LEVEL II SCOUR ANALYSIS FOR BRIDGE 31 (HARDTH00050031) on TOWN HIGHWAY 5, crossing the LAMOILLE RIVER, HARDWICK, VERMONT

U.S. Geological Survey
Open-File Report 96-644

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

1996

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

U.S. GEOLOGICAL SURVEY
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CONTENTS

FIGURES

TABLES

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 31 (HARDTH00050031) ON TOWN HIGHWAY 5, 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 HARDTH00050031 on Town Highway 5 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 in north-central Vermont. The 32.1-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture.

In the study area, the Lamoille River has a sinuous channel with a slope of approximately 0.005 ft/ft, an average channel top width of 53 ft and an average channel depth of 3 ft. The predominant channel bed materials are cobble and gravel with a median grain size (D_{50}) of 61.4 mm (0.201 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 5 crossing of the Lamoille River is a 43-ft-long, two-lane bridge consisting of one 39-foot concrete T-beam type span (Vermont Agency of Transportation, written communication, April 3, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is 25 degrees.

During the Level I assessment, a scour hole 1.5 ft deeper than the mean thalweg depth was observed along the left half of the channel through the bridge opening. Some undermining of the left abutment was present along this scour hole. 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 0.8 to 4.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour at the left abutment ranged from 5.0 to 7.4 ft with the worst-case occurring at the incipient overtopping discharge. Abutment scour at the right abutment ranged from 11.6 to 17.3 ft with the worst-case occurring at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and 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 HARDTH00050031 ***Stream*** Lamoille River

County Caledonia ***Road*** TH5 ***District*** 7

Description of Bridge

Bridge length 43 ***ft*** ***Bridge width*** 24.0 ***ft*** ***Max span length*** 39 ***ft***

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

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

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

Description of stone fill None

Abutments and wingwalls are concrete. The footing of both abutments are exposed. The left abutment is experiencing some undermining.

Y

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

There are mild channel bends through the reach.

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

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

Potential for debris Moderate. There is some debris embedded in the soft sediments under the bridge.

Describe any features near or at the bridge that may affect flow (include observation date) July 26, 1995. The confluence of Stannard Brook is 90 feet downstream of the bridge.

Description of the Geomorphic Setting

General topography The channel is located within a 1000 foot-wide, flat to slightly irregular valley with moderately steep valley walls on both sides.

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 53 ***ft*** ***Average depth*** 3 ***ft***

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

Sinuous but stable with alluvial channel boundaries and flood plains.

7/26/95

Vegetative co

DS left: Pasture

DS right: Pasture

US left: Pasture

US right: Pasture

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

There is minor amount of debris imbedded into the soft sediments under the bridge. July 26, 1995.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 32.1 ***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***: --

Is there a USGS gage on the stream of interest? Yes

USGS gage description Lamoille at Johnson, Vermont

USGS gage number 04292000

Gage drainage area 310 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 5,690 ***ft³/s*** ***Q500*** 8,090 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(32.1/46.0)exp 0.67] with a site having flood frequency estimates in the Flood Insurance Study for the Town of Hardwick (Federal Emergency Management Agency, 1987). The site in the Flood Insurance Study was the Lamoille River upstream of Greensboro Brook.

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 streamward end of the downstream right wingwall (elev. 497.96 ft, arbitrary survey datum). RM2 is a chiseled X on top of the streamward end of the downstream left wingwall (elev. 497.97 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-34	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	13	1	Road Grade section
APPRO	61	2	Modelled Approach section (Templated from APTEM)
APTEM	75	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.045. The overbank "n" value was 0.040.

Although the Lamoille River's confluence with Stannard Brook is only 90 feet downstream, normal depth at the exit section (EXITX) was assumed as the starting water surface. Normal depth at the exit was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.00453 ft/ft which was taken from the 100-year flood profile of the Lamoille River downstream of this 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 (0.0029 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 498.1 *ft*
Average low steel elevation 494.6 *ft*

100-year discharge 5,690 *ft^3/s*
Water-surface elevation in bridge opening 494.8 *ft*
Road overtopping? Y *Discharge over road* 2,580 *ft^3/s*
Area of flow in bridge opening 251 *ft^2*
Average velocity in bridge opening 12.3 *ft/s*
Maximum WSPRO tube velocity at bridge 13.9 *ft/s*

Water-surface elevation at Approach section with bridge 499.9
Water-surface elevation at Approach section without bridge 496.6
Amount of backwater caused by bridge 3.3 *ft*

500-year discharge 8,090 *ft^3/s*
Water-surface elevation in bridge opening 494.8 *ft*
Road overtopping? Y *Discharge over road* 5,050 */s*
Area of flow in bridge opening 251 *ft^2*
Average velocity in bridge opening 12.2 *ft/s*
Maximum WSPRO tube velocity at bridge 13.8 */s*

Water-surface elevation at Approach section with bridge 500.8
Water-surface elevation at Approach section without bridge 497.5
Amount of backwater caused by bridge 3.3

Incipient overtopping discharge 2,400 *ft^3/s*
Water-surface elevation in bridge opening 494.8 *ft*
Area of flow in bridge opening 251 *ft^2*
Average velocity in bridge opening 9.5 *ft/s*
Maximum WSPRO tube velocity at bridge 10.8 *ft/s*

Water-surface elevation at Approach section with bridge 497.3
Water-surface elevation at Approach section without bridge 494.5
Amount of backwater caused by bridge 2.8 *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 was computed by use of the Chang pressure-flow scour equation (Richardson and others, 1995, p. 145-146). For each of the modelled discharges, there was orifice flow at the bridge. 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). The results of Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) were also computed and can be found in appendix F.

Abutment scour was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29). Variables for the HIRE 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	3.6	4.1	0.8
Depth to armoring	28.6	24.9	3.0
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	6.1	5.0	7.4
Right abutment	15.4	17.3	11.6
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	2.9	2.9	1.9
Right abutment	2.9	2.9	1.9
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

