LEVEL II SCOUR ANALYSIS FOR BRIDGE 20 (GRAFTH00010020) on TOWN HIGHWAY 1 (VT 121 & FAS 125), crossing the SAXTONS RIVER, GRAFTON, VERMONT

U.S. Geological Survey
Open-File Report 97-375

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

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By ERICK M. BOEHMLER and RONDA L. BURNS

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Pembroke, New Hampshire

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U.S. DEPARTMENT OF THE INTERIOR
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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 20 (GRAFTH00010020) ON TOWN HIGHWAY 1 (VT 121 & FAS 125), CROSSING THE SAXTONS RIVER, GRAFTON, VERMONT

By **Erick M. Boehmler and Ronda L. Burns**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure GRAFTH00010020 on Town Highway 1 crossing the Saxtons River, Grafton, 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 southeastern Vermont. The 33.9-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest upstream of the bridge and shrub and brush downstream.

In the study area, the Saxtons River has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 97 ft and an average bank height of 2 ft. The predominant channel bed material is gravel with a median grain size (D_{50}) of 58.6 mm (0.192 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 21, 1996, indicated that the reach was laterally unstable due to distinctive cut bank development on the upstream right bank and point bar development on the upstream left bank and downstream right bank.

The Town Highway 1 crossing of the Saxtons River is a 191-ft-long, two-lane bridge consisting of three steel-beam spans (Vermont Agency of Transportation, written communication, March 29, 1995). The bridge is supported by vertical, concrete abutments with spill-through embankments and two piers. The channel is skewed approximately 40 degrees to the opening. The opening-skew-to-roadway is 45 degrees in the VTAOT records but measured 50 degrees from surveyed points.

The scour protection measures at the site were type-1 stone fill (less than 12 inches diameter) on the left abutment, type-2 stone fill (less than 36 inches diameter) on the right abutment and downstream right bank, and a stone wall is noted on the left bank downstream. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 0.9 feet. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 8.0 to 14.9 feet. The worst-case abutment scour occurred at the 500-year discharge for the right abutment. There are two piers for which computed pier scour ranged from 8.7 to 26.0 feet. The left and right piers in this report are presented as pier 1 and pier 2 respectively. The worst-case pier scour occurred at pier 2 for 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.

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number GRAFTH00010020 ***Stream*** Saxtons River

County Windham ***Road*** TH 1 ***District*** 2

Description of Bridge

Bridge length 191 ***ft*** ***Bridge width*** 30.6 ***ft*** ***Max span length*** 62 ***ft***

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

Abutment type Spill-through ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 8/21/96

Description of stone fill Consists of type-1 on the left abutment spill-through embankment, type-2 stone fill on the left abutment spill-through embankment and downstream right bank.

Abutments are vertical concrete abutment walls with spill-through embankments adjacent to each wall. The piers are solid concrete with rounded ends

Yes

40

Y There is

Is bridge skewed to flood flow according to a mild ***survey?*** ***Angle***

channel bend in 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	8/21/96	0	0
Level II	8/21/96	0	0

Potential for debris High. The banks are unstable and are equal to or greater than 50 percent tree covered upstream.

Describe any features near or at the bridge that may affect flow (include observation date) There are accumulations of streambed material on the downstream right sides of the piers and the left abutment, which horizontally occupies about 40 percent of the bridge opening width noted on 8/21/96.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley setting with only narrow overbank areas and steep valley walls on both sides.

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

Date of inspection 8/21/96

DS left: Mildly sloping channel bank to a narrow overbank.

DS right: Mildly sloping channel bank to a narrow overbank and TH 1 roadway.

US left: Mildly sloping channel bank to a narrow overbank and TH 1 roadway.

US right: Steep channel bank and valley wall.

Description of the Channel

Average top width 97 ft ***Average depth*** 2 ft

Predominant bed material Gravel ***Bank material*** Sand to Boulders

Sinuous and laterally unstable with semi-alluvial channel boundaries and wide point bars.

8/21/96

Vegetative co Shrubs and brush with a few trees

DS left: Trees and brush

DS right: Trees

US left: Short grass and brush with a few trees.

US right:

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

The assessment of 8/21/96 noted debris caught on the left side of pier 2 and large accumulations of streambed material on the right sides of the both piers and the downstream end of the left abutment.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 33.9 ***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 Saxtons River at Saxtons River, VT

USGS gage number 01154000 (Discontinued)

Gage drainage area 72.2 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 6,130 ***ft³/s*** ***Q500*** 9,300 ***ft³/s***

The 100- and 500-year discharges were computed by use of a drainage area relationship [(33.9/43.2) exp 0.75] with the 100- and 500- year discharge estimates at the upstream corporate limits documented in the flood insurance study (FIS) for the town of Rockingham [Federal Emergency Management Agency (FEMA), 1979]. The flood frequency curve from the FIS was within a range defined by several empirical flood frequency equations (Benson, 1962; FHWA, 1983; Johnson and Tasker, 1974; Potter, 1957a&b; and 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 VTAOT metallic disk survey mark set in the top of the left abutment concrete at the upstream end (elev. 498.52 ft, arbitrary survey datum). RM2 is the center point of a chiseled "X" on top of the concrete curb at the downstream right corner of the bridge deck (elev. 498.81 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	-130	1	Exit section
FULLV	0	3	Downstream Full-valley section (Combined EXITX and BRIDG)
BRIDG	0	1	Bridge section
RDWAY	25	1	Road Grade section
APPRO	179	2	Modelled Approach section (Templated from APTEM)
APTEM	254	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.050, and overbank "n" values ranged from 0.040 to 0.045.

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 0.0105 ft/ft, which was computed from the 100- year water surface profile downstream of this site presented in the flood insurance study for the town of Grafton (Federal Emergency Management Agency, 1987).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.00735 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 location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.2 *ft*
Average low steel elevation 495.2 *ft*

100-year discharge 6,130 *ft³/s*
Water-surface elevation in bridge opening 495.2 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 949 *ft²*
Average velocity in bridge opening 6.5 *ft/s*
Maximum WSPRO tube velocity at bridge 7.9 *ft/s*

Water-surface elevation at Approach section with bridge 496.3
Water-surface elevation at Approach section without bridge 493.1
Amount of backwater caused by bridge 3.2 *ft*

500-year discharge 9,300 *ft³/s*
Water-surface elevation in bridge opening 495.2 *ft*
Road overtopping? No *Discharge over road* -- *ft³/s*
Area of flow in bridge opening 949 *ft²*
Average velocity in bridge opening 9.8 *ft/s*
Maximum WSPRO tube velocity at bridge 12.1 */s*

Water-surface elevation at Approach section with bridge 498.7
Water-surface elevation at Approach section without bridge 495.9
Amount of backwater caused by bridge 2.8

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

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

The 100- and 500-year events resulted in orifice flow conditions 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). Thus, contraction scour for the 100- and 500-year events was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Results of this analysis are presented in figure 8 and tables 1 and 2. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

Additional estimates of contraction scour also were computed by use of Laursen's clear-water scour equation and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and are presented in Appendix F. Furthermore, for each discharge modeled, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions are provided in Appendix F.

Abutment scour 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. Results from the HIRE equation were not used for the narrow, incised, upland valley at this site.

Because the influence of scour processes on the spill-through embankment material is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, scour depths were applied for the entire spill-through embankment area below the elevation at the toe of each embankment, as shown in figure 8.

Pier scour was computed by use of an equation developed at Colorado State University (Richardson and others, 1995, p. 36, equation 21) for all discharges modeled. Variables for the pier scour equation include pier length, pier width, average depth and maximum velocity (for the froude number) immediately upstream of the bridge, and four correction factors for pier shape, flow attack angle, streambed-form, and streambed armoring.

