	0	0
Level II	7/26/95	0	0

Potential for debris Low to moderate. Local resident reports that ice jamming at the bridge occurs nearly annually.

Describe any features near or at the bridge that may affect flow (include observation date) --, July 26, 1995

Description of the Geomorphic Setting

General topography The channel is located in an approximately 600 foot-wide moderate relief valley with flat to slightly irregular flood plains.

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

Date of inspection 7/26/95

DS left: Flood plain

DS right: Flood plain

US left: Flood plain

US right: Flood plain

Description of the Channel

Average top width 84 ***ft*** ***Average depth*** 4 ***ft***

Predominant bed material Cobbles/Gravel ***Bank material*** Cobbles/Gravel

Sinuous but stable with semi-alluvial channel boundaries and flood plains.

Vegetative co 7/26/95

Brush

DS left: Pasture with brush on immediate channel bank

DS right: Pasture

US left: Pasture

US right:

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

--

None, July 26, 1995

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 64.4 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/New England Upland	100

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None.

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 8,600 ***ft³/s*** ***Q500*** 12,200 ***ft³/s***

The 100- and 500-year discharges were interpolated from discharges published in the Flood Insurance Study for the Town of Hardwick (Federal Emergency Management Agency, 1987). The Flood Insurance Study reports a Q100 of 8,300 cfs and a Q500 of 11,800 cfs at a drainage area of 60 square miles and a Q100 of 8,700 cfs and a Q500 of 12,400 cfs at a drainage are of 66 square miles. The discharges were within a range defined by several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887)

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the right abutment (elev. 499.24 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the left abutment and about two feet downstream of the bridge deck (elev. 499.15ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-47	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	9	1	Road Grade section
APTEM	71	1	Approach section as surveyed (Used as a template)
APPRO	77	2	Modelled Approach section (Templated from APTEM)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.037 to 0.039, and overbank "n" values ranged from 0.050 to 0.057.

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 0.0012 ft/ft which was the 100-year water surface profile downstream of the bridge in the Flood Insurance Study for the Town of Hardwick (Federal Emergency Management Agency, 1987).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0083 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 499.9 *ft*
Average low steel elevation 496.5 *ft*

100-year discharge 8,600 *ft³/s*
Water-surface elevation in bridge opening 496.7 *ft*
Road overtopping? Y *Discharge over road* 2,480 *ft³/s*
Area of flow in bridge opening 619 *ft²*
Average velocity in bridge opening 9.9 *ft/s*
Maximum WSPRO tube velocity at bridge 11.0 *ft/s*

Water-surface elevation at Approach section with bridge 498.9
Water-surface elevation at Approach section without bridge 496.7
Amount of backwater caused by bridge 2.2 *ft*

500-year discharge 12,200 *ft³/s*
Water-surface elevation in bridge opening 496.7 *ft*
Road overtopping? Y *Discharge over road* 5,510
Area of flow in bridge opening 619 *ft²*
Average velocity in bridge opening 10.7 *ft/s*
Maximum WSPRO tube velocity at bridge 12.2 */s*

Water-surface elevation at Approach section with bridge 500.7
Water-surface elevation at Approach section without bridge 498.0
Amount of backwater caused by bridge 2.7

Incipient overtopping discharge 4,170 *ft³/s*
Water-surface elevation in bridge opening 494.0 *ft*
Area of flow in bridge opening 475 *ft²*
Average velocity in bridge opening 8.8 *ft/s*
Maximum WSPRO tube velocity at bridge 10.2 *ft/s*

Water-surface elevation at Approach section with bridge 495.3
Water-surface elevation at Approach section without bridge 494.5
Amount of backwater caused by bridge 0.8 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 100- and 500-year discharges resulted in submerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, for these discharges contraction scour was computed by use of the Chang equation (Richardson and others, 1995,p. 145-146).

Abutment scour for the right abutment was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour at the left abutment was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.6	2.7	0.0
Depth to armoring	4.7	7.2	2.4
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	16.1	17.7	10.3
Right abutment	18.6	17.9	14.8
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.9	2.2	1.6
Right abutment	1.9	2.2	1.6
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