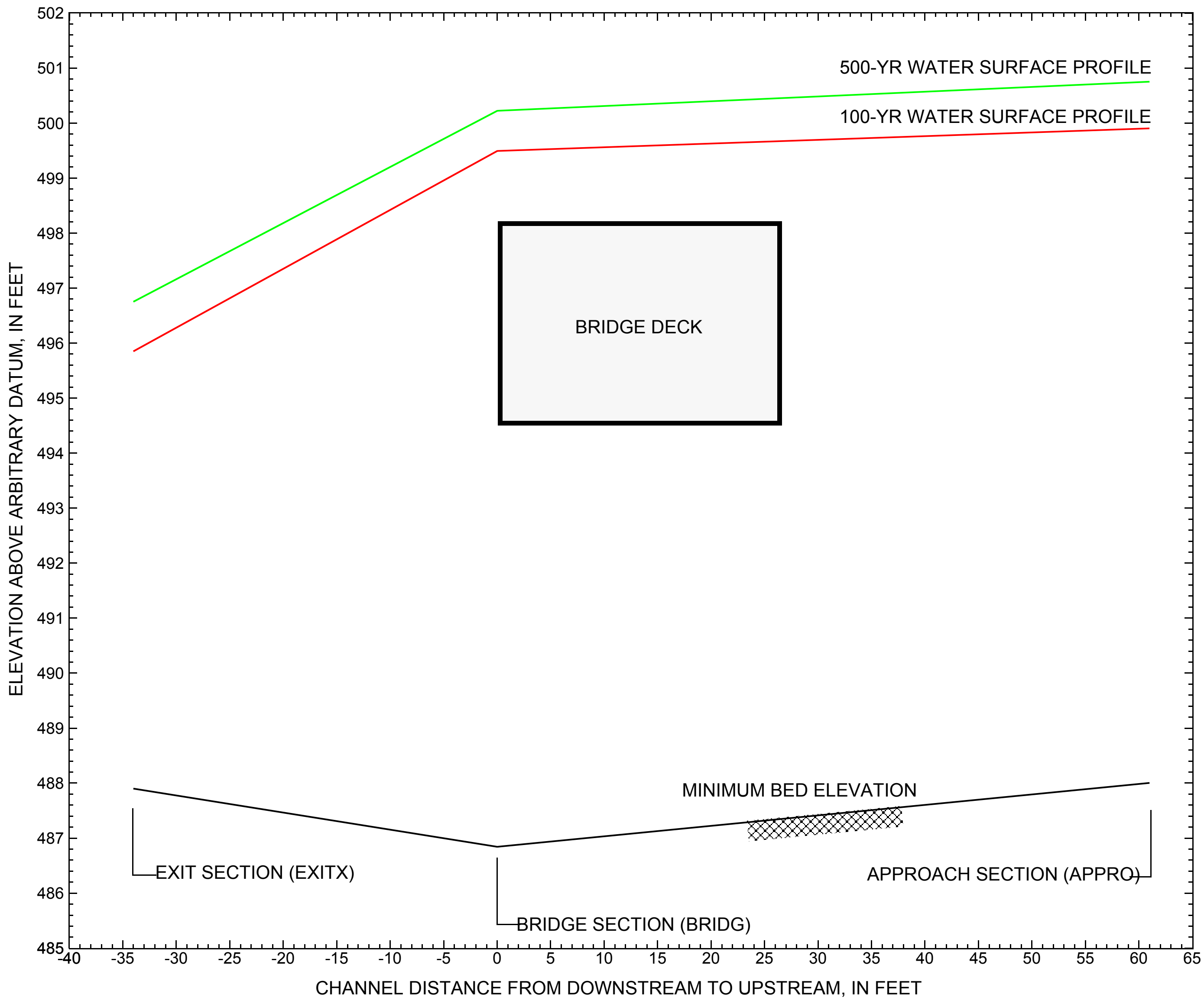

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure HARDTH00050031 on Town Highway 5, crossing the Lamoille River, Hardwick, Vermont.

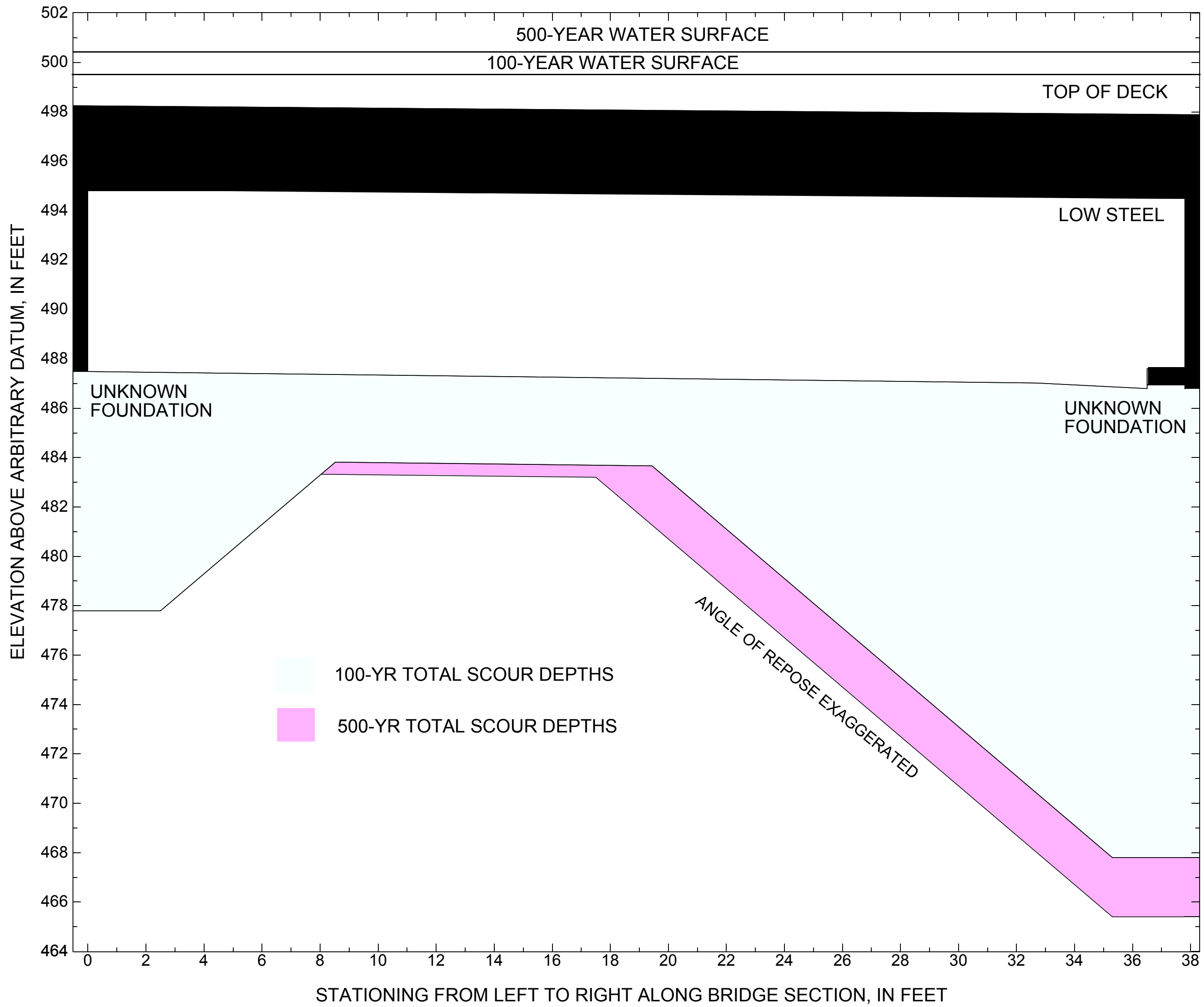

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure HARDTH00050031 on Town Highway 5, crossing the Lamoille River, Hardwick, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure HARDTH00050031 on Town Highway 5, 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 5,690 cubic-feet per second											
Left abutment	0.0	--	494.83	--	487.5	3.6	6.1	--	9.7	477.8	--
Right abutment	37.8	--	494.47	--	486.8	3.6	15.4	--	19.0	467.8	--

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 HARDTH00050031 on Town Highway 5, 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 8,090 cubic-feet per second											
Left abutment	0.0	--	494.83	--	487.5	4.1	5.0	--	9.1	478.4	--
Right abutment	37.8	--	494.47	--	486.8	4.1	17.3	--	21.4	465.4	--

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

SELECTED REFERENCES

Arcement, G.J., Jr., and Schneider, V.R., 1989, Guide for selecting Manning's roughness coefficients for natural channels and flood plains: U.S. Geological Survey Water-Supply Paper 2339, 38 p.

Barnes, H.H., Jr., 1967, Roughness characteristics of natural channels: U.S. Geological Survey Water-Supply Paper 1849, 213 p.