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.9	--
Depth to armoring	12.5	29.9	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	8.0	14.2	--
Right abutment	13.3	14.9	--
Pier scour			
Pier 1	8.7	10.1	--
Pier 2	22.5	26.0	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
	(D_{50} in feet)		
Abutments:			
Left abutment	1.8	2.2	--
Right abutment	1.8	2.2	--
Piers:			
Pier 1	0.6	1.4	--
Pier 2	0.9	2.0	--
	--	--	--

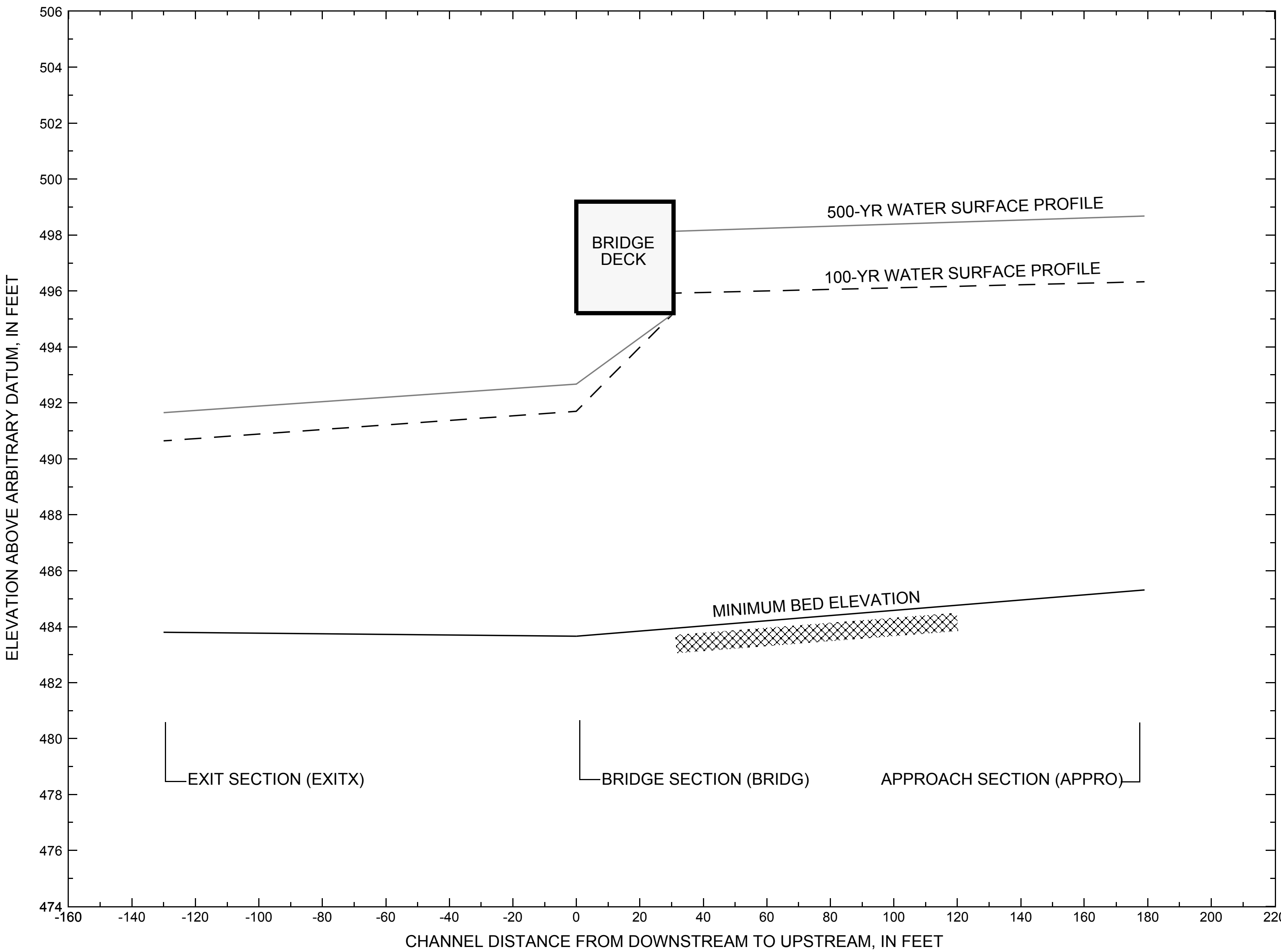

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure GRAFTH00010020 on Town Highway 1, crossing Saxtons River, Grafton, Vermont.