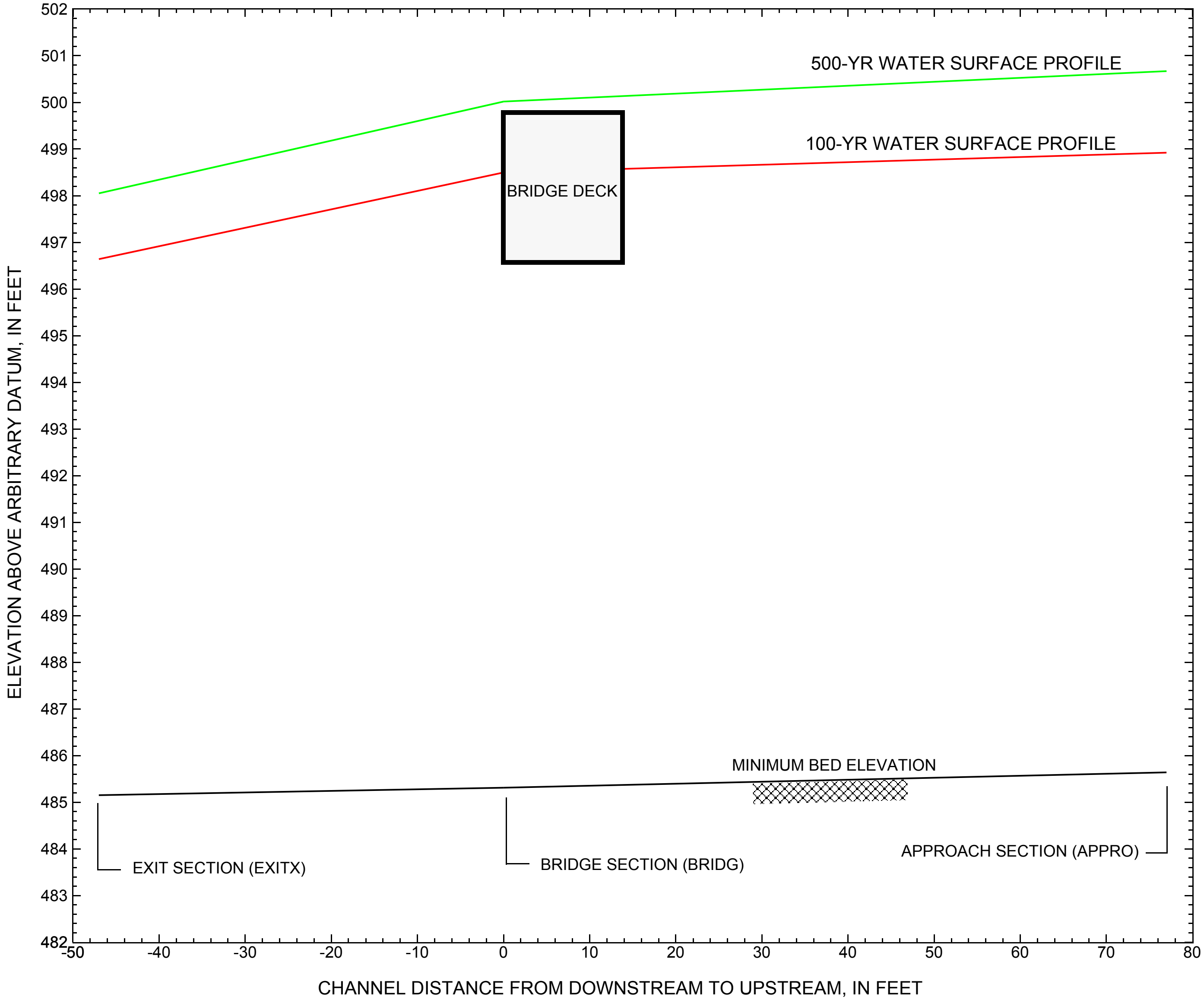

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure HARDTH00310029 on town highway 31, crossing the Lamoille River, Hardwick, Vermont.

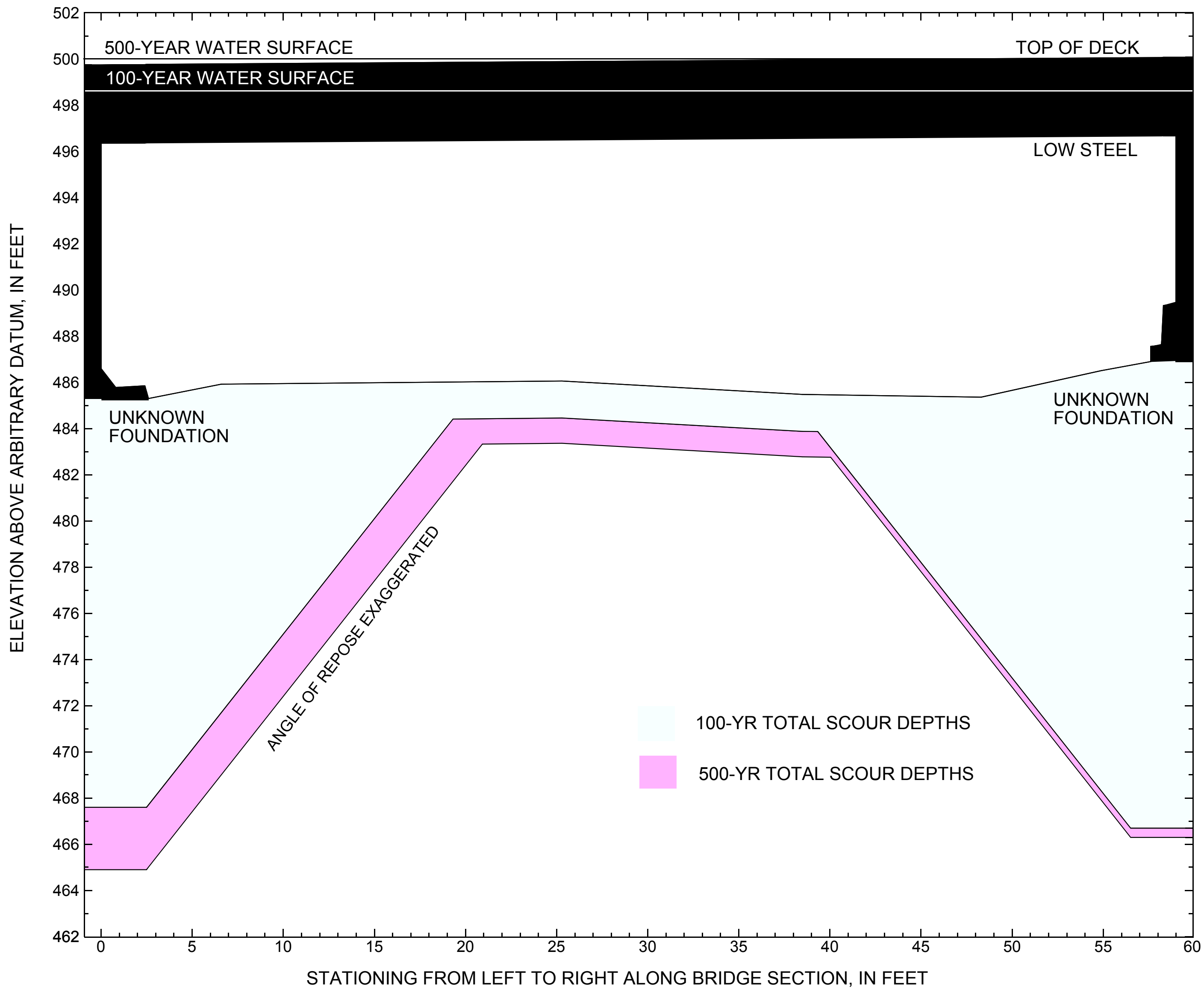

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure HARDTH00310029 on town highway 31, crossing the Lamoille River, Hardwick, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure HARDTH00310029 on Town Highway 31, crossing the Lamoille River, Hardwick, 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 8,600 cubic-feet per second											
Left abutment	0.0	--	496.2	--	485.3	1.6	16.1	--	17.7	467.6	--
Right abutment	59.0	--	496.7	--	486.9	1.6	18.6	--	20.2	466.7	--

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 HARDTH00310029 on Town Highway 31, crossing the Lamoille River, Hardwick, 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 12,200 cubic-feet per second											
Left abutment	0.0	--	496.2	--	485.3	2.7	17.7	--	20.4	464.9	--
Right abutment	59.0	--	496.7	--	486.9	2.7	17.9	--	20.6	466.3	--