Benson, M. A., 1962, Factors Influencing the Occurrence of Floods in a Humid Region of Diverse Terrain: U.S. Geological Survey Water-Supply Paper 1580-B, 64 p.

Brown, S.A. and Clyde, E.S., 1989, Design of riprap revetment: Federal Highway Administration Hydraulic Engineering Circular No. 11, Publication FHWA-IP-89-016, 156 p.

Federal Highway Administration, 1983, Runoff estimates for small watersheds and development of sound design: Federal Highway Administration Report FHWA-RD-77-158

Federal Emergency Management Agency, 1987, Flood Insurance Study, Town of Hardwick, Caledonia County, Vermont: Washington, D.C., January 16, 1987.

Froehlich, D.C., 1989, Local scour at bridge abutments *in* Ports, M.A., ed., Hydraulic Engineering--Proceedings of the 1989 National Conference on Hydraulic Engineering: New York, American Society of Civil Engineers, p. 13-18.

Hayes, D.C.,1993, Site selection and collection of bridge-scour data in Delaware, Maryland, and Virginia: U.S. Geological Survey Water-Resources Investigation Report 93-4017, 23 p.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: U.S. Geological Survey, Bulletin 17B of the Hydrology Subcommittee, 190 p.

Johnson, C.G. and Tasker, G.D.,1974, Progress report on flood magnitude and frequency of Vermont streams: U.S. Geological Survey Open-File Report 74-130, 37 p.

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Chang, F., 1995, Stream Stability at Highway Structures: Federal Highway Administration Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 144 p.

Laursen, E.M., 1960, Scour at bridge crossings: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 86, no. HY2, p. 39-53.

Potter, W. D., 1957a, Peak rates of runoff in the Adirondack, White Mountains, and Maine woods area, Bureau of Public Roads

Potter, W. D., 1957b, Peak rates of runoff in the New England Hill and Lowland area, Bureau of Public Roads

Richardson, E.V. and Davis, S.R., 1995, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 p.

Richardson, E.V., Simons, D.B., and Julien, P.Y., 1990, Highways in the river environment: Federal Highway Administration Publication FHWA-HI-90-016.

Ritter, D.F., 1984, Process Geomorphology: W.C. Brown Co., Debuque, Iowa, 603 p.

Shearman, J.O., 1990, User's manual for WSPRO--a computer model for water surface profile computations: Federal Highway Administration Publication FHWA-IP-89-027, 187 p.

Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model; research report: Federal Highway Administration Publication FHWA-RD-86-108, 112 p.

Talbot, A.N., 1887, The determination of water-way for bridges and culverts.

U.S. Department of Transportation, 1993, Stream stability and scour at highway bridges, Participant Workbook: Federal Highway Administration Publication FHWA HI-91-011.

U.S. Geological Survey, 1986, Caspian Lake, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard031.wsp
T2        CREATED ON 14-AUG-95 FOR BRIDGE HARDTH00050031 USING FILE hard031.dca
T3        HYDRAULIC ANALYSIS OF HARD031    SAO
*
J1         * * 0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q          5690 8090 2400
SK         0.00453 0.00453 0.00453
*
XS   EXIT1    -34
GR         -497.3, 507.07   -423.7, 505.20   -365.7, 501.90   -315.4, 499.51
GR         -254.7, 497.37   -114.7, 495.31     -2.9, 491.73      0.0, 489.78
GR           23.4, 487.90     28.5, 488.48     35.8, 488.35     46.6, 488.81
GR           47.2, 489.81     50.9, 491.80     86.5, 491.85    509.0, 506.43
N            0.040   0.045    0.040
SA               -2.9     50.9
*
XS   FULLV      0
*
BR   BRIDG   0 494.6 25
GR            0.0, 494.83      0.0, 487.49     13.2, 487.38     32.7, 487.02
GR           36.5, 486.84     36.5, 487.63     37.2, 487.63     37.8, 494.47
GR            0.0, 494.83
N            0.040
CD           4 26.5 2.2 498.1 57.5
*
XR   RDWAY   13 24.0 1
GR         -644.5, 512.29   -365.3, 503.65   -179.0, 500.00   -115.5, 499.45
GR           -5.8, 498.10     -5.3, 502.22     36.7, 502.20     37.0, 498.04
GR           41.3, 498.31    169.1, 497.27    299.0, 499.16    408.7, 504.01
GR          470.7, 504.96    512.6, 506.86    526.1, 507.39    541.3, 506.93
GR          611.3, 512.56    638.4, 512.94
*
XT   APTEM     75
GR         -443.0, 508.94   -432.5, 506.95   -388.6, 505.25   -325.6, 500.36
GR         -293.0, 501.92   -220.4, 500.18   -135.7, 499.05    -96.7, 499.36
GR          -62.8, 494.96    -29.2, 493.96      0.0, 493.52      5.3, 489.58
GR           14.2, 488.37     23.6, 488.04     32.2, 488.36     39.6, 489.73
GR           51.8, 491.80     97.8, 492.98    155.5, 494.45    306.2, 491.88
GR          346.7, 493.41    356.6, 496.81    470.7, 498.15    502.3, 505.17
GR          517.7, 501.93    536.0, 507.82
*
AS   APPRO     61
GT            -0.04
N             0.040    0.045    0.040
SA                 0.0      51.8
*
HP 1 BRIDG    494.83 1 494.83
HP 2 BRIDG    494.83 * * 3085
HP 2 RDWAY    499.49 * * 2582
HP 1 APPRO    499.90 1 499.90
HP 2 APPRO    499.90 * * 5690
*
HP 1 BRIDG    494.83 1 494.83
HP 2 BRIDG    494.83 * * 3060
HP 2 RDWAY    500.22 * * 5047
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard031.wsp
        CREATED ON 14-AUG-95 FOR BRIDGE HARDTH00050031 USING FILE hard031.dca
        HYDRAULIC ANALYSIS OF HARD031    SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     251.  19553.     0.    83.                            0.
   494.83          251.  19553.     0.    83.  1.00     0.    38.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       494.83     0.0    37.8   251.0   19553.    3085.  12.29
X STA.         0.0         3.0         5.0         6.9         8.6        10.4
  A(I)            20.1        13.2        12.3        11.9        11.7
  V(I)            7.66       11.69       12.58       12.99       13.17

X STA.        10.4        12.1        13.8        15.5        17.2        18.9
  A(I)            11.5        11.2        11.3        11.2        11.3
  V(I)           13.46       13.73       13.60       13.73       13.71

X STA.        18.9        20.6        22.2        23.9        25.6        27.3
  A(I)            11.1        11.1        11.3        11.2        11.5
  V(I)           13.87       13.84       13.66       13.73       13.44

X STA.        27.3        29.0        30.7        32.5        34.5        37.8
  A(I)            11.4        11.9        12.3        13.3        20.1
  V(I)           13.50       12.98       12.55       11.61        7.66

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.
         WSEL     LEW     REW    AREA        K        Q    VEL
       499.49  -120.1   306.5   468.5   20722.    2582.   5.51
X STA.      -120.1       -34.5        -9.9        54.8        71.6        86.1
  A(I)            43.7        29.3        28.1        22.8        21.7
  V(I)            2.96        4.41        4.59        5.67        5.96

X STA.        86.1        98.9       110.3       121.2       131.3       140.7
  A(I)            20.4        19.4        19.5        18.7        18.4
  V(I)            6.33        6.67        6.63        6.89        7.03