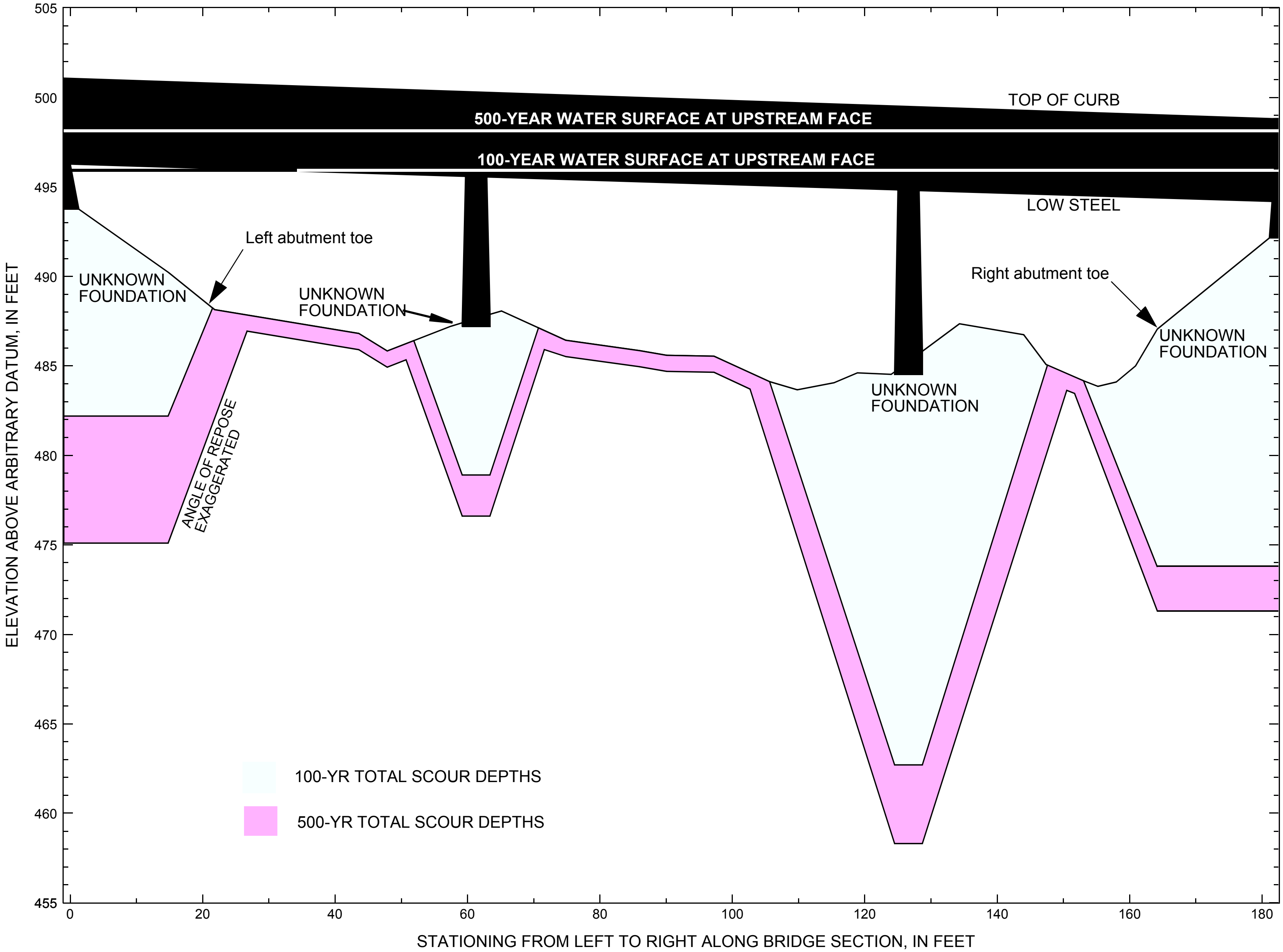

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure GRAFTH00010020 on Town Highway 1, crossing Saxtons River, Grafton, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure GRAFTH00010020 on Town Highway 1, crossing Saxtons River, Grafton, 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 6,130 cubic-feet per second											
Left abutment	0.0	--	496.3	--	493.8	--	--	--	--	--	--
Left abutment toe	14.8	--	--	--	490.2	0.0	8.0	--	8.0	482.2	--
Pier 1	61.3	--	--	--	487.6	0.0	--	8.7	8.7	478.9	--
Pier 2	126.6	--	--	--	485.2	0.0	--	22.5	22.5	462.7	--
Right abutment toe	164.2	--	--	--	487.1	0.0	13.3	--	13.3	473.8	--
Right abutment	181.5	--	494.2	--	492.2	--	--	--	--	--	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure GRAFTH00010020 on Town Highway 1, crossing Saxtons River, Grafton, 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 9,300 cubic-feet per second											
Left abutment	0.0	--	496.3	--	493.8	--	--	--	--	--	--
Left abutment toe	14.8	--	--	--	490.2	0.9	14.2	--	15.1	475.1	--
Pier 1	61.3	--	--	--	487.6	0.9	--	10.1	11.0	476.6	--
Pier 2	126.6	--	--	--	485.2	0.9	--	26.0	26.9	458.3	--
Right abutment toe	164.2	--	--	--	487.1	0.9	14.9	--	15.8	471.3	--
Right abutment	181.5	--	494.2	--	492.2	--	--	--	--	--	--

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

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U.S. Geological Survey, 1984, Saxtons River, Vermont 7.5 by 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Aerial photographs, 1977, Contour interval, 6 meters, Scale 1:25,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File graf020.wsp
T2        Hydraulic analysis for structure GRAFTH00010020   Date: 28-JAN-97
T3        Town Highway 1 (VT 121 and FAS 125) over Saxtons River, Grafton    EMB
*
J1         * * 0.002
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           6130.0   9300.0
SK          0.0105   0.0105
*
XS   EXITX   -130
GR         -108.8, 520.39    -86.7, 508.58    -76.1, 507.90    -57.1, 507.73
GR          -21.5, 502.28     11.9, 500.18     25.7, 491.43     65.7, 486.79
GR           72.8, 485.01     75.0, 484.30     79.1, 483.80     83.6, 484.35
GR           93.9, 484.18    103.3, 483.79    107.8, 484.04    110.5, 484.35
GR          112.7, 484.60    124.3, 485.32    137.7, 484.88    147.1, 486.85
GR          178.4, 489.31    288.0, 488.72    320.6, 493.63    435.0, 492.20
GR          443.9, 495.67    445.0, 499.45
*           442.3, 490.17
*
N           0.045        0.050        0.045        0.04
SA                 65.7        178.4        320.6
*
XS   FULLV      0
GR         -108.8, 520.48    -86.7, 508.67    -76.1, 507.99    -57.1, 507.82
GR          -21.5, 502.37     11.9, 500.27     25.7, 491.52     65.7, 486.88
GR           74.8, 486.43     86.0, 485.85     90.1, 485.59     97.2, 485.54
GR          105.1, 484.18    109.8, 483.66    115.4, 484.06    118.9, 484.61
GR          124.0, 484.53    134.3, 487.36    144.0, 486.74    147.4, 485.07
GR          149.6, 484.66    155.2, 483.86    158.0, 484.10    160.9, 484.99
GR          178.4, 493.72    392.3, 492.29    401.2, 495.76    402.3, 499.54
*
N           0.045        0.045        0.040
SA                 65.7        178.4
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    495.24     45.0
GR            0.0, 496.28      1.3, 493.76     14.8, 490.24     21.8, 488.14
GR           43.6, 486.81     47.9, 485.83     57.5, 487.22     65.1, 488.07
GR           74.8, 486.43     86.0, 485.85     90.1, 485.59     97.2, 485.54
GR          105.1, 484.18    109.8, 483.66    115.4, 484.06    118.9, 484.61
GR          124.0, 484.53    134.3, 487.36    144.0, 486.74    147.4, 485.07
GR          149.6, 484.66    155.2, 483.86    158.0, 484.10    160.9, 484.99
GR          164.2, 487.06    181.1, 492.15    181.5, 494.19      0.0, 496.28
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV
CD           3     50.3     2.0     499.2
*
PW          484.67, 4.2   485.34, 4.2   485.34, 8.4   494.82, 6.4
PW          494.82, 3.2   495.57, 3.2   495.57, 0.0
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     25      30.6     1
GR         -354.0, 516.35   -332.8, 506.14   -321.8, 505.89   -273.6, 503.85
GR         -173.8, 500.62    -90.7, 500.40    -47.8, 500.10     -7.2, 500.07
GR           -3.3, 500.23     -3.2, 500.98      0.0, 501.07    180.8, 498.81
GR          183.4, 498.80    183.5, 498.14    192.4, 502.47
*
*           244.6, 496.61    280.5, 495.90    366.8, 494.15    372.4, 493.96
*           392.3, 494.48    410.0, 503.13    383.4, 490.13
*
XT   APTEM    254
GR         -133.1, 503.61   -118.0, 495.75    -93.5, 494.74    -14.4, 495.33
GR           47.9, 495.43     75.0, 493.10     91.0, 489.85    118.1, 486.89
GR          119.8, 486.64    127.4, 486.18    131.8, 486.48    136.9, 485.86
GR          141.5, 486.52    149.9, 486.10    152.8, 486.80    157.1, 488.08
GR          172.0, 509.32
*
*             0.2, 500.83     31.3, 499.14
AS   APPRO    179   * * *  0.00735
GT
N           0.050        0.044
SA                 75.0
*
*
```

```
HP 2 BRIDG 491.70 * * 6130
HP 1 BRIDG 495.24 1 495.24
HP 2 BRIDG 495.24 * * 6130
HP 2 BRIDG 495.92 * * 6130
HP 1 APPRO 496.33 1 496.33
HP 2 APPRO 496.33 * * 6130
*
HP 2 BRIDG 492.67 * * 9300
HP 1 BRIDG 495.24 1 495.24
HP 2 BRIDG 495.24 * * 9300
HP 2 BRIDG 498.13 * * 9300
HP 1 APPRO 498.68 1 498.68
HP 2 APPRO 498.68 * * 9300
*
EX
ER
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APPENDIX B:

WSPRO OUTPUT FILE

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

      WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
              1     1023    100393    63    200                        23302
    495.24          1023    100393    63    200  1.00      1    182    23302

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        495.24     0.5   181.5  1023.0  100393.    6130.   5.99

 X STA.        0.5       22.5       31.1       38.5       45.3       51.3
  A(I)             64.6       45.2       41.6       40.2       38.6
  V(I)             4.75       6.79       7.38       7.63       7.94

 X STA.       51.3       58.0       65.7       73.2       79.4       85.5
  A(I)             39.9       41.3       41.5       39.4       39.7
  V(I)             7.68       7.42       7.38       7.78       7.72

 X STA.       85.5       92.0      100.4      107.3      114.0      121.3
  A(I)             43.8       57.3       52.7       52.8       54.2
  V(I)             7.00       5.35       5.82       5.80       5.65

 X STA.      121.3      129.5      141.5      151.3      159.4      181.5
  A(I)             57.1       66.0       61.7       59.3       86.2
  V(I)             5.37       4.64       4.97       5.17       3.55

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        495.92     0.2   181.5  1052.0   92539.    6130.   5.83

 X STA.        0.2       19.4       26.8       34.3       43.0       50.4
  A(I)             58.8       40.9       43.9       53.6       49.6
  V(I)             5.21       7.49       6.98       5.72       6.18