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

```
T2        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00310029 USING FILE hard029.dca
T3        HYDRAULIC ANALYSIS OF HARD029     SAO
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q          8600 12200 4170
SK         0.0012 0.0012 0.0012
*
XS   EXITX    -47
GR         -239.7, 506.66   -205.0, 500.78   -178.0, 498.71   -154.6, 493.51
GR          -76.9, 492.35    -12.1, 492.15     -5.8, 489.12      0.0, 486.63
GR           10.9, 485.79     24.9, 485.24     31.6, 485.15     42.2, 485.60
GR           53.0, 486.62     58.6, 488.43     72.4, 493.20    276.0, 491.07
GR          313.8, 505.03
N           0.057        0.039        0.050
SA                 -12.1        72.4
*
XS   FULLV    0 * * * 0.005
*
BR   BRIDG    0 496.5
GR            0.0, 496.22      0.8, 486.57      0.8, 485.78      2.4, 485.85
GR            2.6, 485.31      6.6, 485.92     14.0, 485.97     19.0, 486.01
GR           25.3, 486.06     32.8, 485.74     38.5, 485.48     44.3, 485.42
GR           48.3, 485.36     54.9, 486.51     57.6, 486.89     57.6, 487.56
GR           58.2, 487.61     58.3, 489.33     59.0, 489.39     59.0, 496.73
GR            0.0, 496.22
N            0.037
CD            1 38.5 * * 50.0 17.2
*
XR   RDWAY      9       13.9   2
GR         -272.9, 503.75   -246.6, 500.70   -218.5, 500.86   -188.1, 497.87
GR         -130.3, 495.20    -84.9, 495.51    -53.5, 496.57     -3.4, 499.79
GR           -3.2, 499.73     -3.0, 500.74     -0.4, 500.77     61.0, 501.16
GR           61.2, 500.09    105.5, 500.04    169.8, 500.79    224.9, 503.42
GR          301.7, 510.97    347.9, 512.75
*
XT   APTEM     71
GR         -295.9, 504.54   -262.7, 500.98   -232.3, 501.73   -208.0, 493.66
GR         -197.6, 492.42   -132.9, 492.59    -75.9, 493.03    -27.6, 492.65
GR          -21.6, 489.94      0.0, 488.81     14.3, 487.91     21.0, 486.85
GR           35.2, 486.36     50.5, 485.91     57.2, 485.59     62.1, 485.84
GR           68.5, 486.81     73.8, 491.15     93.1, 500.47    145.7, 500.55
GR          176.6, 499.71    195.0, 499.67    229.8, 509.04
*
AS   APPRO     77
GT            0.05
N            0.055        0.037        0.050
SA                 -27.6        93.1
*
HP 1 BRIDG  496.69 1 496.69
HP 2 BRIDG  496.69 * * 6153
HP 2 RDWAY  498.50 * * 2476
HP 1 APPRO  498.92 1 498.92
HP 2 APPRO  498.92 * * 8600
*
HP 1 BRIDG  496.73 1 496.73
HP 2 BRIDG  496.73 * * 6634
HP 2 RDWAY  500.02 * * 5510
HP 1 APPRO  500.67 1 500.67
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard029.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00310029 USING FILE hard029.dca
        HYDRAULIC ANALYSIS OF HARD029     SAO
           *** RUN DATE & TIME: 09-03-96  11:39
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     619.   69483.     5.   133.                        40657.
   496.69          619.   69483.     5.   133.  1.00     0.    59.  40657.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       496.69     0.0    59.0   619.4   69483.    6153.   9.93
X STA.         0.0         5.0         8.2        11.3        14.2        17.1
  A(I)             48.3        34.0        31.5        30.5        30.1
  V(I)             6.37        9.04        9.78       10.08       10.22

X STA.        17.1        20.0        22.8        25.6        28.4        31.1
  A(I)             29.5        29.8        28.8        29.2        28.7
  V(I)            10.44       10.32       10.67       10.54       10.73

X STA.        31.1        33.8        36.3        38.9        41.4        43.9
  A(I)             28.5        28.0        28.1        28.2        27.9
  V(I)            10.79       10.99       10.93       10.91       11.01

X STA.        43.9        46.5        49.0        51.6        54.5        59.0
  A(I)             28.2        28.2        28.9        30.7        42.1
  V(I)            10.91       10.90       10.64       10.02        7.30

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       9.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.50  -194.5   -23.5   364.6   15776.    2476.   6.79
X STA.      -194.5      -163.8      -152.8      -145.0      -138.7      -133.3
  A(I)             31.0        22.0        19.2        17.4        16.4
  V(I)             3.99        5.64        6.44        7.10        7.56

X STA.      -133.3      -128.5      -123.9      -119.3      -114.6      -109.9
  A(I)             15.4        15.2        14.8        15.0        14.9
  V(I)             8.02        8.13        8.34        8.23        8.31

X STA.      -109.9      -105.1      -100.3       -95.2       -90.1       -84.8
  A(I)             15.1        15.0        15.5        15.5        15.9
  V(I)             8.17        8.26        7.97        7.98        7.78

X STA.       -84.8       -79.2       -72.5       -64.7       -54.5       -23.5
  A(I)             16.3        18.1        19.0        21.7        31.0
  V(I)             7.59        6.86        6.53        5.70        3.99

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      77.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1150.  101001.   196.   197.                        15803.
             2    1194.  220443.   117.   122.                        21598.
   498.92         2344.  321444.   313.   319.  1.37  -224.    90.  31041.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      77.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.92  -223.7    89.8  2343.6  321444.    8600.   3.67
X STA.      -223.7      -181.1      -152.9      -125.2       -95.9       -64.9
  A(I)            207.8       179.2       174.5       178.6       183.1
  V(I)             2.07        2.40        2.46        2.41        2.35

X STA.       -64.9       -35.7       -18.4        -8.5         0.3         8.5
  A(I)            176.8       124.1        92.5        86.5        85.3
  V(I)             2.43        3.46        4.65        4.97        5.04

X STA.         8.5        16.1        22.8        29.0        35.3        41.3
  A(I)             82.3        78.6        76.2        78.0        76.0
  V(I)             5.22        5.47        5.64        5.52        5.66

X STA.        41.3        47.4        53.4        59.6        66.6        89.8
  A(I)             77.7        77.3        81.6        90.3       137.2
  V(I)             5.53        5.56        5.27        4.76        3.13
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard029.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00310029 USING FILE hard029.dca
        HYDRAULIC ANALYSIS OF HARD029     SAO
           *** RUN DATE & TIME: 09-03-96  11:39
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     619.  67922.     0.   138.                            0.
   496.73          619.  67922.     0.   138.  1.00     0.    59.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      496.73     0.0    59.0   619.5   67922.    6634.  10.71