X STA.       140.7       149.8       158.4       166.7       175.4       184.7
  A(I)            18.5        18.0        18.1        19.0        19.1
  V(I)            6.98        7.17        7.14        6.80        6.74

X STA.       184.7       195.7       208.3       224.0       246.2       306.5
  A(I)            21.0        22.1        24.0        28.1        38.9
  V(I)            6.16        5.84        5.38        4.60        3.32

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      61.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     518.  36037.   202.   203.                         4699.
             2     546.  85033.    52.    53.                        10056.
             3    2359. 274194.   427.   428.                        31458.
   499.90         3422. 395264.   681.   684.  1.13  -202.   479.  40999.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      61.
         WSEL     LEW     REW    AREA        K        Q    VEL
       499.90  -202.4   478.8  3422.3  395264.    5690.   1.66
X STA.      -202.4       -27.8         3.9        15.6        25.5        35.8
  A(I)           345.2       203.1       127.4       117.0       119.1
  V(I)            0.82        1.40        2.23        2.43        2.39

X STA.        35.8        49.6        66.8        85.4       106.9       131.2
  A(I)           133.6       137.6       139.9       150.2       156.1
  V(I)            2.13        2.07        2.03        1.89        1.82

X STA.       131.2       160.6       189.2       214.6       237.9       259.5
  A(I)           169.4       166.1       159.6       156.4       152.6
  V(I)            1.68        1.71        1.78        1.82        1.86

X STA.       259.5       280.5       301.1       321.9       351.1       478.8
  A(I)           156.3       160.4       163.2       199.0       310.1
  V(I)            1.82        1.77        1.74        1.43        0.92
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard031.wsp
        CREATED ON 14-AUG-95 FOR BRIDGE HARDTH00050031 USING FILE hard031.dca
        HYDRAULIC ANALYSIS OF HARD031    SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     251.   19553.     0.    83.                          0.
   494.83          251.   19553.     0.    83.  1.00     0.    38.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       494.83     0.0    37.8   251.0   19553.    3060.  12.19
X STA.         0.0        3.0        5.0        6.9        8.6       10.4
  A(I)            20.1       13.2       12.3       11.9       11.7
  V(I)            7.60      11.60      12.48      12.88      13.07

X STA.        10.4       12.1       13.8       15.5       17.2       18.9
  A(I)            11.5       11.2       11.3       11.2       11.3
  V(I)           13.36      13.62      13.49      13.62      13.59

X STA.        18.9       20.6       22.2       23.9       25.6       27.3
  A(I)            11.1       11.1       11.3       11.2       11.5
  V(I)           13.76      13.73      13.54      13.62      13.33

X STA.        27.3       29.0       30.7       32.5       34.5       37.8
  A(I)            11.4       11.9       12.3       13.3       20.1
  V(I)           13.39      12.88      12.45      11.51       7.60

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.
         WSEL     LEW     REW    AREA        K        Q    VEL
       500.22  -190.2   323.0   784.1   42824.    5047.   6.44
X STA.      -190.2      -72.0      -38.0      -14.3       50.6       68.1
  A(I)            77.8       51.5       44.3       44.8       36.1
  V(I)            3.24       4.90       5.70       5.63       7.00

X STA.        68.1       83.9       97.9      111.3      123.7      135.3
  A(I)            34.5       32.5       32.6       31.2       30.5
  V(I)            7.31       7.76       7.75       8.08       8.28

X STA.       135.3      146.7      157.5      167.9      178.6      190.4
  A(I)            31.1       30.2       30.3       30.8       32.3
  V(I)            8.11       8.36       8.33       8.20       7.82

X STA.       190.4      203.8      219.2      238.5      263.6      323.0
  A(I)            34.0       35.9       40.3       44.0       59.4
  V(I)            7.42       7.02       6.27       5.73       4.25

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      61.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     714.   52039.   260.   261.                       6707.
             2     590.   96769.    52.    53.                      11297.
             3    2723.  346292.   431.   432.                      38852.
   500.75         4027.  495101.   743.   746.  1.13  -331.   483.  49977.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      61.
         WSEL     LEW     REW    AREA        K        Q    VEL
       500.75  -331.1   482.6  4026.9  495101.    8090.   2.01
X STA.      -331.1      -39.9       -3.9       13.6       24.7       36.2
  A(I)           436.3      249.6      174.1      140.4      142.2
  V(I)            0.93       1.62       2.32       2.88       2.84

X STA.        36.2       51.7       69.8       90.0      112.3      137.7
  A(I)           159.8      159.0      166.7      172.9      180.5
  V(I)            2.53       2.54       2.43       2.34       2.24

X STA.       137.7      167.5      195.4      220.7      243.9      266.0
  A(I)           193.9      189.5      182.9      177.7      177.1
  V(I)            2.09       2.13       2.21       2.28       2.28

X STA.       266.0      287.0      307.5      330.9      372.1      482.6
  A(I)           176.4      180.0      197.0      237.8      333.0
  V(I)            2.29       2.25       2.05       1.70       1.21
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard031.wsp
        CREATED ON 14-AUG-95 FOR BRIDGE HARDTH00050031 USING FILE hard031.dca
        HYDRAULIC ANALYSIS OF HARD031    SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     251.   19553.     0.    83.                          0.
   494.83          251.   19553.     0.    83.  1.00     0.    38.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      494.83     0.0    37.8   251.0   19553.    2400.   9.56
X STA.         0.0         3.0         5.0         6.9         8.6        10.4
  A(I)            20.1        13.2        12.3        11.9        11.7
  V(I)            5.96        9.10        9.79       10.10       10.25

X STA.        10.4        12.1        13.8        15.5        17.2        18.9
  A(I)            11.5        11.2        11.3        11.2        11.3
  V(I)           10.47       10.68       10.58       10.68       10.66

X STA.        18.9        20.6        22.2        23.9        25.6        27.3
  A(I)            11.1        11.1        11.3        11.2        11.5
  V(I)           10.79       10.77       10.62       10.68       10.46

X STA.        27.3        29.0        30.7        32.5        34.5        37.8
  A(I)            11.4        11.9        12.3        13.3        20.1
  V(I)           10.50       10.10        9.77        9.03        5.96

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      61.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     222.   16186.    81.    81.                       2087.
             2     410.   52807.    52.    53.                       6550.
             3    1283.  113899.   348.   349.                      13978.
   497.28         1915.  182892.   481.   484.  1.11   -81.   400.  20544.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      61.
        WSEL     LEW     REW    AREA        K        Q    VEL
      497.28   -81.0   400.0  1915.5  182892.    2400.   1.25
X STA.       -81.0       -23.5         4.6        13.3        20.6        27.5
  A(I)           137.0       110.2        71.9        65.7        63.6
  V(I)            0.88        1.09        1.67        1.83        1.89

X STA.        27.5        34.8        44.3        58.7        75.1        94.2
  A(I)            65.2        72.5        83.8        84.0        89.5
  V(I)            1.84        1.65        1.43        1.43        1.34

X STA.        94.2       117.9       150.3       188.7       216.4       240.3
  A(I)            97.7       110.7       119.9       101.6        98.6
  V(I)            1.23        1.08        1.00        1.18        1.22

X STA.       240.3       261.2       280.1       298.4       317.6       400.0
  A(I)            93.8        91.2        94.5       101.5       162.7
  V(I)            1.28        1.32        1.27        1.18        0.74
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       U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard031.wsp
       CREATED ON 14-AUG-95 FOR BRIDGE HARDTH00050031 USING FILE hard031.dca
       HYDRAULIC ANALYSIS OF HARD031    SAO