 X STA.       50.4       58.8       69.2       77.8       85.4       92.8
  A(I)             52.9       57.2       53.5       49.7       49.8
  V(I)             5.79       5.35       5.73       6.16       6.15

 X STA.       92.8      100.0      106.4      112.1      118.3      125.1
  A(I)             49.6       47.7       45.5       47.4       49.6
  V(I)             6.18       6.43       6.73       6.46       6.17

 X STA.      125.1      134.2      144.7      152.7      160.4      181.5
  A(I)             55.7       57.1       53.9       55.9       79.5
  V(I)             5.50       5.36       5.68       5.48       3.86

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        491.70     9.2   179.6   611.8   58311.    6130.  10.02

 X STA.        9.2       33.5       44.0       52.2       62.4       74.2
  A(I)             47.6       34.2       32.1       32.5       35.6
  V(I)             6.44       8.97       9.55       9.42       8.62

 X STA.       74.2       81.9       89.0       95.3      101.3      106.2
  A(I)             29.8       28.9       27.4       27.0       25.5
  V(I)            10.28      10.60      11.18      11.34      12.03

 X STA.      106.2      110.6      115.0      119.8      124.9      131.7
  A(I)             24.6       24.4       24.8       25.8       28.6
  V(I)            12.48      12.56      12.35      11.89      10.70

 X STA.      131.7      141.7      149.1      154.1      159.5      179.6
  A(I)             32.5       29.9       26.2       29.2       45.2
  V(I)             9.43      10.26      11.71      10.49       6.78

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     179.

      WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
              1      352     15505   195    196                         2680
              2      751    101815    88     94                        12430
    496.33          1103    117320   283    289  1.43   -119    163    10314

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     179.

          WSEL     LEW     REW    AREA        K        Q    VEL
        496.33  -120.2   163.3  1102.8  117320.    6130.   5.56

 X STA.     -120.2      -47.0       47.0       80.6       90.2       96.8
  A(I)            132.8      146.7       96.8       56.2       48.5
  V(I)             2.31       2.09       3.17       5.45       6.32

 X STA.       96.8      102.4      107.5      112.0      116.2      120.0
  A(I)             44.8       43.5       40.8       40.1       38.2
  V(I)             6.84       7.05       7.51       7.65       8.02

 X STA.      120.0      123.7      127.2      130.7      134.3      137.7
  A(I)             38.4       36.8       37.2       37.5       37.7
  V(I)             7.98       8.32       8.25       8.18       8.14