X STA.         0.0        5.0        8.1       11.1       13.9       16.8
  A(I)            48.5       32.1       30.8       29.9       29.5
  V(I)            6.84      10.32      10.76      11.10      11.25

X STA.        16.8       19.6       22.3       25.1       27.8       30.5
  A(I)            28.9       28.3       29.2       28.0       28.4
  V(I)           11.49      11.72      11.36      11.83      11.68

X STA.        30.5       33.1       35.7       38.2       40.6       43.2
  A(I)            27.7       28.1       27.8       27.3       28.2
  V(I)           11.96      11.81      11.94      12.15      11.77

X STA.        43.2       45.7       48.2       51.0       54.0       59.0
  A(I)            27.9       28.9       30.1       32.1       47.9
  V(I)           11.90      11.49      11.03      10.34       6.93

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       9.
        WSEL     LEW     REW    AREA        K        Q    VEL
      500.02  -210.0    -3.1   653.9   37567.    5510.   8.43
X STA.      -210.0     -175.0     -162.5     -152.6     -144.6     -137.6
  A(I)            55.5       38.0       35.4       31.6       30.6
  V(I)            4.96       7.24       7.78       8.72       9.00

X STA.      -137.6     -131.4     -125.6     -120.0     -114.2     -108.4
  A(I)            28.5       27.7       27.0       27.4       27.2
  V(I)            9.67       9.96      10.19      10.04      10.12

X STA.      -108.4     -102.6      -96.6      -90.6      -84.5      -77.8
  A(I)            26.9       27.5       27.2       27.9       29.3
  V(I)           10.23      10.00      10.13       9.89       9.40

X STA.       -77.8      -70.8      -62.5      -53.3      -40.5       -3.1
  A(I)            29.3       32.1       33.3       38.5       52.9
  V(I)            9.41       8.59       8.27       7.16       5.20

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      77.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1498.  154000.   201.   203.                        23180.
             2    1402.  282640.   121.   125.                        27119.
             3      40.     617.   105.   106.                          138.
   500.67         2940.  437257.   427.   433.  1.36  -229.   199.  37574.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      77.
        WSEL     LEW     REW    AREA        K        Q    VEL
      500.67  -229.0   198.5  2939.7  437257.   12200.   4.15
X STA.      -229.0     -184.6     -159.7     -134.3     -108.6      -81.7
  A(I)           258.1      202.4      204.8      204.1      208.7
  V(I)            2.36       3.01       2.98       2.99       2.92

X STA.       -81.7      -54.6      -28.6      -16.1       -6.4        2.7
  A(I)           207.1      204.3      123.3      109.2      107.1
  V(I)            2.95       2.99       4.95       5.59       5.69

X STA.         2.7       11.0       18.8       25.9       32.7       39.4
  A(I)           101.7      100.5       97.3       95.4       96.2
  V(I)            6.00       6.07       6.27       6.39       6.34

X STA.        39.4       46.0       52.9       59.8       67.4      198.5
  A(I)            95.5      100.7      103.2      110.0      210.0
  V(I)            6.39       6.06       5.91       5.55       2.90
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard029.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00310029 USING FILE hard029.dca
        HYDRAULIC ANALYSIS OF HARD029     SAO
           *** RUN DATE & TIME: 09-03-96  11:39
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     475.   66049.    59.    74.                        7655.
   494.02          475.   66049.    59.    74.  1.00     0.    59.   7655.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       494.02     0.2    59.0   474.8   66049.    4170.   8.78
X STA.         0.2         5.3         8.5        11.4        14.2        16.9
  A(I)            40.4        26.0        23.2        22.4        22.1
  V(I)            5.16        8.01        8.99        9.29        9.45

X STA.        16.9        19.6        22.3        24.9        27.6        30.2
  A(I)            21.5        21.4        21.1        21.2        20.9
  V(I)            9.68        9.75        9.90        9.82       10.00

X STA.        30.2        32.7        35.2        37.6        40.0        42.5
  A(I)            20.5        20.8        20.6        20.7        21.0
  V(I)           10.16       10.03       10.13       10.07        9.92

X STA.        42.5        44.9        47.5        50.1        53.4        59.0
  A(I)            20.8        22.1        22.6        26.3        39.1
  V(I)           10.04        9.41        9.21        7.93        5.33

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      77.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     464.   23121.   185.   186.                        4161.
             2     784.  114784.   110.   113.                       11891.
   495.32         1248.  137905.   295.   299.  1.49  -213.    82.  11914.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      77.
         WSEL     LEW     REW    AREA        K        Q    VEL
       495.32  -212.8    82.3  1248.0  137905.    4170.   3.34
X STA.      -212.8      -157.1      -107.4       -47.5       -17.8        -8.5
  A(I)           140.2       131.6       141.2        94.9        53.8
  V(I)            1.49        1.58        1.48        2.20        3.87

X STA.        -8.5        -0.2         7.3        14.0        19.7        24.8
  A(I)            51.9        49.6        47.9        44.7        42.9
  V(I)            4.02        4.21        4.35        4.66        4.86

X STA.        24.8        29.6        34.4        38.9        43.4        47.8
  A(I)            41.3        42.0        40.3        40.8        40.5
  V(I)            5.05        4.96        5.17        5.11        5.15

X STA.        47.8        52.1        56.5        61.0        66.2        82.3
  A(I)            40.9        41.3        43.4        47.5        71.1
  V(I)            5.10        5.05        4.81        4.39        2.93
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard029.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00310029 USING FILE hard029.dca
        HYDRAULIC ANALYSIS OF HARD029     SAO
           *** RUN DATE & TIME: 09-03-96  11:39

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

EXITX:XS   ******  -169.    2353.  0.33 *****  496.97  494.22   8600.  496.64
      -47. ******   291.  248147.  1.60 ***** *******    0.36    3.66

FULLV:FV      47.  -168.    2267.  0.36  0.06  497.05 *******   8600.  496.69
        0.    47.   291.  235646.  1.61  0.01    0.00    0.38    3.79
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      77.  -217.    1653.  0.61  0.12  497.29 *******   8600.  496.68
       77.    77.    85.  198358.  1.45  0.13   -0.01    0.47    5.20