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

EXIT1:XS   ******  -151.    1018.  0.65 *****  496.50  494.91   5690.  495.85
      -34. ******   202.   84514.  1.33 ***** *******    0.67    5.59

FULLV:FV      34.  -168.    1109.  0.55  0.14  496.64 *******   5690.  496.10
        0.    34.   210.   93244.  1.33  0.00    0.01    0.61    5.13
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "APPRO"     KRATIO =  1.56

APPRO:AS      61.    -75.    1593.  0.22  0.15  496.79 *******   5690.  496.56
       61.    61.   356.  145365.  1.12  0.00    0.00    0.35    3.57
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   496.10     494.60

            <<<<<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      34.      0.     251.  2.35 *****  497.18  493.65   3085.  494.83
        0. ******    38.   19553.  1.00 ***** *******    0.84   12.29

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   6.  0.800  0.000  494.60 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.    37.  0.01  0.05  499.94    0.00   2582.  499.49

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    423.   115.  -121.    -6.   1.4   0.7   4.9   5.4   1.1   3.1
   RT:   2159.   270.    37.   307.   2.2   1.4   6.3   5.5   1.9   3.1

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

APPRO:AS      35.  -202.    3421.  0.05  0.18  499.95  494.87   5690.  499.90
       61.    73.   479.  394998.  1.13  0.00    0.00    0.14    1.66

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXIT1:XS     -34.  -151.    202.   5690.    84514.    1018.    5.59  495.85
   FULLV:FV       0.  -168.    210.   5690.    93244.    1109.    5.13  496.10
   BRIDG:BR       0.     0.     38.   3085.    19553.     251.   12.29  494.83
   RDWAY:RG      13.*******    423.   2582.******************    1.00  499.49
   APPRO:AS      61.  -202.    479.   5690.   394998.    3421.    1.66  499.90

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT1:XS    494.91    0.67  487.90  507.07************  0.65  496.50  495.85
   FULLV:FV  ********    0.61  487.90  507.07  0.14  0.00  0.55  496.64  496.10
   BRIDG:BR    493.65    0.84  486.84  494.83************  2.35  497.18  494.83
   RDWAY:RG  ****************  497.27  512.94  0.01******  0.05  499.94  499.49
   APPRO:AS    494.87    0.14  488.00  508.90  0.18  0.00  0.05  499.95  499.90
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WSPRO OUTPUT FILE (continued)

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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard031.wsp
        CREATED ON 14-AUG-95 FOR BRIDGE HARDTH00050031 USING FILE hard031.dca
        HYDRAULIC ANALYSIS OF HARD031    SAO

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

EXIT1:XS   ****** -213.    1379.  0.71 ***** 497.47  495.69   8090.  496.75
      -34. ******  229.  120172.  1.33 ***** *******    0.67    5.87

FULLV:FV      34.  -230.    1495.  0.60  0.14  497.61 *******   8090.  497.01
        0.    34.  236.  132198.  1.32  0.00    0.01    0.61    5.41
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  1.48

APPRO:AS      61.   -83.    2029.  0.28  0.15  497.79 *******   8090.  497.51
       61.    61.   420.  195506.  1.12  0.00    0.02    0.37    3.99
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                          WS3N,LSEL =   497.01     494.60

            <<<<<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      34.     0.     251.  2.31 ***** 497.14  493.61   3060.  494.83
        0. ******    38.   19553.  1.00 ***** *******    0.83   12.19

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   6.  0.800  0.000  494.60 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       13.    37.  0.01  0.07  500.81    0.00   5047.  500.22

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1208.   185.  -190.    -6.   2.1   1.0   6.0   6.3   1.6   3.2
   RT:   3839.   286.    37.   323.   3.0   2.1   7.6   6.5   2.7   3.1

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

APPRO:AS      35.  -331.    4026.  0.07  0.20  500.82  495.36   8090.  500.75
       61.    63.   483.  494998.  1.13  0.00    0.00    0.16    2.01

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

   FIRST USER DEFINED TABLE.
     XSID:CODE    SRD    LEW     REW       Q        K      AREA     VEL    WSEL
    EXIT1:XS     -34.  -213.    229.   8090.  120172.    1379.    5.87  496.75
    FULLV:FV       0.  -230.    236.   8090.  132198.    1495.    5.41  497.01
    BRIDG:BR       0.     0.     38.   3060.   19553.     251.   12.19  494.83
    RDWAY:RG      13.******* 1208.   5047.******************    1.00  500.22
    APPRO:AS      61.  -331.    483.   8090.  494998.    4026.    2.01  500.75

  SECOND USER DEFINED TABLE.
     XSID:CODE    CRWS      FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
    EXIT1:XS    495.69     0.67  487.90  507.07************  0.71  497.47  496.75
    FULLV:FV  ********     0.61  487.90  507.07  0.14  0.00  0.60  497.61  497.01
    BRIDG:BR    493.61     0.83  486.84  494.83************  2.31  497.14  494.83
    RDWAY:RG  ****************  497.27  512.94  0.01******  0.07  500.81  500.22
    APPRO:AS    495.36     0.16  488.00  508.90  0.20  0.00  0.07  500.82  500.75
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        U.S. GEOLOGICAL SURVEY WSPRO INPUT FILE hard031.wsp
        CREATED ON 14-AUG-95 FOR BRIDGE HARDTH00050031 USING FILE hard031.dca
        HYDRAULIC ANALYSIS OF HARD031    SAO
           *** RUN DATE & TIME: 10-25-96  08:44

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

EXIT1:XS   ******   -72.     489.  0.50 *****  494.46  493.18   2400.  493.96
      -34. ******   148.   35630.  1.35 ***** *******    0.67    4.91

FULLV:FV      34.   -80.     542.  0.41  0.14  494.60 *******   2400.  494.19
        0.    34.   154.   40156.  1.35  0.00    0.00    0.60    4.43
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      61.   -50.     743.  0.23  0.18  494.77 *******   2400.  494.54
       61.    61.   350.   48396.  1.44  0.00   -0.01    0.50    3.23
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   493.15     496.01     496.17     494.60

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

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

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

BRIDG:BR      34.     0.     251.  1.41 *****  496.24  492.65   2390.  494.83
        0. ******    38.   19553.  1.00 ***** *******    0.65    9.52

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   2.  0.488  0.000  494.60 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS      35.   -81.    1916.  0.03  0.11  497.31  493.60   2400.  497.28
       61.    68.   400.  182958.  1.11  0.45    0.00    0.12    1.25

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   497.27

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

   FIRST USER DEFINED TABLE.
     XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL   WSEL
    EXIT1:XS     -34.   -72.   148.   2400.   35630.     489.    4.91  493.96
    FULLV:FV       0.   -80.   154.   2400.   40156.     542.    4.43  494.19
    BRIDG:BR       0.     0.    38.   2390.   19553.     251.    9.52  494.83
    RDWAY:RG      13.**************      0.       0.       0.    1.00********
    APPRO:AS      61.   -81.   400.   2400.  182958.    1916.    1.25  497.28

  SECOND USER DEFINED TABLE.
     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
    EXIT1:XS    493.18    0.67  487.90  507.07************  0.50  494.46  493.96
    FULLV:FV   ********   0.60  487.90  507.07  0.14  0.00  0.41  494.60  494.19
    BRIDG:BR    492.65    0.65  486.84  494.83************  1.41  496.24  494.83
    RDWAY:RG   ****************  497.27  512.94************  0.03  497.30********
    APPRO:AS    493.60    0.12  488.00  508.90  0.11  0.45  0.03  497.31  497.28
```
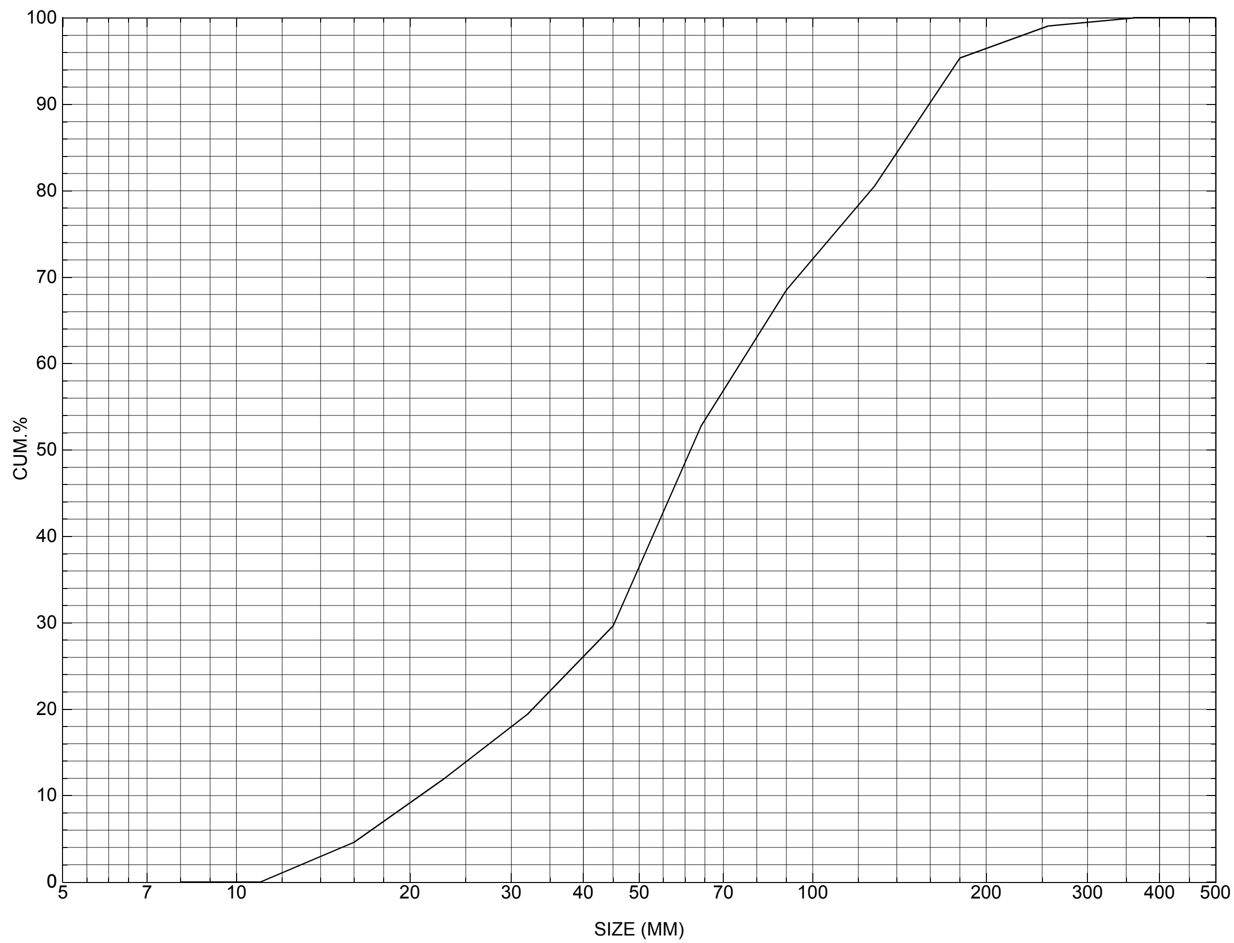

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for one pebble count transect in the channel approach of structure HARDTH00050031, in Hardwick, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number HARDTH00050031

General Location Descriptive

Data collected by (First Initial, Full last name) M. IVANOFF

Date (MM/DD/YY) 04 / 03 / 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 TH005

Vicinity (I - 9) 0.1 MI JCT TH 5 + VT 16

Topographic Map Caspian.Lake

Hydrologic Unit Code:

Latitude (I - 16; nnnn.n) 44326

Longitude (i - 17; nnnnn.n) 72161

Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10030500310305

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0039

Year built (I - 27; YYYY) 1924

Structure length (I - 49; nnnnnn) 000043

Average daily traffic, ADT (I - 29; nnnnnn) 000750

Deck Width (I - 52; nn.n) 235

Year of ADT (I - 30; YY) 93

Channel & Protection (I - 61; n) 5

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

Waterway adequacy (I - 71; n) 7

Operational status (I - 41; X) A

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

Structure type (I - 43; nnn) 104

Year Reconstructed (I - 106) 0000

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

Clear span (nnn.n ft) -

Number of spans (I - 45; nnn) 001

Vertical clearance from streambed (nnn.n ft) 006.0

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

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

Comments:

The structural inspection report of 06/01/95 indicates the structure is a concrete T-beam type bridge an asphalt roadway surface. The abutment walls and wingwalls are concrete. A section of concrete footing is exposed on the left abutment. The ends of the right abutment and its wingwalls have numerous cracks and leaks reported with some surface spalling. The upstream left wingwall has cracks and leaks reported overall. The channel is scoured down 2 - 3 feet in front of the left abutment and 1” - 1.5’ at the downstream end of the right abutment and the downstream right wingwall. A few random boulders are evident along the up- and downstream banks. Some erosion along the banks from **(Continued, page 33)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

Q_{50} - Q_{100} - Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft^3/ sec*): -

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

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

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

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

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): -

Comments:

past flooding is reported. Point bars and debris accumulation problems in the channel are minor.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **32.07** mi^2
Lake and pond area **.882** mi^2
Watershed storage *(ST)* **2.75** %
Bridge site elevation **1170** ft
Headwater elevation **1798** ft
Main channel length **9.61** mi
10% channel length elevation **1158** ft
85% channel length elevation **1434** ft
Main channel slope *(S)* **38.28** 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: 04/16/96
Computerized by: EW Date: 04/18/96
Reviewd by: SAO Date: 10/28/96

Structure Number HARDTH00050031

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. DEGNAN Date *(MM/DD/YY)* 07 / 26 / 1995

2. Highway District Number 07 Mile marker 000000

County CALEDONIA 005 Town HARDWICK 31825

Waterway *(I - 6)* LAMOILLE RIVER Road Name -

Route Number TH005 Hydrologic Unit Code: 02010005

3. Descriptive comments:

Bridge is located 0.1 mile from the intersection of TH05 with VT16.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 4 LBDS 4 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 1 UB 1 DS 2 *(**1**- pool; **2**- riffle)*

6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*

7. Bridge length 43 *(feet)* Span length 39 *(feet)* Bridge width 24 *(feet)*

Road approach to bridge:

8. LB 2 RB 1 *(**0** even, **1**- lower, **2**- higher)*

9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*

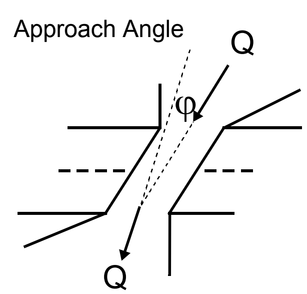
10. Embankment slope (*run / rise in feet / foot*):
US left 2.5:1 US right 1.8:1

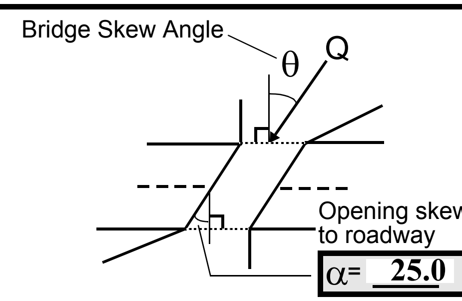
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	0	-	3	1
RBDS	0	-	2	1
LBDS	0	-	2	2

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

Channel approach to bridge (BF):

15. Angle of approach: 0 16. Bridge skew: 10





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 2
Range? 0 feet DS *(US, UB, DS)* to 12 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 2
Range? 75 feet DS *(US, UB, DS)* to 100 feet DS

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

18. Bridge Type: **4**

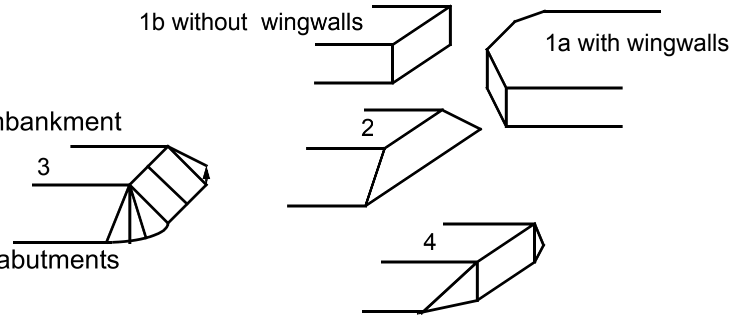
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

#8: The road approaches have only a slight elevation difference from the bridge.
#13: The channel erosion on the upstream right road embankment is due to a confluence running along its banks.