 X STA.      137.7      141.3      145.0      148.9      153.0      163.3
  A(I)             38.1       38.8       40.7       43.2       66.1
  V(I)             8.05       7.91       7.53       7.09       4.64
```

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

     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1     1023    100393    63    200                        23302
   495.24          1023    100393    63    200  1.00      1    182    23302

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

         WSEL     LEW     REW    AREA         K        Q    VEL
       495.24     0.5   181.5  1023.0  100393.    9300.   9.09

X STA.        0.5       22.5       31.1       38.5       45.3       51.3
  A(I)            64.6       45.2       41.6       40.2       38.6
  V(I)            7.20      10.30      11.19      11.57      12.05

X STA.       51.3       58.0       65.7       73.2       79.4       85.5
  A(I)            39.9       41.3       41.5       39.4       39.7
  V(I)           11.65      11.25      11.20      11.80      11.72

X STA.       85.5       92.0      100.4      107.3      114.0      121.3
  A(I)            43.8       57.3       52.7       52.8       54.2
  V(I)           10.63       8.11       8.83       8.80       8.57

X STA.      121.3      129.5      141.5      151.3      159.4      181.5
  A(I)            57.1       66.0       61.7       59.3       86.2
  V(I)            8.14       7.04       7.54       7.85       5.39

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

         WSEL     LEW     REW    AREA         K        Q    VEL
       498.13     0.0   181.5  1056.0   87782.    9300.   8.81

X STA.        0.0       22.3       32.1       40.9       48.8       56.4
  A(I)            77.8       56.9       53.7       51.5       49.6
  V(I)            5.98       8.17       8.66       9.04       9.37

X STA.       56.4       65.8       74.7       82.4       89.6       96.6
  A(I)            53.0       52.0       49.7       48.1       47.6
  V(I)            8.78       8.94       9.36       9.67       9.78

X STA.       96.6      103.1      108.9      114.5      120.6      127.4
  A(I)            46.5       44.8       44.3       45.6       47.9
  V(I)            9.99      10.38      10.50      10.21       9.70

X STA.      127.4      136.8      146.5      153.6      160.9      181.5
  A(I)            54.1       54.4       50.0       52.9       75.6
  V(I)            8.60       8.54       9.30       8.79       6.15

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

         WSEL     LEW     REW    AREA         K        Q    VEL
       492.67     5.5   181.2   730.7   76595.    9300.  12.73

X STA.        5.5       31.2       41.8       50.2       59.7       71.0
  A(I)            57.1       41.0       37.6       38.8       40.2
  V(I)            8.14      11.34      12.37      11.97      11.57

X STA.       71.0       79.3       86.6       93.3       99.6      105.1
  A(I)            35.9       34.7       33.0       32.5       30.9
  V(I)           12.94      13.41      14.11      14.33      15.05

X STA.      105.1      109.9      114.6      119.7      125.1      132.3
  A(I)            29.9       29.2       30.4       30.9       34.4
  V(I)           15.57      15.92      15.32      15.06      13.51

X STA.      132.3      141.7      149.1      154.7      160.5      181.2
  A(I)            37.1       35.0       33.1       35.0       54.1
  V(I)           12.55      13.28      14.04      13.27       8.59

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     179.

     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      816     61920   200    201                         9356
             2      960    150346    90     97                        17809
   498.68          1776    212265   290    297  1.33   -124    165    21617

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     179.

         WSEL     LEW     REW    AREA         K        Q    VEL
       498.68  -124.7   164.9  1776.1  212265.    9300.   5.24

X STA.     -124.7      -84.6      -53.0      -17.7       18.8       56.6
  A(I)           148.8      136.4      143.2      141.3      147.6
  V(I)            3.12       3.41       3.25       3.29       3.15

X STA.       56.6       77.6       88.3       95.8      102.5      108.4
  A(I)           115.1       82.8       71.1       68.4       64.4
  V(I)            4.04       5.61       6.54       6.80       7.22

X STA.      108.4      113.8      118.7      123.5      128.0      132.6
  A(I)            62.9       60.1       59.8       58.6       59.8
  V(I)            7.39       7.73       7.78       7.94       7.77

X STA.      132.6      137.1      141.9      146.8      152.1      164.9
  A(I)            59.0       61.2       63.7       68.7      103.0
  V(I)            7.88       7.59       7.30       6.76       4.52
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File graf020.wsp
        Hydraulic analysis for structure GRAFTH00010020   Date: 28-JAN-97
        Town Highway 1 (VT 121 and FAS 125) over Saxtons River, Grafton    EMB
           *** RUN DATE & TIME: 03-26-97  10:27

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

EXITX:XS   ******     33      812  1.04 *****  491.68  490.31    6130  490.64
      -129 ******    301    59821  1.18 ***** *******    0.83    7.55

FULLV:FV      130     25      741  1.13  1.10  492.83 *******    6130  491.70
         0    130    174    74130  1.07  0.05    0.00    0.68    8.27
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
               FNTEST,FR#,WSEL,CRWS =  0.80    1.08    492.84     493.06
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                    WSLIM1,WSLIM2,DELTAY =  491.20     508.77    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                    WSLIM1,WSLIM2,CRWS =  491.20     508.77     493.06
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
               ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                    WSBEG,WSEND,CRWS =  493.06     508.77     493.06

APPRO:AS      179     69      468  2.68 *****  495.75  493.06    6130  493.06
       179    179    161    47417  1.01 ***** *******    1.03   13.10
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===225 NO ENERGY BALANCE IN 15 ITERATIONS.
                     FLOW,Q =    1      6130.
               WS1,WSSD,WS3 =  493.42        0.00      491.69
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                    WS,QBO,QRD =  503.07          1.       6129.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===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      130      1      949  0.65 *****  495.89  491.22    6131  495.24
         0 ******    182   100393  1.00 ***** *******    0.50    6.46

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   2.  0.403  0.073  495.24 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      25.        <<<<<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      129   -119     1104  0.69  0.41  497.02  493.06    6130  496.33
       179    129    163   117429  1.43  0.00    0.00    0.59    5.55

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   495.93

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -130.    33.   301.   6130.   59821.     812.    7.55  490.64
   FULLV:FV       0.    25.   174.   6130.   74130.     741.    8.27  491.70
   BRIDG:BR       0.     1.   182.   6131.  100393.     949.    6.46  495.24
   RDWAY:RG      25.**************      0.        0.*********    1.00********
   APPRO:AS      179.  -120.   163.   6130.  117429.    1104.    5.55  496.33

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL     WSEL
   EXITX:XS    490.31    0.83  483.79  520.39************  1.04  491.68  490.64
   FULLV:FV  ********    0.68  483.66  520.48  1.10  0.05  1.13  492.83  491.70
   BRIDG:BR    491.22    0.50  483.66  496.28************  0.65  495.89  495.24
   RDWAY:RG  ****************  498.14  516.35************  0.25  498.75********
   APPRO:AS    493.06    0.59  485.31  508.77  0.41  0.00  0.69  497.02  496.33
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File graf020.wsp
        Hydraulic analysis for structure GRAFTH00010020   Date: 28-JAN-97
        Town Highway 1 (VT 121 and FAS 125) over Saxtons River, Grafton    EMB
           *** RUN DATE & TIME: 03-26-97  10:27

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

EXITX:XS   ******     25     1090  1.29 *****  492.93  491.22    9300  491.65
      -129 ******    307    90693  1.14 ***** *******    0.82    8.54

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.92     492.67     491.83
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.15     520.48    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.15     520.48     491.83

FULLV:FV      130     24      898  1.80  1.28  494.46  491.83    9300  492.67
         0    130    393    97182  1.08  0.26    0.00    0.92   10.36
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.30     493.92     495.94
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.17     508.77    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.17     508.77     495.94
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   495.94     508.77     495.94

APPRO:AS      179   -118      993  1.93 *****  497.87  495.94    9300  495.94
       179    179    163   104921  1.42 ***** *******    1.05    9.37
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===230 REJECTED FLOW CLASS 1 SOLUTION.
             WS1,WSSD,WS3 =   495.94        0.00      492.75
                     CRWS =   495.94    ********      492.75
                     YMAX =   508.77    ********      496.28
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   503.92          0.      9300.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===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      130      1      949  1.50 *****  496.74  492.75    9308  495.24
         0 ******    182   100393  1.00 ***** *******    0.76    9.81

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   2.  0.496  0.073  495.24 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      25.         <<<<<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      129   -124     1775  0.57  0.55  499.24  495.94    9300  498.68
       179    135    165   212033  1.33  0.00    0.00    0.43    5.24

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   498.39

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -130.    25.   307.   9300.   90693.    1090.    8.54  491.65
   FULLV:FV       0.    24.   393.   9300.   97182.     898.   10.36  492.67
   BRIDG:BR       0.     1.   182.   9308.  100393.     949.    9.81  495.24
   RDWAY:RG      25.**************      0.       0.       0.    1.00********
   APPRO:AS     179.  -125.   165.   9300.  212033.    1775.    5.24  498.68

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************

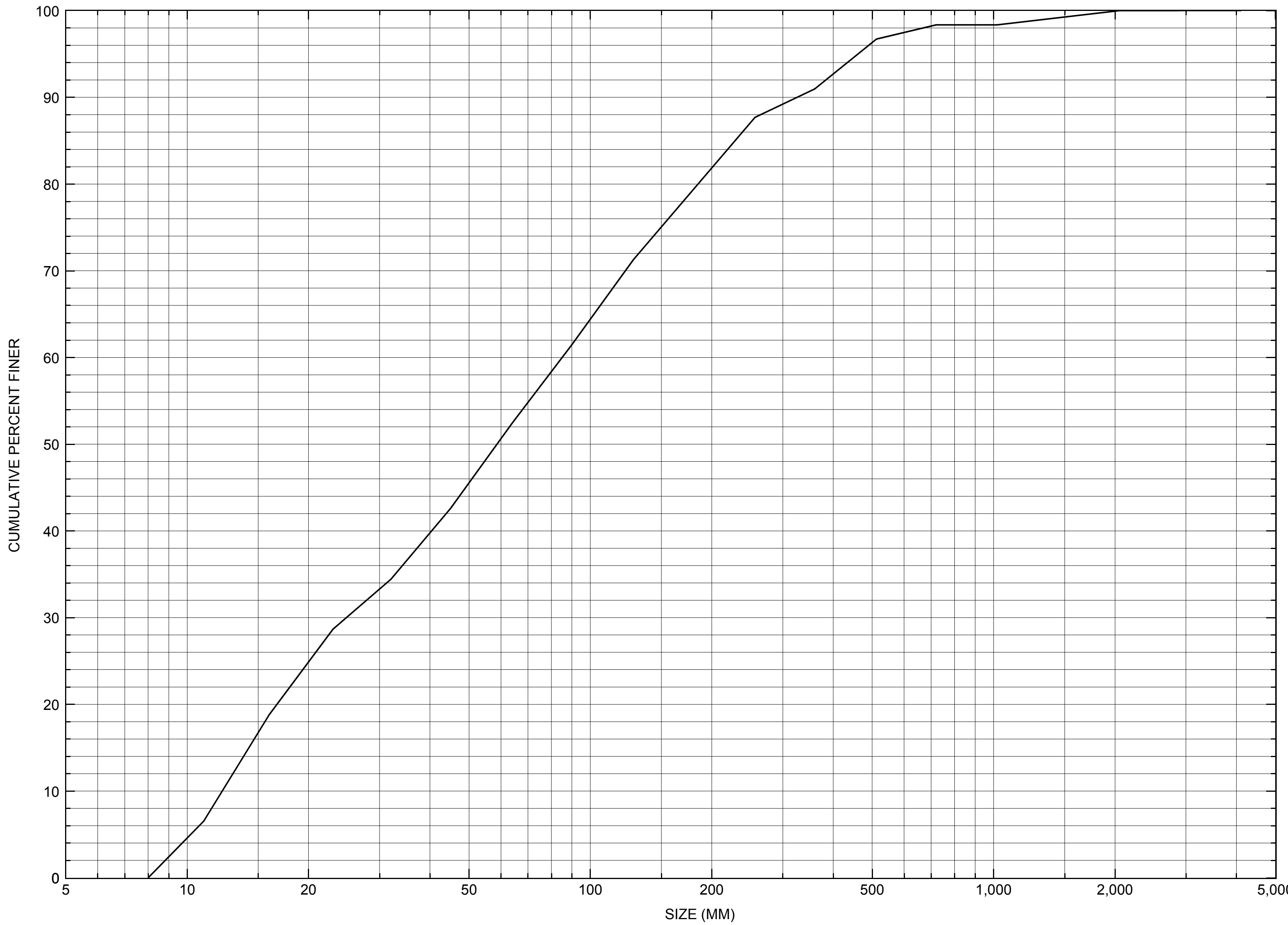
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    491.22    0.82  483.79  520.39************  1.29  492.93  491.65
   FULLV:FV    491.83    0.92  483.66  520.48  1.28  0.26  1.80  494.46  492.67
   BRIDG:BR    492.75    0.76  483.66  496.28************  1.50  496.74  495.24
   RDWAY:RG  ****************  498.14  516.35************  0.57  498.96********
   APPRO:AS    495.94    0.43  485.31  508.77  0.55  0.00  0.57  499.24  498.68
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure GRAFTH00010020, in Grafton, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number GRAFTH00010020

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 29 / 95

Highway District Number *(I - 2; nn)* 02

County *(FIPS county code; I - 3; nnn)* 025

Town *(FIPS place code; I - 4; nnnnn)* 28900

Mile marker *(I - 11; nnn.nnn)* 002960

Waterway *(I - 6)* SAXTON RIVER

Road Name *(I - 7):* -

Route Number TH001

Vicinity *(I - 9)* 1.2 MI E JCT. VT.35 N

Topographic Map Saxtons.River

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43106

Longitude *(i - 17; nnnnn.n)* 72352

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20012500201306

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

Maximum span length *(I - 48; nnnn)* 0062

Year built *(I - 27; YYYY)* 1937

Structure length *(I - 49; nnnnnn)* 000191

Average daily traffic, ADT *(I - 29; nnnnnn)* 000780

Deck Width *(I - 52; nn.n)* 306

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

Channel & Protection *(I - 61; n)* 6

Opening skew to Roadway *(I - 34; nn)* 50

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)* 1972

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

Clear span (*nnn.n ft*) -

Number of spans *(I - 45; nnn)* 003

Vertical clearance from streambed (*nnn.n ft*) 007.5

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

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

Comments:

The structural inspection report of 8/9/94 indicates the structure is a steel stringer type bridge with a concrete deck and an asphalt roadway surface. The bridge is part of the Federal Aid System listed under the route number, FAS 125. The bridge was widened in 1972, with extensions made to the piers and abutment walls on the downstream side. The abutment walls are concrete, which have a few randomly distributed minor cracks and stains. The original portion of concrete along the pier caps are reported as having some random scaling and rust staining with the most extensive scaling on the left side of the right pier (pier 1). The footing of pier 1 is noted as slightly exposed at the up- and downstream ends. **(Continued, page 32)**

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:

The waterway is reported to proceed straight through the structure. Currently, all of the flow is on the pier 1 side of the middle span. The streambed consists of stone and gravel with some random boulders, according to the report. There is some small vegetation noted growing beneath the left and right spans. Riprap is reported along the abutment walls and natural boulder material is noted around the piers. The report indicates there is no streambank erosion evident.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **33.86** mi^2 Lake and pond area **0.14** mi^2

Watershed storage *(ST)* **0.6** %

Bridge site elevation **768** ft Headwater elevation **2854** ft

Main channel length **10.50** mi

10% channel length elevation **807** ft 85% channel length elevation **1791** ft

Main channel slope *(S)* **124.97** 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: 10/7/96
Computerized by: EW Date: 10/8/96
Reviewd by: EB Date: 2/25/97

Structure Number GRAFTH00010020

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. BURNS Date *(MM/DD/YY)* 08 / 21 / 1996

2. Highway District Number 02 Mile marker 002960

County Windham (025) Town Grafton (28900)

Waterway *(I - 6)* Saxtons River Road Name -

Route Number TH001 Hydrologic Unit Code: 01080107

3. Descriptive comments:

Located 1.2 miles east of the intersection of VT 35 with TH 1 at the intersecton of Pickel Street / Cambridgeport Road and Fisher Hill Road. There was a flood this past June; the Grafton Fire Department has documented the event. The water was even with the low steel elevation. The bridge deck is curved and banked.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 6 LBDS 5 RBDS 5 Overall 5
*(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 2 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*

7. Bridge length 191 *(feet)* Span length 62 *(feet)* Bridge width 30.6 *(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 -- US right --

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

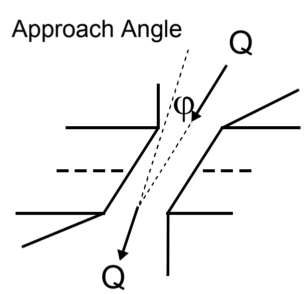
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

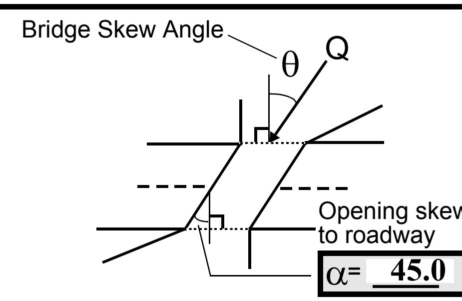
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: 0 16. Bridge skew: 40





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 30 feet US *(US, UB, DS)* to 20 feet UB

Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 170 feet DS *(US, UB, DS)* to 190 feet DS

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

18. Bridge Type: **1b**

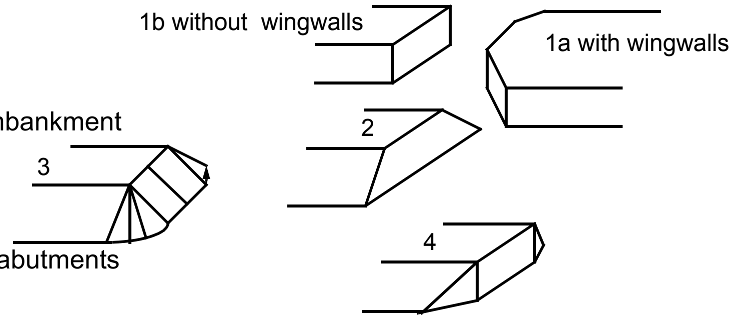
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

The surface cover upstream consists of trees mainly. The tree cover is divided by a gravel road and a house on the right overbank upstream and by TH 1 and an open area of grassland on the upstream left overbank. Surface cover on the DSRB consists of shrubs and brush with TH1 on the overbank parallel to channel. Surface cover on the DSLB is shrubs and brush with a gravel road on the overbank and houses and lawns on a steep hill.

Bridge dimensions measured at the time of the site visit were: bridge length = 187.5 feet (DS bridge face) and 195 feet (US bridge face); maximum bridge span = 65 feet; and bridge width = 40 feet between the outside edges of the curbs.

There is a culvert under Fisher Hill Road which runs into a gully along the downstream left road embankment; it enters the stream on top of the side bar. There is a dry channel along the bankward side of the side bar.

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
179.5	3.5			1.5	2	4	452	154	1	2

23. Bank width **10.0** 24. Channel width **15.0** 25. Thalweg depth **82.0** 29. Bed Material **3452**

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.):

From 50 feet upstream to the upstream bridge face, the right bank is eroded exposing many large boulders. From 190 feet upstream to 50 feet upstream, the right bank is moderately eroded with silt and clay bank material.

From 90 feet downstream to the upstream bridge face, the stream bed is mostly gravel and sand. Further upstream, the bed material consists of more cobbles and boulders with the gravel and sand.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 213 35. Mid-bar width: 24

36. Point bar extent: 300 feet US (US, UB) to 173 feet DS (US, UB, DS) positioned 0 %LB to 40 %RB

37. Material: 5234

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

This side bar goes under the bridge between the left abutment and left pier, and is also streamward of the left pier a bit. Under the bridge, the bar is mostly sand along the abutment. There is another point bar from 400 feet US to 300 feet US, positioned 75% LB to 100% RB. The mid-bar distance is 370 feet upstream, where it is 28 feet wide. It is comprised of cobbles, boulders, and gravel with sand along the bank.

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: 213 42. Cut bank extent: 300 feet US (US, UB) to 108 feet US (US, UB, DS)

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

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

The cut-bank is very steep and high, only a few trees lean into stream and most roots are exposed. Where no trees exists along the bank, it looks like a landslide occurred.
Another cut-bank exists on the left bank from 360 feet upstream to 300 feet upstream. The bank has eroded and is steep with only large bank material remaining and exposed tree roots.

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

There is local scour around the large boulders in the stream. Where the bed is scoured around the boulders, sand and gravel have built-up downstream of boulders.

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
62.0		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.):

3452

Most of the channel flow goes between the right abutment and right pier. Between the piers, cobbles and boulders have built-up such that the water flows along the left side of the right pier. The stream bed drops quite a bit from the upstream bridge face to the downstream bridge face, as well as from left to right.

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

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

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

70. Debris and Ice Comments:

2

There is debris on the tops of banks, at the piers, in the protection along the abutments, and on the downstream point bar.

Capture efficiency is high because of the two piers and low clearance.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		-	90	0	0	-	-	90.0
RABUT	1	5	90			0	0	128.5

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.):

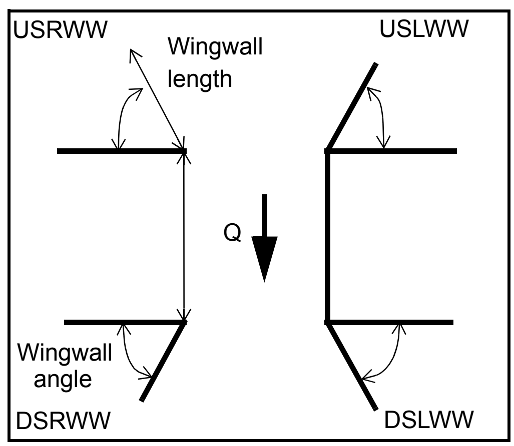
-

-

1

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						105.5	
USRWW:	N		-		-	2.0	
DSLWW:	-		-		N	53.5	
DSRWW:	-		-		-	47.0	



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	-	-	N	-	-	-	1	1
Condition	N	-	-	-	-	-	1	1
Extent	-	-	-	-	-	1	2	-

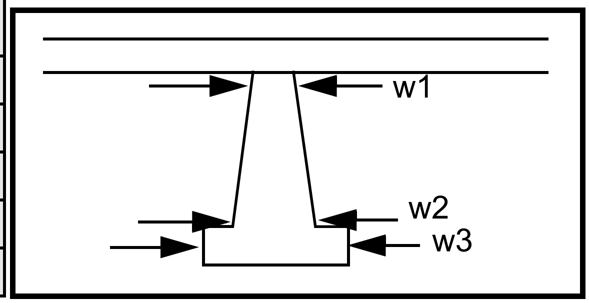
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	-	-	-	-	-	-
Pier 2	-	3.2	4.2	-	495.6	487.6
Pier 3	-	3.2	4.2	-	494.8	485.2
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	the	crete		0	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	right	and		0	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	abut	reba	Y	-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	ment	r.	MC	-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	pro-		L	MC	*Y- yes; N- no*
91. Attack ∠ (BF)	tec-		1	R	
92. Pushed	tion		2	1	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	there		1	2	
95. Cross-members	are		N	1	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	piece		-	N	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	s of		-	20	
98. Exposure depth	con-		-	LB	

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

-
0
2
0
2

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) **46.3**   Thalweg depth (Amb) **41.2**   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.):

The abutments and piers are not parallel. There are pools in remanant holes immediately upstream of each pier nose. There is a side bar on both sides of pier 1. Pier 2 has a large tree along the entire left side and a side bar along the right side. There are two footings exposed on the left side of pier 2. The uppermost footing of pier 2 is exposed 1 foot for the entire length of the pier on the left side only. The lower footing is also exposed one foot for the downstream half of pier 2 on the left side and the downstream end. The total footing exposure at the downstream end of pier 2 is two feet.

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):

1
1
254
254
1

106. Point/Side bar present? 1 *(Y or N. if N type ctrl-n pb)* Mid-bar distance: 3452 Mid-bar width: 5

Point bar extent: 2 feet 1 *(US, UB, DS)* to 1 feet Si *(US, UB, DS)* positioned mil %LB to ar %RB

Material: to the

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

upstream channel, the streambed here is mostly sand and gravel from 70 feet downstream to 150 feet downstream. Cobbles and boulders are more prominent with the sand and gravel greater than 150 feet downstream.

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

Cut bank extent: t feet ba *(US, UB, DS)* to nk feet pro *(US, UB, DS)*

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

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

tion extends from the downstream bridge face to 15 feet downstream. The right bank and the right side of the mid-channel bar is eroded and scalloped from the downstream bridge face to about 64 feet downstream.

The left bank protection is a stone wall extending from 184 feet downstream to 237 feet downstream. There is

Is channel scour present? no *(Y or if N type ctrl-n cs)* Mid-scour distance: bank

Scour dimensions: Length pro- Width tec- Depth: tion Positioned fro %LB to m %RB

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

the bridge to 184 feet downstream. Downstream of the wall along the left bank there are native boulders.

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

Confluence 1: Distance - Enters on NO *(LB or RB)* Type DR (***1***- *perennial;* ***2***- *ephemeral)*

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

Confluence comments (eg. confluence name):

TURE

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

1- *Constructed*
2- *Stable*
3- *Aggraded*
4- *Degraded*
5- *Laterally unstable*
6- *Vertically and laterally unstable*

108. Evolution comments *(Channel evolution not considering bridge effects; See HEC-20, Figure 1 for geomorphic descriptors)*:

Y
350
90
120
DS
700
DS
35
100
4325

109. G. Plan View Sketch

T

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:	GRAFTH00010020	Town:	Grafton
Road Number:	TH 1	County:	Windham
Stream:	Saxtons River		

Initials EMB   Date: 2/25/97 Checked: SAO

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	6130	9300	N/A
Main Channel Area, ft2	751	960	0
Left overbank area, ft2	352	816	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	88	90	0
Top width L overbank, ft	195	200	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.1923	0.1923	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.5	10.7	ERR
y1, average depth, LOB, ft	1.8	4.1	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	117320	212265	0
Conveyance, main channel	101815	150346	0
Conveyance, LOB	15505	61920	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	-0.0005	ERR
Qm, discharge, MC, cfs	5319.9	6587.1	ERR
Ql, discharge, LOB, cfs	810.1	2712.9	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	7.1	6.9	ERR
Vl, mean velocity, LOB, ft/s	2.3	3.3	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	9.2	9.6	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

Armoring
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	6130	9300	N/A
Main channel area (DS), ft2	559.8	672	0
Main channel width (normal), ft	120.8	120.8	0.0
Cum. width of piers, ft	7.4	7.4	0.0
Adj. main channel width, ft	113.4	113.4	0.0
D90, ft	1.0660	1.0660	0.0000
D95, ft	1.5110	1.5110	0.0000
Dc, critical grain size, ft	0.7426	1.0857	ERR
Pc, Decimal percent coarser than Dc	0.152	0.098	0.000
Depth to armoring, ft	12.47	29.88	ERR

Clear Water Contraction Scour in MAIN CHANNEL

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

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	6130	9300	N/A
(Q) discharge thru bridge, cfs	6130	9300	0
Main channel conveyance	100393	100393	0
Total conveyance	100393	100393	0
Q2, bridge MC discharge,cfs	6130	9300	ERR
Main channel area, ft2	949	949	0
Main channel width (normal), ft	120.8	120.8	0.0
Cum. width of piers in MC, ft	7.4	7.4	0.0
W, adjusted width, ft	113.4	113.4	0
y_bridge (avg. depth at br.), ft	8.37	8.37	ERR
Dm, median (1.25*D50), ft	0.240375	0.240375	0
y2, depth in contraction,ft	5.69	8.13	ERR
ys, scour depth (y2-ybridge), ft	-2.68	-0.24	N/A

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	6130	9300	N/A
Q, thru bridge MC, cfs	6130	9300	N/A
Vc, critical velocity, ft/s	9.25	9.60	N/A
Va, velocity MC approach, ft/s	7.08	6.86	N/A
Main channel width (normal), ft	120.8	120.8	0.0
Cum. width of piers in MC, ft	7.4	7.4	0.0
W, adjusted width, ft	113.4	113.4	0.0
qbr, unit discharge, ft2/s	54.1	82.0	ERR
Area of full opening, ft2	949.0	949.0	0.0
Hb, depth of full opening, ft	8.37	8.37	ERR
Fr, Froude number, bridge MC	0.5	0.76	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	559.8	672	N/A
**Hb, depth at downstream face, ft	4.94	5.93	ERR
**Fr, Froude number at DS face	0.87	1.00	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	495.24	495.24	0
Elevation of Bed, ft	486.87	486.87	N/A
Elevation of Approach, ft	496.33	498.68	0
Friction loss, approach, ft	0.41	0.55	0
Elevation of WS immediately US, ft	495.92	498.13	0.00
ya, depth immediately US, ft	9.05	11.26	N/A
Mean elevation of deck, ft	499.2	499.2	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.98	0.93	ERR
**Cc, for downstream face (<=1.0)	0.79	0.79	0.79
Ys, scour w/Chang equation, ft	-2.41	0.86	N/A
Ys, scour w/Umbrell equation, ft	0.12	1.76	N/A

**=for UNsubmerged orifice flow only.

**Ys, scour w/Chang equation, ft	2.46	4.89	N/A
**Ys, scour w/Umbrell equation, ft	3.55	4.21	ERR

In UNsubmerged orifice flow, an adjusted scour depth using the Laursen equation results and the estimated downstream bridge face properties can also be computed (ys=y2-ybridgeDS)

y2, from Laursen's equation, ft	5.69	8.13	0.00
WSEL at downstream face, ft	491.70	492.67	--
Depth at downstream face, ft	4.83	5.80	ERR
Ys, depth of scour (Laursen), ft	0.86	2.33	N/A

Abutment Scour

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

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	6130	9300	N/A	6130	9300	N/A
a', abut.length blocking flow, ft	150.4	154.9	0	12.3	13.9	0
Ae, area of blocked flow ft2	253.3	614.2	0	87.2	117.3	0
Qe, discharge blocked abut.,cfs	558.2	2000	0	456	561.5	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.20	3.26	ERR	5.23	4.79	ERR
ya, depth of f/p flow, ft	1.68	3.97	ERR	7.09	8.44	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	45	45	45	135	135	135
K2	0.91	0.91	0.91	1.05	1.05	1.05
Fr, froude number f/p flow	0.299	0.288	ERR	0.346	0.290	ERR
ys, scour depth, ft	8.04	14.21	N/A	13.28	14.91	N/A

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

a'(abut length blocked, ft)	150.4	154.9	0	12.3	13.9	0
y1 (depth f/p flow, ft)	1.68	3.97	ERR	7.09	8.44	ERR
a'/y1	89.30	39.07	ERR	1.73	1.65	ERR
Skew correction (p. 49, fig. 16)	0.80	0.80	0.80	1.10	1.10	1.10
Froude no. f/p flow	0.30	0.29	N/A	0.35	0.29	N/A
Ys w/ corr. factor K1/0.55:						
vertical	6.58	15.30	ERR	ERR	ERR	ERR
vertical w/ ww's	5.40	12.55	ERR	ERR	ERR	ERR
spill-through	3.62	8.42	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number (DS)	0.87	1.00	0.00	0.87	1.00	0.00
y, depth of flow in bridge (DS), ft	4.94	5.93	ERR	4.94	5.93	ERR
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	N/A	ERR	ERR	N/A
Fr>0.8 (vertical abut.)	1.98	2.48	ERR	1.98	2.48	ERR
Fr<=0.8 (spillthrough abut.)	ERR	ERR	N/A	ERR	ERR	N/A
Fr>0.8 (spillthrough abut.)	1.75	2.19	ERR	1.75	2.19	ERR

Pier Scour

ys/y1=2.0*K1*K2*K3*K4*(a/y1)^0.65*Fr1^0.43
(Richardson and others, 1995, p. 36, eq. 21)

K1, corr. factor for pier nose shape
Sharp nose, 0.9; round nose, cylinder, or cylinder grp., 1.0; square nose, 1.1

K2, corr. factor attack angle (see Table 3, p 37)
K2=[cos(attackangle)+L/a*sin(attackangle)]^0.65

K3, corr. factor for bed condition
Clear-water, plane bed, antidune, 1.1; med. dunes, 1.1-1.2 (see Tab.4,p37)

K4, corr. factor for armoring (the following equations are in Si units)
K4=[1-0.89*(1-Vr)^2]^0.5
Vr=(V1-Vi)/(Vc90-Vi)

V1=0.645*((D50/a)^0.053)*Vc50
Vc=6.19*(y^1/6)*(Dc^1/3)

Note for round nose piers:
ys<=2.4 times the pier width (a) for Fr<=0.8
ys<=3.0 times the pier width (a) for Fr>0.8

Pier 1	Q100	Q500	Qother
Pier stationing, ft	61.3	61.3	0
Area of WSPRO flow tube, ft2	38.6	44.3	0
Skewed width of flow tube, ft	4.24	3.96	0
y1, pier approach depth, ft	9.10	11.19	ERR
y1 in meters	2.775	3.410	N/A
V1, pier approach velocity, ft/s	7.94	10.5	0
a, pier width, ft	4.2	4.2	0
L, pier length, ft	46.3	46.3	0
Fr1, Froude number at pier	0.464	0.553	ERR
Pier attack angle, degrees	0	0	0
K1, shape factor	1	1	0
K2, attack factor	1.00	1.00	ERR
K3, bed condition factor	1.1	1.1	0
D50, ft	0.1923	0.1923	0
D50, m	0.05861	0.05861	0
D90, ft	1.066	1.066	0
D90, m	0.324901	0.324901	0
Vc50,critical velocity(D50),m/s	2.850	2.950	N/A
Vc90,critical velocity(D90),m/s	5.044	5.221	N/A
Vi,incipient velocity,m/s	1.561	1.616	ERR
Vr, velocity ratio	0.247	0.440	ERR
K4, armor factor	0.00	0.00	N/A
ys, scour depth (K4 applicable) ft	ERR	ERR	ERR
ys, scour depth (K4 not applied)ft	8.70	10.09	ERR

Pier 2	Q100	Q500	Qother
Pier stationing, ft	126.6	126.6	0
Area of WSPRO flow tube, ft2	38.6	44.3	0
Skewed width of flow tube, ft	4.24	3.96	0
y1, pier approach depth, ft	9.10	11.19	ERR
y1 in meters	2.775	3.410	N/A
V1, pier approach velocity, ft/s	7.94	10.5	0
a, pier width, ft	4.2	4.2	0
L, pier length, ft	41.2	41.2	0
Fr1, Froude number at pier	0.464	0.553	ERR
Pier attack angle, degrees	20	20	0
K1, shape factor	1	1	0
K2, attack factor	2.58	2.58	ERR
K3, bed condition factor	1.1	1.1	0
D50, ft	0.1923	0.1923	0
D50, m	0.05861	0.05861	0
D90, ft	1.066	1.066	0
D90, m	0.324901	0.324901	0
Vc50,critical velocity(D50),m/s	2.850	2.950	N/A
Vc90,critical velocity(D90),m/s	5.044	5.221	N/A
Vi,incipient velocity,m/s	1.561	1.616	ERR
Vr, velocity ratio	0.247	0.440	ERR
K4, armor factor	0.00	0.00	N/A
ys, scour depth, (K4 applicable) ft	ERR	ERR	ERR
ys, scour depth, (K4 not applied)ft	22.45	26.03	ERR

Pier rip-rap sizing
D50=0.692(K*V)^2/(Ss-1)*2*g
(Richardson and others, 1995, p.115, eq. 83)

Pier-shape coefficient (K), round nose, 1.5; square nose, 1.7
Characteristic avg. channel velocity, V, (Q/A):
(Mult. by 0.9 for bankward piers in a straight, uniform reach,
up to 1.7 for a pier in main current of flow around a bend)

Pier 1 Used 1.0 as V multiplier	Q100	Q500	Qother
K, pier shape coeff.	1.5	1.5	0
V, velocity on pier, ft/s	6.46	9.81	0
D50, median stone diameter, ft	0.61	1.41	0.00

Pier 2 Used 1.2 as V multiplier			
K, pier shape coeff.	1.5	1.5	0
V, velocity on pier, ft/s	7.75	11.8	0
D50, median stone diameter, ft	0.88	2.04	0.00