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =    496.69     496.50

            <<<<<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      47.     0.     619.  1.54 *****  498.22  492.92   6153.  496.69
        0. ******    59.   69600.  1.00 ***** *******    0.54    9.94

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  496.50 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    63.  0.05  0.29  499.16    0.00   2476.  498.50

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   2476.   171.  -194.   -23.   3.3   2.1   7.8   6.8   2.8   3.1
   RT:      0.   157.    31.   189.   1.6   1.2   7.1  10.0   2.4   3.0

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

APPRO:AS      39.  -224.    2342.  0.29  0.12  499.20  494.35   8600.  498.92
       77.    50.    90.  321182.  1.37  0.00    0.00    0.28    3.67

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -47.  -169.   291.   8600.  248147.    2353.    3.66  496.64
   FULLV:FV       0.  -168.   291.   8600.  235646.    2267.    3.79  496.69
   BRIDG:BR       0.     0.    59.   6153.   69600.     619.    9.94  496.69
   RDWAY:RG       9.******* 2476.   2476.*********       0.    2.00  498.50
   APPRO:AS      77.  -224.    90.   8600.  321182.    2342.    3.67  498.92

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    494.22    0.36  485.15  506.66************  0.33  496.97  496.64
   FULLV:FV  ********    0.38  485.38  506.89  0.06  0.01  0.36  497.05  496.69
   BRIDG:BR    492.92    0.54  485.31  496.73************  1.54  498.22  496.69
   RDWAY:RG  ****************  495.20  512.75  0.05******  0.29  499.16  498.50
   APPRO:AS    494.35    0.28  485.64  509.09  0.12  0.00  0.29  499.20  498.92
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WSPRO OUTPUT FILE (continued)

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard029.wsp
        CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00310029 USING FILE hard029.dca
        HYDRAULIC ANALYSIS OF HARD029     SAO
           *** RUN DATE & TIME: 09-03-96  11:39

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

EXITX:XS   ******  -175.    3007.  0.38 *****  498.43  495.00  12200.  498.05
      -47. ******   295.  352059.  1.49 ***** *******    0.34    4.06

FULLV:FV      47.  -174.    2921.  0.41  0.06  498.50 *******  12200.  498.10
        0.    47.   294.  337517.  1.50  0.01    0.00    0.36    4.18
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      77.  -221.    2070.  0.76  0.13  498.80 *******  12200.  498.04
       77.    77.    88.  269979.  1.40  0.18   -0.01    0.48    5.89
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =    498.10     496.50

            <<<<<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      47.     0.     619.  1.78 *****  498.51  493.28   6634.  496.73
        0. ******    59.   67922.  1.00 ***** *******    0.58   10.71

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  496.50 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    63.  0.05  0.36  500.99    0.00   5510.  500.02

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   5510.   207.  -210.    -3.   4.8   3.2   9.7   8.4   4.1   3.2
   RT:      0.    54.    61.   115.   0.1   0.1   4.4  37.5   1.1   2.8

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

APPRO:AS      39.  -229.    2941.  0.36  0.16  501.04  495.42  12200.  500.67
       77.    52.   199.  437552.  1.36  0.00    0.00    0.32    4.15

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -47.  -175.   295.  12200.  352059.    3007.    4.06  498.05
   FULLV:FV       0.  -174.   294.  12200.  337517.    2921.    4.18  498.10
   BRIDG:BR       0.     0.    59.   6634.   67922.     619.   10.71  496.73
   RDWAY:RG       9.******* 5510.   5510.*********       0.    2.00  500.02
   APPRO:AS      77.  -229.   199.  12200.  437552.    2941.    4.15  500.67

  SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    495.00    0.34  485.15  506.66************  0.38  498.43  498.05
   FULLV:FV  ********    0.36  485.38  506.89  0.06  0.01  0.41  498.50  498.10
   BRIDG:BR    493.28    0.58  485.31  496.73************  1.78  498.51  496.73
   RDWAY:RG  ****************  495.20  512.75  0.05******  0.36  500.99  500.02
   APPRO:AS    495.42    0.32  485.64  509.09  0.16  0.00  0.36  501.04  500.67
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       U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard029.wsp
       CREATED ON 11-AUG-95 FOR BRIDGE HARDTH00310029 USING FILE hard029.dca
       HYDRAULIC ANALYSIS OF HARD029     SAO
          *** RUN DATE & TIME: 09-03-96  11:39

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

EXITX:XS   ******  -159.    1351.  0.27 *****  494.70  491.23   4170.  494.42
      -47. ******   285.  120352.  1.85 ***** *******    0.42    3.09

FULLV:FV      47.  -158.    1265.  0.32  0.06  494.78 *******   4170.  494.46
        0.    47.   285.  111423.  1.87  0.02    0.00    0.47    3.30
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      77.  -210.    1017.  0.39  0.11  494.92 *******   4170.  494.53
       77.    77.    81.  108080.  1.48  0.04    0.00    0.47    4.10
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   495.32       0.00     494.02     495.20

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

BRIDG:BR      47.     0.     475.  1.32  0.10  495.34  491.33   4170.  494.02
        0.    47.    59.   66013.  1.10  0.54    0.00    0.57    8.79

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  0.953 ******  496.50 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.        <<<<<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      39.  -213.    1248.  0.26  0.09  495.58  491.47   4170.  495.32
       77.    46.    82.  137964.  1.49  0.15    0.00    0.35    3.34

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.798  0.412   81015.    -1.    58. ********

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -47.  -159.   285.   4170.  120352.    1351.    3.09  494.42
   FULLV:FV       0.  -158.   285.   4170.  111423.    1265.    3.30  494.46
   BRIDG:BR       0.     0.    59.   4170.   66013.     475.    8.79  494.02
   RDWAY:RG       9.**************      0.       0.       0.    2.00********
   APPRO:AS      77.  -213.    82.   4170.  137964.    1248.    3.34  495.32

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -1.    58.   81015.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    491.23    0.42  485.15  506.66************  0.27  494.70  494.42
   FULLV:FV  ********    0.47  485.38  506.89  0.06  0.02  0.32  494.78  494.46
   BRIDG:BR    491.33    0.57  485.31  496.73  0.10  0.54  1.32  495.34  494.02
   RDWAY:RG  ****************  495.20  512.75  0.06******  0.26  495.51********
   APPRO:AS    491.47    0.35  485.64  509.09  0.09  0.15  0.26  495.58  495.32
```
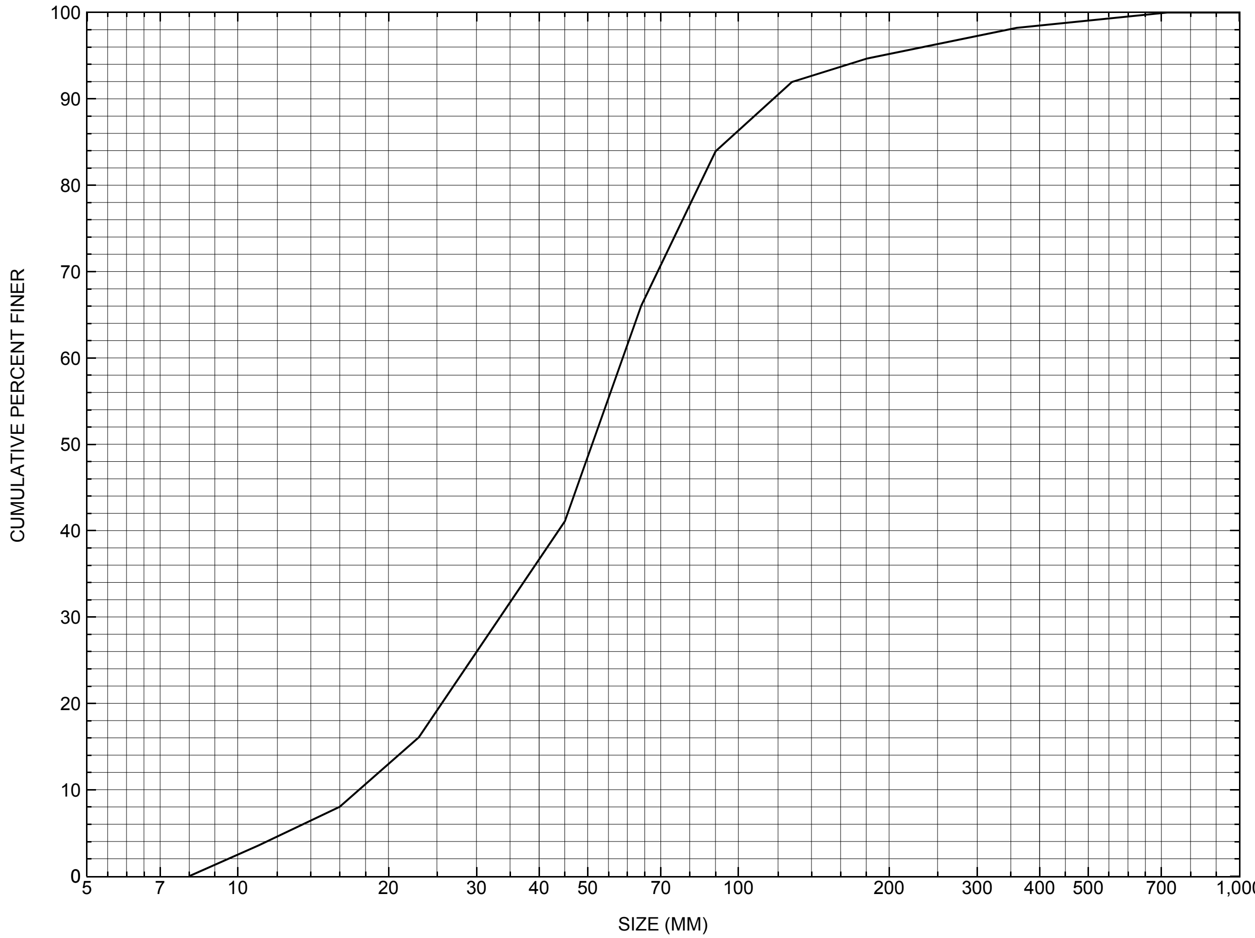