#17: The upstream channel impact zone starts on the USLWW and continues to the DS end of the LABUT.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
48.5	**4.0**			**2.0**	**1**	**1**	**342**	**342**	**1**	**1**

23. Bank width **35.0** 24. Channel width **10.0** 25. Thalweg depth **52.0** 29. Bed Material **432**

30 .Bank protection type: LB **0** RB **0** 31. 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*

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

There is a small dry gully which runs down to the LB and drains water from road and pasture. The RB gully which is presently flowing is described in #49.
The LB is covered with grasses. The RB has shrubs ten feet to fifteen feet in height within two bridge lengths.

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

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

37. Material: -

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

NO POINT BARS

39. Is a cut-bank present? N (Y or if N type ctrl-n cb) 40. Where? - (LB or RB)

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

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

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

NO CUT BANKS

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 0 UB

47. Scour dimensions: Length 50 Width 20 Depth : 1.5 Position 0 %LB to 50 %RB

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

There is a second scour hole starting upstream of the upstream confluence. It has a length of 26 feet, a width of 12 feet and a scour depth of 1.5 feet. The mid-scour distance is 0 feet US.

49. Are there major confluences? Y (Y or if N type ctrl-n mc) 50. How many? 1

51. Confluence 1: Distance 12 52. Enters on RB (LB or RB) 53. Type 1 (*1*- perennial; *2*- ephemeral)

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

54. Confluence comments (eg. confluence name):

The confluence enters at the upstream end of the USRWW. It looks like it is connected with the scour hole existing at this location.

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
35.0		1.5		2	7	7	-

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

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

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

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

203

The bed material under the bridge is sand, but it is very loose. After approximately one foot of penetration, some hard material was hit. Near the LABUT there seems to be more gravel. Near the RABUT more organics accumulated.

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

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

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

70. Debris and Ice Comments:

1

The debris potential is moderate because the bridge opening is in a lower velocity pooled area. Debris has accumulated in the soft sediment under the bridge.

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		20	90	2	3	1.5	1	90.0
RABUT	1	-	90			2	2	34.5

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

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

1

0.5

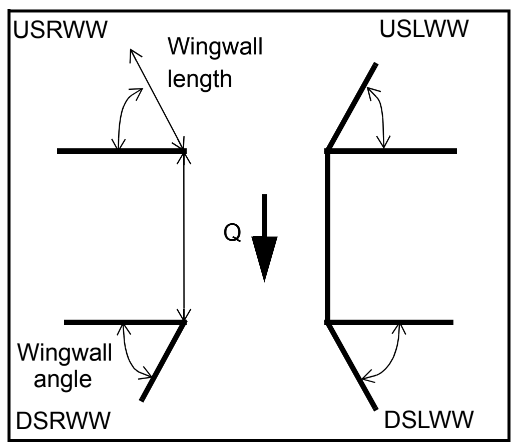
1

The LABUT toe protrudes a great deal; the whole wingwall and abutment are in the channel.
The soft sediments in the middle and right side of the channel at these flow levels make high level prediction difficult.
The actual amount of undermining of left abutment is less than 0.1 ft.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						34.5	
USRWW:	Y		1		1	2.5	
DSLWW:	0.5		-		Y	26.5	
DSRWW:	1		2		1.5	26.5	

*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	1	1	Y	-	-	-	-	-
Condition	Y	0.5	1	-	-	-	-	-
Extent	1	-	0	0	0	0	0	0

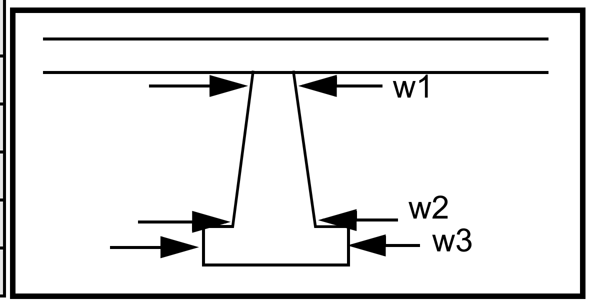
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				**30.0**	**12.0**	**85.0**
Pier 2			**9.5**	**10.0**	**90.0**	**35.0**
Pier 3		--	--	**12.0**	--	--
Pier 4	--	--	--	--	--	--



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

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
--	--			--	-	NO	PIE	RS		

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.):

1
1
1234
1234
1
1
432
0
0
-
-
Both banks downstream have a thick grass covering.
There is evidence of road overtopping on the DSRB. There is a hole in the middle of the flood plain which was

101. Is a drop structure present? **pr** *(Y or N, if N type ctrl-n ds)* 102. Distance: -- feet

103. Drop: -- feet 104. Structure material: **ob** *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

105. Drop structure comments (eg. downstream scour depth):
ably dug out by water flowing swiftly down the road embankment.

106. Point/Side bar present? _____ *(Y or N. if N type ctrl-n pb)* Mid-bar distance: ______ Mid-bar width: ______

Point bar extent: ______ feet ____ *(US, UB, DS)* to ______ feet ____ *(US, UB, DS)* positioned **N** %LB to **-** %RB

Material: **NO**

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

DROP STRUCTURE

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

Cut bank extent: **125** feet **25** *(US, UB, DS)* to **100** feet **DS** *(US, UB, DS)*

Bank damage: **240** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
0
30
432

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

Scour dimensions: Length ______ Width ______ Depth: **Y** Positioned **RB** %LB to **100** %RB

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

75
DS
160
DS

Are there major confluences? **3** *(Y or if N type ctrl-n mc)* How many? **The**

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

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

Confluence comments (eg. confluence name):

ss from the entrance of the confluence into the channel.
There is also a cut-bank on the LB of the confluence just above the point bar which is located where the main

F. Geomorphic Channel Assessment

107. Stage of reach evolution **cha**

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)*:

nnel impacts the mouth of the confluence.

N
-
-
-
-
-
-
NO CHANNEL SCOUR

See # 48.

109. G. Plan View Sketch

-- Y

point bar pb	debris	flow Q	stone wall
cut-bank cb	rip rap or stone fill	cross-section	other wall
scour hole		ambient channel	

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: HARDTH00050031 Town: Hardwick
Road Number: TH5 County: Caledonia
Stream: Lamoille River

Initials SAO Date: 6/17/96 Checked: MAI

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	5690	8090	2400
Main Channel Area, ft2	546	590	410
Left overbank area, ft2	518	714	222
Right overbank area, ft2	2359	2723	1283
Top width main channel, ft	52	52	52
Top width L overbank, ft	202	260	81
Top width R overbank, ft	427	431	348
D50 of channel, ft	0.20128	0.20128	0.20128
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	10.5	11.3	7.9
y1, average depth, LOB, ft	2.6	2.7	2.7
y1, average depth, ROB, ft	5.5	6.3	3.7
Total conveyance, approach	395264	495101	182892
Conveyance, main channel	85033	96769	52807
Conveyance, LOB	36037	52039	16186
Conveyance, ROB	274194	346292	113899
Percent discrepancy, conveyance	0.0000	0.0002	0.0000
Qm, discharge, MC, cfs	1224.1	1581.2	693.0
Ql, discharge, LOB, cfs	518.8	850.3	212.4
Qr, discharge, ROB, cfs	3947.1	5658.4	1494.6
Vm, mean velocity MC, ft/s	2.2	2.7	1.7
Vl, mean velocity, LOB, ft/s	1.0	1.2	1.0
Vr, mean velocity, ROB, ft/s	1.7	2.1	1.2
Vc-m, crit. velocity, MC, ft/s	9.7	9.8	9.3
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	546	590	410
Main channel width, ft	52	52	52
y1, main channel depth, ft	10.50	11.35	7.88

Bridge Section			
(Q) total discharge, cfs	5690	8090	2400
(Q) discharge thru bridge, cfs	3085	3060	2400
Main channel conveyance	19553	19553	19553
Total conveyance	19553	19553	19553
Q2, bridge MC discharge,cfs	3085	3060	2400
Main channel area, ft2	251	251	251
Main channel width (skewed), ft	34.3	34.3	34.3
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	34.3	34.3	34.3
y_bridge (avg. depth at br.), ft	7.32	7.32	7.32
Dm, median (1.25*D50), ft	0.2516	0.2516	0.2516
y2, depth in contraction,ft	8.68	8.62	7.00
ys, scour depth (y2-ybridge), ft	1.36	1.30	-0.32
ys, scoour depth (y2-yfullv), ft	N/A	N/A	0.14

Pressure Flow Scour (contraction scour for orifice flow conditions)

Hb+Ys=Cq*qbr/Vc   Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)
Chang Equation   Cc=SQRT[0.10*(Hb/(ya-w)-0.56)]+0.79 (<=1)
(Richardson and others, 1995, p. 145-146)

	Q100	Q500	OtherQ
Q thru bridge main chan, cfs	3085	3060	2400
Vc, critical velocity, ft/s	9.722	9.848	9.268
Vc, critical velocity, m/s	2.963121	3.001524	2.824749
Main channel width (skewed), ft	34.3	34.3	34.3
Cum. width of piers, ft	0	0	0
W, adjusted width, ft	34.3	34.3	34.3
qbr, unit discharge, ft^2/s	89.94169	89.21283	69.97085
qbr, unit discharge, m^2/s	8.355041	8.287334	6.49987
Area of full opening, ft^2	251	251	251
Hb, depth of full opening, ft	7.317784	7.317784	7.317784
Hb, depth of full opening, m	2.230352	2.230352	2.230352
Fr, Froude number MC	0.84	0.83	0.65
Cf, Fr correction factor (<=1.0)	1	1	1

Elevation of Low Steel, ft	494.65	494.65	494.65
Elevation of Bed, ft	487.3322	487.3322	487.3322
Elevation of approach WS, ft	499.9	500.75	497.28
HF, bridge to approach, ft	0.18	0.2	0.11
Elevation of WS immediately US, ft	499.72	500.55	497.17
ya, depth immediately US, ft	12.38778	13.21778	9.837784
ya, depth immediately US, m	3.849529	4.107453	3.057111
Mean elev. of deck, ft	502.21	502.21	502.21
w, depth of overflow, ft (>=0)	0	0	0
Cc, vert contrac correction (<=1.0)	0.845431	0.79	0.925589
Ys, depth of scour (chang), ft	3.624987	4.149278	0.838883

ARMORING

D90	0.522	0.522	0.522
D95	0.586	0.586	0.586
Critical grain size,Dc, ft	0.5762	0.5669	0.3487
Decimal-percent coarser than Dc	0.057	0.064	0.258
Depth to armoring,ft	28.60	24.87	3.01

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	5690	8090	2400	5690	8090	2400
a', abut.length blocking flow, ft	205.9	334.6	84.5	441	444.8	362.2
Ae, area of blocked flow ft2	467.4	568.9	242.9	2100.9	2274.2	1379.1
Qe, discharge blocked abut.,cfs	--	--	235.3	--	--	1642.1
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.04	1.29	0.97	1.70	2.10	1.19
ya, depth of f/p flow, ft	2.27	1.70	2.87	4.76	5.11	3.81
--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	65	65	65	115	115	115
K2	0.96	0.96	0.96	1.03	1.03	1.03
Fr, froude number f/p flow	0.112	0.151	0.101	0.126	0.146	0.108
ys, scour depth, ft	9.67	10.98	8.28	22.90	25.84	17.12

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)	205.9	334.6	84.5	441	444.8	362.2
y1 (depth f/p flow, ft)	2.27	1.70	2.87	4.76	5.11	3.81
a'/y1	90.70	196.80	29.40	92.57	87.00	95.13
Skew correction (p. 49, fig. 16)	0.92	0.92	0.92	1.07	1.07	1.07
Froude no. f/p flow	0.11	0.15	0.10	0.13	0.15	0.11
Ys w/ corr. factor K1/0.55:						
vertical	7.37	6.10	9.02	18.71	21.09	14.20
vertical w/ ww's	6.05	5.00	7.39	15.35	17.29	11.64
spill-through	4.06	3.35	4.96	10.29	11.60	7.81

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.84	0.83	0.65	0.84	0.83	0.65
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	7.3	7.3	7.3	7.3	7.3	7.3
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	1.91	ERR	ERR	1.91
Fr>0.8 (vertical abut.)	2.91	2.90	ERR	2.91	2.90	ERR
Fr<=0.8 (spillthrough abut.)	ERR	ERR	1.66	ERR	ERR	1.66
Fr>0.8 (spillthrough abut.)	2.57	2.56	ERR	2.57	2.56	ERR