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count transect at the approach cross-section of structure HARDTH00310029, in Hardwick, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number HARDTH00310029

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 27 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 31825

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

Waterway *(I - 6)* LAMOILLE RIVER

Road Name *(I - 7):* -

Route Number TH031

Vicinity *(I - 9)* 0.05 MI JCT TH 31 + VT16

Topographic Map Caspian.Lake

Hydrologic Unit Code: 02010005

Latitude *(I - 16; nnnn.n)* 44303

Longitude *(i - 17; nnnnn.n)* 72191

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10030500290305

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

Maximum span length *(I - 48; nnnn)* 0061

Year built *(I - 27; YYYY)* 1932

Structure length *(I - 49; nnnnnn)* 000065

Average daily traffic, ADT *(I - 29; nnnnnn)* 000070

Deck Width *(I - 52; nn.n)* 139

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

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

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) ______

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

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

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

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

Comments:

The structural inspection report of 6/6/93 indicates the structure is a steel stringer type bridge with a timber deck. The abutments and wingwalls are constructed of "laid-up" stone blocks. The right abutment has a concrete facing and a concrete subfooter, while the left does not. The concrete has cracks and leaks, and surface spalls reported overall. Deep spalling on the right abutment wall has created several small holes that penetrate completely through the concrete facing. The right downstream wingwall has a vertical crack, which bisects the wall. There is displacement along the crack as one half of the wingwall is leaning about 5 inches further toward the stream. A similar crack in the right upstream **(Continued, page 33)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} - Q_{25} - Q_{50} - Q_{100} - Q_{500} -

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

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

Ice conditions *(Heavy, Moderate, Light)* : - Debris *(Heavy, Moderate, Light)*: -

The stage increases to maximum highwater elevation (*Rapidly, Not rapidly*): -

The stream response is (*Flashy, Not flashy*): -

Describe any significant site conditions upstream or downstream that may influence the stream's stage: -

Watershed storage area (*in percent*): - %

The watershed storage area is: - (*1-mainly at the headwaters; 2- uniformly distributed; 3-immediatly upstream oi the site*)

Water Surface Elevation Estimates for Existing Structure:

Peak discharge frequency	$Q_{2.33}$	Q_{10}	Q_{25}	Q_{50}	Q_{100}
Water surface elevation (*ft*)	-	-	-	-	-
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

wingwall has developed but without the displacement. Small voids are reported in the stonework of the left abutment. Three of the stone blocks at the bottom of this abutment are broken in two. Several stone blocks have slid out or displaced at the ends of the wingwalls. The stream banks are noted as having areas of erosion from recent flooding.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **64.44** mi^2 Lake and pond area **2.175** mi^2

Watershed storage *(ST)* **3.38** %

Bridge site elevation **965** ft Headwater elevation **1798** ft

Main channel length **13.99** mi

10% channel length elevation **1027** ft 85% channel length elevation **1355** ft

Main channel slope *(S)* **31.27** 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? N *If no, type ctrl-n xs*

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 04/12/96
Computerized by: EW Date: 4/15/96
Reviewd by: SAO Date: 8/6/96

Structure Number HARDTH00310029

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. IVANOFF Date *(MM/DD/YY)* 07 / 26 / 1995
2. Highway District Number 07 Mile marker 000000
County CALENDONIA 005 Town HARDWICK 31825
Waterway *(I - 6)* LAMOILLE RIVER Road Name -
Route Number TH31 Hydrologic Unit Code: 02010005
3. Descriptive comments:
LOCATED 0.05 MILE FROM THE JUNCTION OF TOWN HIGHWAY 31 AND VT 16.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 4 LBDS 5 RBDS 4 Overall 4
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 2 UB 2 DS 2 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 65 *(feet)* Span length 61 *(feet)* Bridge width 13.9 *(feet)*

Road approach to bridge:

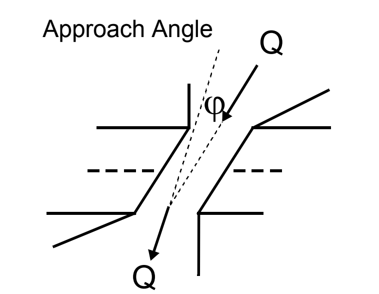
8. LB 1 RB 0 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left 0.0:1 US right 0.0:1

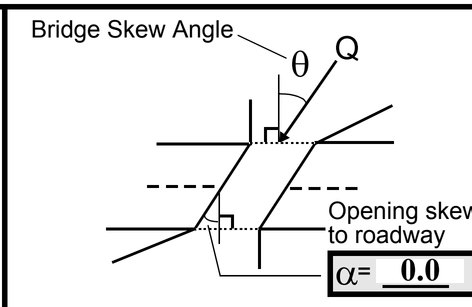
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

*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: 5 16. Bridge skew: 5





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 10 feet US *(US, UB, DS)* to 70 feet US
Channel impact zone 2: Exist? N *(Y or N)*
Where? _____ *(LB, RB)* Severity _____
Range? _____ feet _____ *(US, UB, DS)* to _____ feet _____

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

18. Level II Bridge Type: **1a**

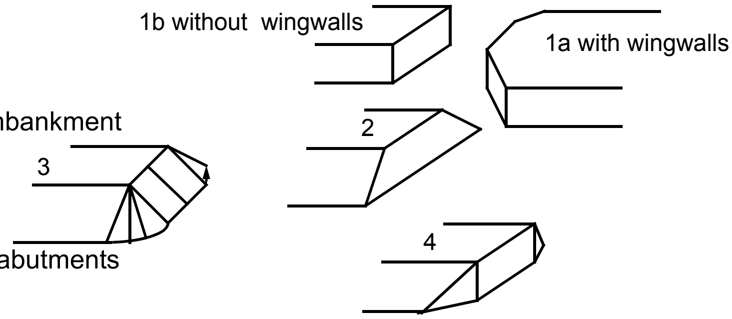
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face

3- Spill through abutments

4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

#7: values from VTAOT; measured values: bridge length = 64 feet; bridge span = 59 feet; bridge width = 13.9 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
57.0	6.0			4.5	1	1	452	452	0	1

23. Bank width **5.0** 24. Channel width **40.0** 25. Thalweg depth **102.5** 29. Bed Material **435**

30 .Bank protection type: LB **0** RB **2** 31. Bank protection condition: LB **-** RB **3**

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.):

#31: RB protection extends from 120 to 260 feet US of bridge.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 80 35. Mid-bar width: 50

36. Point bar extent: 0 feet US (US, UB) to 400 feet US (US, UB, DS) positioned 0 %LB to 20 %RB

37. Material: 432

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? RB (LB or RB)

41. Mid-bank distance: 80 42. Cut bank extent: 6 feet US (US, UB) to 120 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.):

Beyond the cut-bank there is stone fill protection extending to 260 feet US.

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
49.0		1.0		2	7	7	-

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

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

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

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

435

Bed material is comprised of cobble, gravel and some boulders.

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

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

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

70. Debris and Ice Comments:

2

#65: There is no debris accumulation or trees along channel banks. The bridge opening is greater than 80% of bank full width.

#69: Ice blockage was reported by US resident, who has indicated ice builds-up each year which results in the flooding of the fields by the river.

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		5	90	2	2	0.5	2.5	90.0
RABUT	2	0	90			2	2	58.0

Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: *1-* Concrete; *2-* Stone masonry or drywall; *3-* steel or metal; *4-* wood

79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0

2.8

2

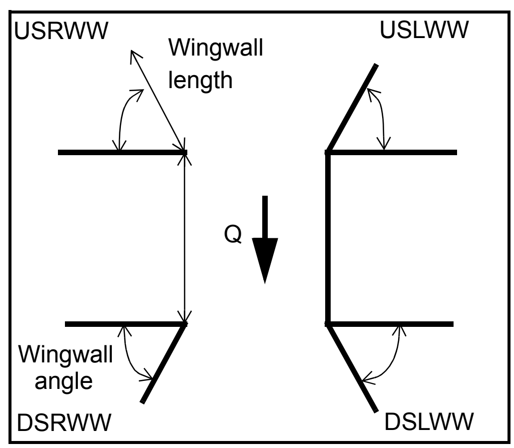
#76: LABUT maximum depth extends from the middle of abutment to downstream end of abutment. This depth is a result of additional stone blocks which raises the footing height.

RABUT maximum depth exists at the upstream end of abutment where stone masonry and overlying concrete footing are exposed.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						58.0	
USRWW:	Y		2		2	1.0	
DSLWW:	0		0.3		Y	18.5	
DSRWW:	1		2		0	17.5	

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	0	2	Y	0	-	-	-	-
Condition	Y	0	1	0.5	-	-	-	-
Extent	2	0.3	2	0	0	0	0	-

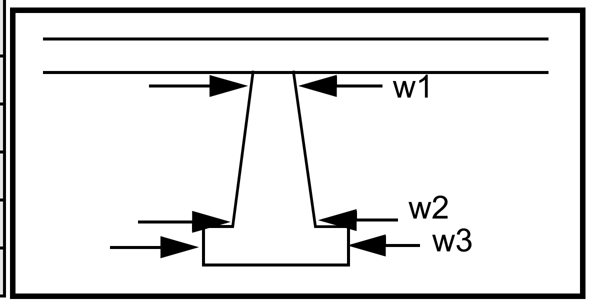
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? So (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				50.0	36.0	50.0
Pier 2				17.5	80.0	10.5
Pier 3			-	45.0	11.5	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	-	-	-	-	-

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

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

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

Comments (eg. bank material variation, minor inflows, protection extent, etc.):
-
-
-
-
-
-
-
-
-
NO PIERS

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):

2
2
342
324

106. <u>Point/Side bar present</u>? **1** (*Y or N. if N type ctrl-n pb*) Mid-bar distance: **0** Mid-bar width: **4325**

Point bar extent: **0** feet **0** (*US, UB, DS*) to **-** feet **-** (*US, UB, DS*) positioned **Be** %LB to **d** %RB

Material: **ma**

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

terial is comprised of cobbles, gravel, sand, and boulders.

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

Cut bank extent: _____ feet ____ (*US, UB, DS*) to _____ feet ____ (*US, UB, DS*)

Bank damage: _____ (***1***- *eroded and/or creep;* ***2***- *slip failure;* ***3***- *block failure*)

Cut bank comments (eg. additional cut banks, protection condition, etc.):

N

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

Scour dimensions: Length **DRO** Width **P** Depth: **STR** Positioned **UC** %LB to **TU** %RB

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

RE

<u>Are there major confluences?</u> _____ (*Y or if N type ctrl-n mc*) How many? _____

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

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

Confluence comments (eg. confluence name):

-

-

F. Geomorphic Channel Assessment

107. <u>Stage of reach evolution</u> -

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)*:

-

NO POINT BARS

Y

LB

60

55

DS

70

DS

1

109. G. Plan View Sketch

- Sli

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: HARDTH00310029 Town: Hardwick
Road Number: TH31 County: Caledonia
Stream: Lamoille River

Initials SAO Date: 6/13/96 Checked: EMB

Analysis of contraction scour, live-bed or clear water?

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1995, p. 28, eq. 16)
Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	8600	12200	4170
Main Channel Area, ft2	1194	1402	784
Left overbank area, ft2	1150	1498	464
Right overbank area, ft2	0	40	0
Top width main channel, ft	117	121	110
Top width L overbank, ft	196	201	185
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.167	0.167	0.167
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	10.2	11.6	7.1
y1, average depth, LOB, ft	5.9	7.5	2.5
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	321444	437257	137905
Conveyance, main channel	220443	282640	114784
Conveyance, LOB	101001	154000	23121
Conveyance, ROB	0	617	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	5897.8	7886.0	3470.9
Ql, discharge, LOB, cfs	2702.2	4296.8	699.1
Qr, discharge, ROB, cfs	0.0	17.2	0.0
Vm, mean velocity MC, ft/s	4.9	5.6	4.4
Vl, mean velocity, LOB, ft/s	2.3	2.9	1.5
Vr, mean velocity, ROB, ft/s	ERR	0.4	ERR
Vc-m, crit. velocity, MC, ft/s	9.1	9.3	8.6
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?			
Main Channel	0	0	0
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

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	6153	6634	4170
Main channel area (DS), ft2	619	619	475

Main channel width (normal), ft	59.0	59	58.9
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	59.0	59.0	58.9
D90, ft	0.3853	0.3853	0.3853
D95, ft	0.6337	0.6337	0.6337
Dc, critical grain size, ft	0.2957	0.3437	0.2530
Pc, Decimal percent coarser than Dc	0.160	0.126	0.242
Depth to armoring, ft	4.66	7.15	2.38

Clear Water Contraction Scour in MAIN CHANNEL

y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)   Converted to English Units
ys=y2-y_bridge
(Richardson and others, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	8600	12200	4170
(Q) discharge thru bridge, cfs	6153	6634	4170
Main channel conveyance	69483	67922	66049
Total conveyance	69483	67922	66049
Q2, bridge MC discharge,cfs	6153	6634	4170
Main channel area, ft2	619	619	475
Main channel width (normal), ft	59.0	59.0	58.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	59	59	58.9
y_bridge (avg. depth at br.), ft	10.49	10.49	8.06
Dm, median (1.25*D50), ft	0.20875	0.20875	0.20875
y2, depth in contraction,ft	10.40	11.09	7.46
ys, scour depth (y2-ybridge), ft	-0.09	0.60	-0.60

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation   Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	8600	12200	4170
Q, thru bridge MC, cfs	6153	6634	4170
Vc, critical velocity, ft/s	9.09	9.29	8.56
Va, velocity MC approach, ft/s	4.94	5.62	4.43
Main channel width (normal), ft	59.0	59.0	58.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	59.0	59.0	58.9
qbr, unit discharge, ft2/s	104.3	112.4	70.8
Area of full opening, ft2	619.0	619.0	475.0
Hb, depth of full opening, ft	10.49	10.49	8.06
Fr, Froude number, bridge MC	0.54	0.58	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	N/A	N/A	N/A
**Hb, depth at downstream face, ft	N/A	N/A	N/A
**Fr, Froude number at DS face	ERR	ERR	ERR
**Cf, for downstream face (<=1.0)	N/A	N/A	N/A

Elevation of Low Steel, ft	496.5	496.5	0
Elevation of Bed, ft	486.01	486.01	-8.06
Elevation of Approach, ft	498.92	500.67	0
Friction loss, approach, ft	0.12	0.16	0
Elevation of WS immediately US, ft	498.80	500.51	0.00
ya, depth immediately US, ft	12.79	14.50	8.06
Mean elevation of deck, ft	500.95	500.95	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.95	0.92	1.00
**Cc, for downstream face (<=1.0)	ERR	ERR	ERR
Ys, scour w/Chang equation, ft	1.57	2.70	N/A
Ys, scour w/Umbrell equation, ft	-0.73	1.32	N/A

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	8600	12200	4170	8600	12200	4170
a', abut.length blocking flow, ft	223.7	229	213	30.8	139.5	23.3
Ae, area of blocked flow ft2	1036	1143	616.3	235.4	332	137.9
Qe, discharge blocked abut.,cfs	--	--	1262	901.6	1291	509.7
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.75	3.29	2.05	3.83	3.89	3.70
ya, depth of f/p flow, ft	4.63	4.99	2.89	7.64	2.38	5.92
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.194	0.207	0.212	0.244	0.444	0.268
ys, scour depth, ft	21.43	23.41	16.18	18.60	17.93	14.81

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

a'(abut length blocked, ft)	223.7	229	213	30.8	139.5	23.3
y1 (depth f/p flow, ft)	4.63	4.99	2.89	7.64	2.38	5.92
a'/y1	48.30	45.88	73.62	4.03	58.62	3.94
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.19	0.21	0.21	0.24	0.44	0.27
Ys w/ corr. factor K1/0.55:						
vertical	19.60	21.59	12.62	ERR	13.24	ERR
vertical w/ ww's	16.08	17.70	10.34	ERR	10.86	ERR
spill-through	10.78	11.87	6.94	ERR	7.28	ERR

Abutment riprap Sizing

Isbash Relationship

D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)

(Richardson and others, 1995, p112, eq. 81,82)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.54	0.58	0.57	0.54	0.58	0.57
y, depth of flow in bridge, ft	10.49	10.49	8.06	10.49	10.49	8.06
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	1.89	2.18	1.62	1.89	2.18	1.62
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	1.65	1.90	1.41	1.65	1.90	1.41
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR