LEVEL II SCOUR ANALYSIS FOR BRIDGE 15 (SHEFTH00320015) on TOWN HIGHWAY 32, crossing an UNNAMED TRIBUTARY OF MILLER RUN, SHEFFIELD, VERMONT

Open-File Report 98-080

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

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By LORA K. STRIKER AND JAMES R. DEGNAN

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Pembroke, New Hampshire

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

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 15 (SHEFTH00320015) ON TOWN HIGHWAY 32, CROSSING AN UNNAMED TRIBUTARY OF MILLER RUN, SHEFFIELD, VERMONT

By **Lora K. Striker and James R. Degnan**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure SHEFTH00320015 on Town Highway 32 crossing an unnamed tributary of Miller Run in Sheffield, 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 (Federal Highway Administration, 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 White Mountain section of the New England physiographic province in north-eastern Vermont. The 6.1-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is predominantly pasture.

In the study area, the Unnamed Tributary of Miller Run has an incised, straight channel with a slope of approximately 0.03 ft/ft, an average channel top width of 50 ft and an average bank height of 8 ft. The channel bed material ranges from sand to boulder with a median grain size (D_{50}) of 66.2 mm (0.217 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 31, 1995, indicated that the reach was stable.

The Town Highway 32 crossing of the Unnamed Tributary of Miller Run is a 31-ft-long, two-lane bridge consisting of one 27-foot concrete slab span (Vermont Agency of Transportation, written communication, March 28, 1995). The opening length of the structure parallel to the bridge face is 26.7 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 35 degrees to the opening and the opening-skew-to-roadway is also 35 degrees.

Scour 0.5 ft in depth was observed along the upstream right wingwall during the Level I assessment. Scour protection measures at the site include type-2 stone fill (less than 36 inches) at the upstream end of the downstream left wingwall, and type-3 stone fill (less than 48 inches) at the upstream end of the upstream left and right wingwalls, along the entire base length of the downstream right wingwall, and along the upstream and downstream left and right banks. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. 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 1.0 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge, which was less than the 100-year discharge. Abutment scour ranged from 7.6 to 11.2 ft. The worst-case left abutment scour occurred at the 500-year discharge. The worst-case right abutment scour occurred at the incipient roadway-overtopping discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Lyndonville, VT. Quadrangle, 1:24,000, 1986, and Stannard, 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 SHEFTH00320015 ***Stream*** Branch of Miller Run

County Caledonia ***Road*** TH 32 ***District*** 7

Description of Bridge

Bridge length 31 ***ft*** ***Bridge width*** 25.3 ***ft*** ***Max span length*** 27 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 7/31/95

Description of stone fill Type-3, along the upstream end of the left and right upstream wingwalls and along the entire base length of the downstream right wingwall. Type-2 at the upstream end of the downstream left wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete.

Is bridge skewed to flood flow according to No ***survey?*** Yes ***Angle*** 35

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

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	7/31/95	0	0
Level II	7/31/95	0	0

Potential for debris Low.

Describe any features near or at the bridge that may affect flow (include observation date) None as of 7/31/95.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with a narrow flood plain and steep valley walls.

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

Date of inspection 7/31/95

DS left: Steep channel bank to irregular overbank and steep valley wall

DS right: Steep channel bank to irregular overbank

US left: Steep channel bank to moderately sloping overbank and steep valley wall

US right: Steep channel bank to irregular overbank

Description of the Channel

Average top width 50 ft ***Average depth*** 8 ft

Predominant bed material Sand to boulder ***Bank material*** Sand to boulder

Straight and stable equiwidth stream with non-alluvial channel boundaries and narrow point bars.

Vegetative co 7/31/95

Trees and brush with pasture overbank

DS left: Trees and brush with road and pasture overbank

DS right: Trees and brush with pasture overbank

US left: Trees and brush with pasture overbank

US right:

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

None as of 7/31/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 6.1 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 1,740 ***ft³/s*** ***Q500*** 2,750 ***ft³/s***

The 10-, 25-, 50-, and 100-year discharges are available from the VTAOT database. The discharge curve was extrapolated to the 500-year event. The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans Upstream left (499.61 ft) and right (498.10 ft) top of abutments.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the right abutment (elev. 498.12 ft, arbitrary survey datum). RM2 is the center point of an engraved triangle on top of the downstream right wingwall (elev. 497.30 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-40	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	17	1	Road Grade section
APPRO	56	2	Modelled Approach section (Templated from APTEM)
APTEM	62	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 0.055 to 0.060, and overbank "n" values ranged from 0.045 to 0.070.

Normal depth at the exit section (EXIT1) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.026 ft/ft, which was estimated from the appropriate topographic map (U.S. Geological Survey, 1986).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.015 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 provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 498.7 ***ft***
Average low steel elevation 497.2 ***ft***

100-year discharge 1,740 ***ft³/s***
Water-surface elevation in bridge opening 497.9 ***ft***
Road overtopping? Yes ***Discharge over road*** 224 ***ft³/s***
Area of flow in bridge opening 179 ***ft²***
Average velocity in bridge opening 8.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.6 ***ft/s***

Water-surface elevation at Approach section with bridge 498.9
Water-surface elevation at Approach section without bridge 496.1
Amount of backwater caused by bridge 2.8 ***ft***

500-year discharge 2,750 ***ft³/s***
Water-surface elevation in bridge opening 497.2 ***ft***
Road overtopping? Yes ***Discharge over road*** 985 ***ft³/s***
Area of flow in bridge opening 175 ***ft²***
Average velocity in bridge opening 10.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 18.2 ***ft/s***

Water-surface elevation at Approach section with bridge 500.1
Water-surface elevation at Approach section without bridge 497.9
Amount of backwater caused by bridge 2.2 ***ft***

Incipient overtopping discharge 1,150 ***ft³/s***
Water-surface elevation in bridge opening 493.4 ***ft***
Area of flow in bridge opening 97 ***ft²***
Average velocity in bridge opening 11.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.4 ***ft/s***

Water-surface elevation at Approach section with bridge 497.3
Water-surface elevation at Approach section without bridge 494.8
Amount of backwater caused by bridge 2.5 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analyses for the 100- and 500-year discharges are presented in tables 1 and 2 and the scour depths are shown graphically in figure 8.

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 100-year and 500-year discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144) and is presented in appendix F. Furthermore, for those discharges resulting in unsubmerged orifice flow, 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 Davis, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.9	1.0
Depth to armoring	N/A	13.6	26.9
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	10.1	11.2	8.4
Right abutment	7.6	8.3	9.0
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	500-year discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	2.2	2.6	1.8
Right abutment	2.2	2.6	1.8
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

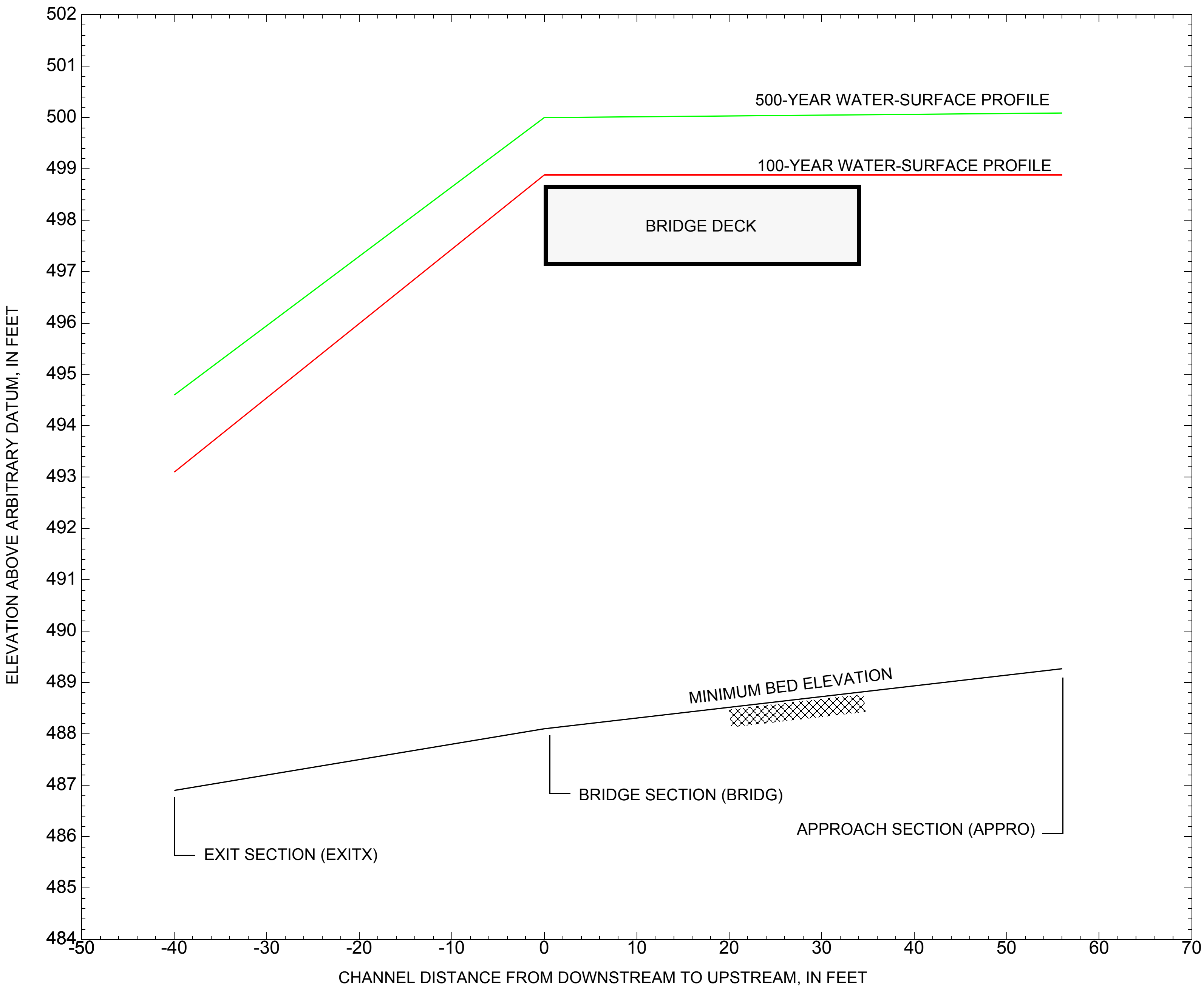

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure SHEFTH00320015 on Town Highway 32, crossing an Unnamed Tributary of Miller Run, Sheffield, Vermont.

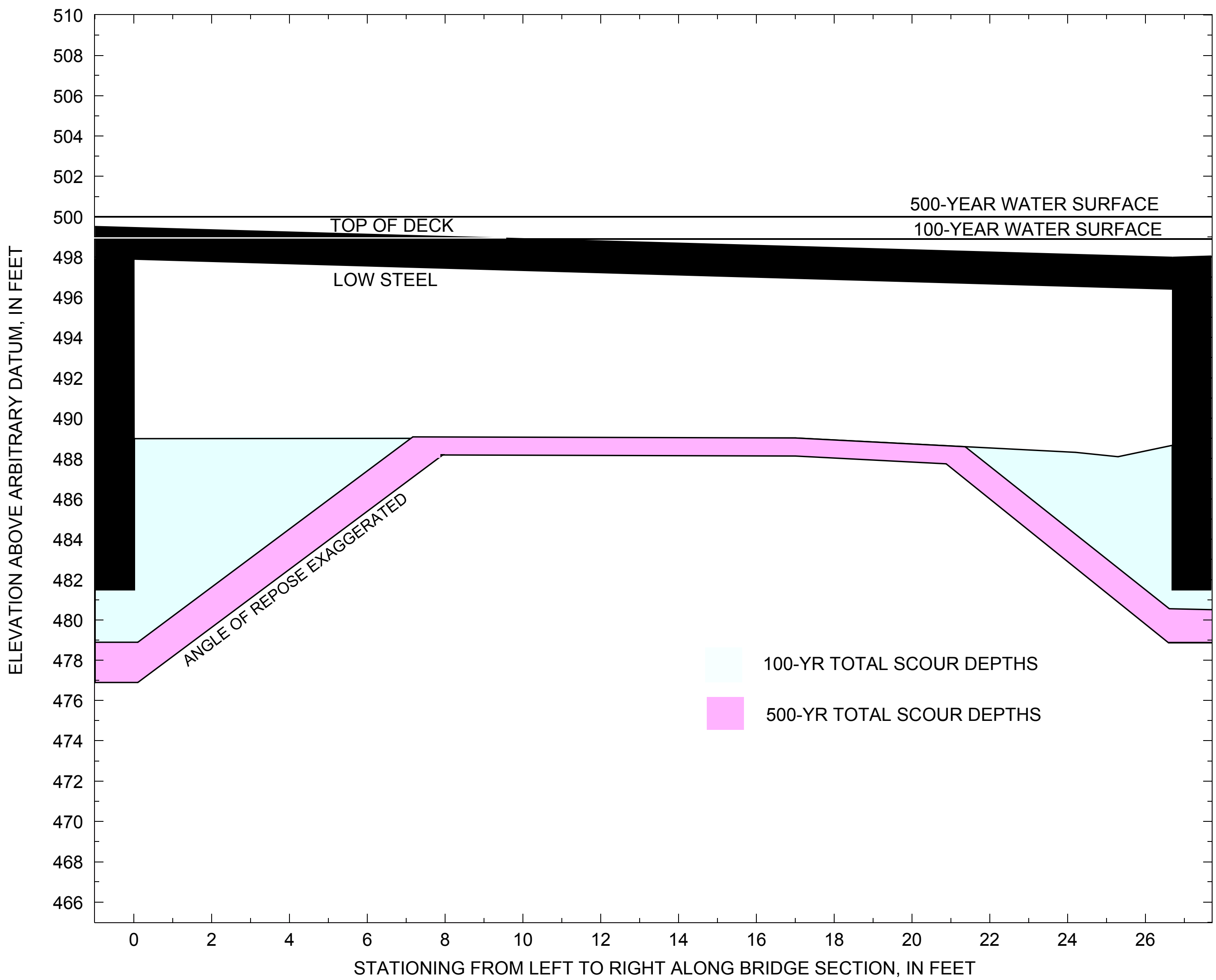

Figure 8. Scour elevations for the 100- and 500-year discharges at structure SHEFTH00320015 on Town Highway 32, crossing an Unnamed Tributary of Miller Run, Sheffield, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure SHEFTH00320015 on Town Highway 32, crossing an Unnamed Tributary of Miller Run, Sheffield, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 1,740 cubic-feet per second											
Left abutment	0.0	497.9	497.9	481.5	489.0	0.0	10.1	--	10.1	478.9	-2.6
Right abutment	26.7	496.4	496.4	481.5	488.1	0.0	7.6	--	7.6	480.5	-1.0

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure SHEFTH00320015 on Town Highway 32, crossing an Unnamed Tributary of Miller Run, Sheffield, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 2,750 cubic-feet per second											
Left abutment	0.0	497.9	497.9	481.5	489.0	0.9	11.2	--	12.1	476.9	-4.6
Right abutment	26.7	496.4	496.4	481.5	488.1	0.9	8.3	--	9.2	478.9	-2.6

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 Highway Administration, 1993, Stream Stability and Scour at Highway Bridges: Participant Workbook: Federal Highway Administration Report FHWA-HI-91-011.

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. Geological Survey, 1986, Lydonville and Stannard, 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 shef015.wsp
T2        Hydraulic analysis for structure SHEFTH00320015   Date: 17-JUN-97
T3        The bridge is located at the junction of TH 32 and TH 33
*
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           1740.0   2750.0    1150.0
SK          0.0260   0.0260    0.0260
*
XS   EXIT1    -40          0.
GR         -198.0, 535.19
GR         -123.0, 497.69   -113.0, 497.69    -81.5, 499.30    -27.6, 496.52
GR           -7.8, 494.32      0.0, 491.32      5.0, 487.54     10.0, 487.12
GR           12.9, 486.88     17.5, 486.90     22.2, 487.12     23.3, 487.45
GR           24.8, 487.68     29.7, 491.39     37.4, 494.27     59.9, 495.03
GR           77.5, 495.14
* GR          89.4, 494.70    105.8, 494.39
* GR          122.1, 493.23    139.8, 492.99    180.1, 496.62    232.1, 504.07
* GR          332.1, 509.07
*
N           0.070        0.055        0.045
SA                  -7.8         37.4
*
*
XS   FULLV      0  * * *   0.0288
*
*           SRD     LSEL    XSSKEW
BR   BRIDG     0    497.15      35.0
GR            0.0, 497.89      0.1, 489.49      0.2, 488.99      2.8, 489.06
GR            7.7, 489.08     17.0, 489.02     24.2, 488.31     25.3, 488.09
GR           26.2, 488.65     26.7, 496.41      0.0, 497.89
*
*
*        BRTYPE  BRWDTH       WWANGL    WWWID
CD          1      43.4 * *     42.4     13.4
N           0.055
*
*
*            SRD    EMBWID   IPAVE
XR   RDWAY     17      25.3     2
GR         -235.2, 549.68
GR         -160.2, 512.18   -143.2, 504.58    -51.7, 502.03      0.0, 499.45
GR           27.9, 497.98     39.4, 497.84
GR           69.5, 497.82     88.8, 499.16    140.7, 500.10
GR          166.2, 504.39    189.4, 508.11    289.4, 513.11
*
*       Rdway section was changed to reflect a more accurate road overflow
*       discharge. The roadway section was changed to follow the approach,
*       since the flow on the roadway will be what escapes from the approach on
*       the right over bank. Rdway flow in the real world will be in a swale
*       of the roadway to the right of the bridge.
*
* Old roadway section-
* GR           39.4, 497.48
* GR           52.7, 496.90     86.8, 496.10    126.3, 496.10    147.5, 496.41
* GR          174.8, 497.27    205.8, 504.20    224.6, 505.77    324.6, 510.77
*
*
XT   APTEM     62          0.
GR         -281.0, 554.5
GR         -206.0, 517.00   -161.6, 511.38   -115.6, 506.78    -70.8, 503.59
GR          -22.3, 500.80    -15.1, 499.51     -6.2, 494.79      0.0, 490.92
GR            3.9, 490.07      5.2, 489.58     10.5, 489.48     17.2, 489.36
GR           21.2, 489.45     23.2, 489.96     30.3, 492.98     39.4, 497.84
GR           69.5, 497.82     88.8, 499.16    140.7, 500.10
GR          166.2, 504.39    189.4, 508.11    289.4, 513.11
*
AS   APPRO     56  * * * 0.0150
GT
N           0.065        0.060        0.045
SA                -15.1        39.4
*
HP 1 BRIDG   497.89 1 497.89
HP 2 BRIDG   497.89 * * 1518
HP 1 BRIDG   494.27 1 494.27
HP 2 RDWAY   498.88 * *  224
HP 1 APPRO   498.88 1 498.88
HP 2 APPRO   498.88 * * 1740
*
HP 1 BRIDG   497.15 1 497.15
HP 2 BRIDG   497.15 * * 1760
HP 1 BRIDG   495.66 1 495.66
HP 2 RDWAY   500.00 * *  985
HP 1 APPRO   500.09 1 500.09
```

APPENDIX B:

WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File shef015.wsp
      Hydraulic analysis for structure SHEFTH00320015   Date: 17-JUN-97
      The bridge is located at the junction of TH 32 and TH 33
         *** RUN DATE & TIME: 01-22-98  12:57
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     179.   10018.     0.    60.                          0.
 497.89          179.   10018.     0.    60.  1.00     0.    27.      0.

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     497.89     0.0    26.7   178.8   10018.    1518.   8.49

X STA.        0.0        3.3        4.3        5.3        6.4        7.4
  A(I)           23.0        7.2        7.3        7.2        7.2
  V(I)           3.31      10.56      10.35      10.51      10.47

X STA.        7.4        8.5        9.6       10.7       11.8       12.9
  A(I)            7.4        7.3        7.5        7.6        7.5
  V(I)          10.30      10.38      10.18      10.01      10.08

X STA.       12.9       14.1       15.2       16.4       17.5       18.7
  A(I)            7.6        7.6        7.6        7.5        7.7
  V(I)           9.97      10.04       9.99      10.13       9.89

X STA.       18.7       19.8       21.0       22.1       23.1       26.7
  A(I)            7.5        7.5        7.4        7.2       22.2
  V(I)          10.17      10.14      10.29      10.50       3.42

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

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     116.    7348.    22.    32.                       1522.
 494.27          116.    7348.    22.    32.  1.00     0.    27.   1522.

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      17.

       WSEL     LEW     REW    AREA        K        Q    VEL
     498.88    10.8    84.8    58.5    1605.     224.   3.83

X STA.       10.8       27.2       30.7       33.9       36.9       39.4
  A(I)            7.1        3.2        3.1        3.0        2.5
  V(I)           1.59       3.52       3.66       3.73       4.50

X STA.       39.4       41.7       43.9       46.3       48.6       50.7
  A(I)            2.4        2.4        2.4        2.4        2.3
  V(I)           4.65       4.74       4.59       4.65       4.95

X STA.       50.7       52.9       55.1       57.3       59.5       61.7
  A(I)            2.2        2.4        2.3        2.3        2.4
  V(I)           5.05       4.73       4.82       4.85       4.75

X STA.       61.7       64.0       66.2       68.4       70.7       84.8
  A(I)            2.3        2.4        2.3        2.3        6.9
  V(I)           4.77       4.74       4.79       4.77       1.62

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           2     356.   29705.    53.    58.                       5207.
           3      44.    1392.    47.    47.                        241.
 498.88          400.   31097.   100.   104.  1.11   -14.    86.   4305.

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

       WSEL     LEW     REW    AREA        K        Q    VEL
     498.88   -14.1    86.1   399.6   31097.    1740.   4.35

X STA.      -14.1       -0.1        1.8        3.6        5.2        6.8
  A(I)           53.7       15.6       15.5       14.8       14.8
  V(I)           1.62       5.59       5.61       5.87       5.89

X STA.        6.8        8.3        9.9       11.5       13.0       14.6
  A(I)           14.6       14.7       14.9       14.8       14.8
  V(I)           5.95       5.90       5.84       5.89       5.87

X STA.       14.6       16.1       17.7       19.2       20.8       22.4
  A(I)           15.0       15.1       14.7       14.9       14.9
  V(I)           5.79       5.78       5.93       5.86       5.83

X STA.       22.4       24.1       26.1       28.5       32.2       86.1
  A(I)           15.3       16.2       17.8       21.6       66.0
  V(I)           5.67       5.36       4.88       4.04       1.32
```

```
        U.S. Geological Survey WSPRO Input File shef015.wsp
        Hydraulic analysis for structure SHEFTH00320015   Date: 17-JUN-97
        The bridge is located at the junction of TH 32 and TH 33
           *** RUN DATE & TIME: 01-22-98  12:57
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     175.   11139.    11.    48.                       3967.
   497.15          175.   11139.    11.    48.  1.00     0.    27.   3967.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.15     0.0    26.7   174.8   11139.    1760.  10.07

X STA.        0.0         3.3         4.2         5.1         6.1         7.0
  A(I)            21.4         6.0         6.3         6.2         6.2
  V(I)            4.11       14.79       13.95       14.18       14.15

X STA.        7.0         8.0         8.9         9.9        10.9        11.8
  A(I)             6.4         6.3         6.5         6.6         5.8
  V(I)           13.68       13.94       13.51       13.31       15.07

X STA.       11.8        12.5        13.4        14.7        15.9        17.2
  A(I)             4.8         5.9         8.3         8.2         8.4
  V(I)           18.15       15.03       10.61       10.67       10.48

X STA.       17.2        18.5        19.7        20.9        22.2        26.7
  A(I)             8.1         8.3         8.0         8.1        28.8
  V(I)           10.80       10.55       10.95       10.89        3.06

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     146.   10235.    22.    35.                       2150.
   495.66          146.   10235.    22.    35.  1.00     0.    27.   2150.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      17.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.00   -11.0   135.2   176.9    6316.     985.   5.57

X STA.      -11.0        17.8        23.2        27.2        30.8        34.3
  A(I)            21.2         8.7         7.6         7.3         7.2
  V(I)            2.32        5.63        6.50        6.78        6.80

X STA.       34.3        37.6        40.6        43.7        46.8        49.0
  A(I)             7.1         6.5         6.5         6.7         4.9
  V(I)            6.97        7.56        7.58        7.34       10.06

X STA.       49.0        50.8        53.4        56.0        58.6        61.3
  A(I)             3.8         5.6         5.7         5.7         5.7
  V(I)           12.81        8.76        8.66        8.62        8.61

X STA.       61.3        63.9        66.5        69.1        71.8       135.2
  A(I)             5.7         5.6         5.6         5.8        43.8
  V(I)            8.66        8.73        8.75        8.44        1.13
    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       1.      14.     4.     4.                          4.
             2     421.   38879.    55.    59.                       6650.
             3     132.    5190.   102.   102.                        852.
   500.09          555.   44083.   160.   164.  1.22    -19.   141.   5311.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.09   -18.8   141.2   554.6   44083.    2750.   4.96

X STA.      -18.8        -1.0         1.3         3.4         5.3         7.1
  A(I)            64.7        21.4        20.2        19.3        19.2
  V(I)            2.12        6.41        6.81        7.13        7.17

X STA.        7.1         8.9        10.7        12.5        14.2        16.0
  A(I)            19.0        19.1        19.4        19.2        19.2
  V(I)            7.24        7.18        7.10        7.17        7.15

X STA.       16.0        17.8        19.6        21.4        23.3        25.5
  A(I)            19.3        19.3        19.4        19.9        20.8
  V(I)            7.11        7.13        7.07        6.90        6.62

X STA.       25.5        28.0        31.3        44.8        61.0       141.2
  A(I)            22.0        25.0        49.0        38.0        81.2
  V(I)            6.25        5.51        2.81        3.62        1.69
```

```
        U.S. Geological Survey WSPRO Input File shef015.wsp
        Hydraulic analysis for structure SHEFTH00320015   Date: 17-JUN-97
        The bridge is located at the junction of TH 32 and TH 33
           *** RUN DATE & TIME: 01-22-98  12:57

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      97.    5615.    22.    31.                       1156.
   493.37           97.    5615.    22.    31.  1.00     0.    27.   1156.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.37     0.1    26.5    96.5    5615.    1150.  11.91

X STA.        0.1        3.5        4.7        5.8        6.9        8.1
  A(I)           12.3        4.0        4.0        4.0        4.1
  V(I)           4.67      14.51      14.27      14.52      14.16

X STA.        8.1        9.2       10.4       11.5       12.7       13.8
  A(I)            4.0        4.0        4.1        4.0        4.0
  V(I)          14.33      14.23      14.10      14.24      14.22

X STA.       13.8       15.0       16.1       17.2       18.4       19.4
  A(I)            4.1        4.1        4.0        4.0        3.9
  V(I)          14.11      14.09      14.39      14.21      14.80

X STA.       19.4       20.4       21.4       22.4       23.3       26.5
  A(I)            3.9        3.8        3.8        3.7       12.6
  V(I)          14.65      15.14      14.98      15.38       4.57

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     273.   20124.    50.    53.                       3632.
   497.28          273.   20124.    50.    53.  1.00   -11.    39.   3632.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      56.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.28   -11.1    38.5   272.8   20124.    1150.   4.22

X STA.      -11.1        0.4        2.1        3.7        5.2        6.6
  A(I)           36.8       11.7       11.3       11.2       10.6
  V(I)           1.56       4.92       5.08       5.15       5.43

X STA.        6.6        8.0        9.4       10.7       12.1       13.5
  A(I)           11.0       10.8       10.7       11.0       11.0
  V(I)           5.23       5.32       5.38       5.24       5.22

X STA.       13.5       14.9       16.2       17.6       18.9       20.3
  A(I)           10.9       10.9       10.7       10.9       10.8
  V(I)           5.28       5.26       5.37       5.30       5.34

X STA.       20.3       21.6       23.1       24.7       26.6       38.5
  A(I)           10.5       11.1       11.5       12.4       37.0
  V(I)           5.45       5.16       4.99       4.63       1.56
```

WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File shef015.wsp
        Hydraulic analysis for structure SHEFTH00320015   Date: 17-JUN-97
        The bridge is located at the junction of TH 32 and TH 33
           *** RUN DATE & TIME: 01-22-98  12:57

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

EXIT1:XS   ******    -5.     162.  1.79 *****  494.89  492.84   1740.  493.10
      -40. ******    34.   10791.  1.00 ***** *******    0.93   10.73

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.96     494.12     493.99

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.60     536.34    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.60     536.34     493.99

FULLV:FV      40.    -4.     157.  1.90  1.08  496.03  493.99   1740.  494.12
        0.    40.    34.   10372.  1.00  0.06    0.00    0.96   11.06
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  1.43

APPRO:AS      56.    -9.     218.  0.99  1.10  497.12 *******   1740.  496.13
       56.    56.    36.   14803.  1.00  0.00   -0.01    0.64    7.97
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   499.46       0.00     494.77     497.82

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   494.36     498.58     498.74     497.15

 ===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      40.     0.     179.  1.12 *****  499.01  494.27   1518.  497.89
        0. ******    27.   10018.  1.00 ***** *******    0.58    8.49

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.460  0.000  497.15 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       17.    31.  0.10  0.33  499.11    0.00    224.  498.88

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     0.     4.    10.    14.   0.2   0.1   2.3   4.7   0.3   2.6
   RT:   224.    71.    14.    85.   1.1   0.8   4.5   3.8   1.1   2.9

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

APPRO:AS      13.   -14.     400.  0.33  0.11  499.21  494.64   1740.  498.88
       56.    13.    86.   31128.  1.11  1.86    0.00    0.40    4.35

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -40.    -5.    34.   1740.   10791.     162.   10.73  493.10
   FULLV:FV       0.    -4.    34.   1740.   10372.     157.   11.06  494.12
   BRIDG:BR       0.     0.    27.   1518.   10018.     179.    8.49  497.89
   RDWAY:RG      17.*******     0.    224.       0.*********    2.00  498.88
   APPRO:AS      56.   -14.    86.   1740.   31128.     400.    4.35  498.88

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT1:XS    492.84    0.93  486.88  535.19************  1.79  494.89  493.10
   FULLV:FV    493.99    0.96  488.03  536.34  1.08  0.06  1.90  496.03  494.12
   BRIDG:BR    494.27    0.58  488.09  497.89************  1.12  499.01  497.89
   RDWAY:RG   ***************  497.82  549.68  0.10******  0.33  499.11  498.88
   APPRO:AS    494.64    0.40  489.27  554.41  0.11  1.86  0.33  499.21  498.88
```

```
        U.S. Geological Survey WSPRO Input File shef015.wsp
        Hydraulic analysis for structure SHEFTH00320015   Date: 17-JUN-97
        The bridge is located at the junction of TH 32 and TH 33
           *** RUN DATE & TIME: 01-22-98  12:57

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

EXIT1:XS   ******   -10.     228.  2.29 *****  496.89  494.51   2750.  494.60
      -40. ******    47.   17044.  1.01 ***** *******    1.07   12.05

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.07     495.62     495.66
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   494.10     536.34    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   494.10     536.34     495.66
 ===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 "FULLV"
                  WSBEG,WSEND,CRWS =   495.66     536.34     495.66

FULLV:FV      40.   -10.     223.  2.38 *****  498.04  495.66   2750.  495.66
        0.    40.    45.   16544.  1.01 ***** *******    1.07   12.31
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.84     497.85     496.17
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   495.16     554.41    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   495.16     554.41     496.17
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  1.41

APPRO:AS      56.   -12.     306.  1.28  1.10  499.14  496.17   2750.  497.86
       56.    56.    71.   23245.  1.02  0.00    0.00    0.84    8.99
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   503.19       0.00     496.57     497.82
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   501.85        -1.      2751.
 ===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      40.     0.     175.  1.58 *****  498.73  494.83   1760.  497.15
        0. ******    27.   11139.  1.00 ***** *******    0.69   10.07

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.491  0.000  497.15 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      17.    31.  0.12  0.47  500.43    0.00    985.  500.00

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     79.    25.   -11.    14.   1.3   0.6   4.6   5.2   1.1   3.0
   RT:    906.   121.    14.   135.   2.2   1.3   6.4   5.6   1.8   3.2

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS      13.   -19.     554.  0.47  0.14  500.55  496.17   2750.  500.09
       56.    14.   141.   44019.  1.22  0.00    0.00    0.52    4.96

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXIT1:XS     -40.   -10.    47.   2750.   17044.     228.   12.05  494.60
   FULLV:FV       0.   -10.    45.   2750.   16544.     223.   12.31  495.66
   BRIDG:BR       0.     0.    27.   1760.   11139.     175.   10.07  497.15
   RDWAY:RG      17.*******    79.    985.        0.*********   2.00  500.00
   APPRO:AS      56.   -19.   141.   2750.   44019.     554.    4.96  500.09

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT1:XS    494.51    1.07  486.88  535.19************  2.29  496.89  494.60
   FULLV:FV    495.66    1.07  488.03  536.34************  2.38  498.04  495.66
   BRIDG:BR    494.83    0.69  488.09  497.89************  1.58  498.73  497.15
   RDWAY:RG  ***************   497.82  549.68  0.12******  0.47  500.43  500.00
   APPRO:AS    496.17    0.52  489.27  554.41  0.14  0.00  0.47  500.55  500.09
```

```
        U.S. Geological Survey WSPRO Input File shef015.wsp
        Hydraulic analysis for structure SHEFTH00320015   Date: 17-JUN-97
        The bridge is located at the junction of TH 32 and TH 33
           *** RUN DATE & TIME: 01-22-98  12:57

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

EXIT1:XS   ******    -1.     118.  1.49 *****  493.33  491.55   1150.  491.84
      -40. ******    31.    7130.  1.00 ***** *******    0.90    9.79

 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.94     492.87     492.70

 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =    491.34     536.34    0.50

 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =    491.34     536.34     492.70

FULLV:FV      40.    -1.     114.  1.59  1.08  494.47  492.70   1150.  492.88
        0.    40.    31.    6840.  1.00  0.05    0.00    0.94   10.11
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            “APPRO”     KRATIO =  1.41

APPRO:AS      56.    -6.     161.  0.80  1.12  495.58 *******   1150.  494.78
       56.    56.    34.    9668.  1.00  0.00   -0.01    0.63    7.15
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID “BRIDG”     Q,CRWS =     1150.     493.37

            <<<<<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      40.     0.      96.  2.21 *****  495.58  493.37   1150.  493.37
        0.    40.    27.    5608.  1.00 ***** *******    1.00   11.93

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.15 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      17.        <<<<<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      13.   -11.     273.  0.28  0.15  497.56  493.55   1150.  497.28
       56.    13.    39.   20142.  1.00  1.83   -0.02    0.32    4.21

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.343  0.059   19025.    -1.    26.   497.18

   FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -40.    -1.    31.   1150.    7130.     118.    9.79  491.84
   FULLV:FV       0.    -1.    31.   1150.    6840.     114.   10.11  492.88
   BRIDG:BR       0.     0.    27.   1150.    5608.      96.   11.93  493.37
   RDWAY:RG      17.**************       0.******************     2.00********
   APPRO:AS      56.   -11.    39.   1150.   20142.     273.    4.21  497.28

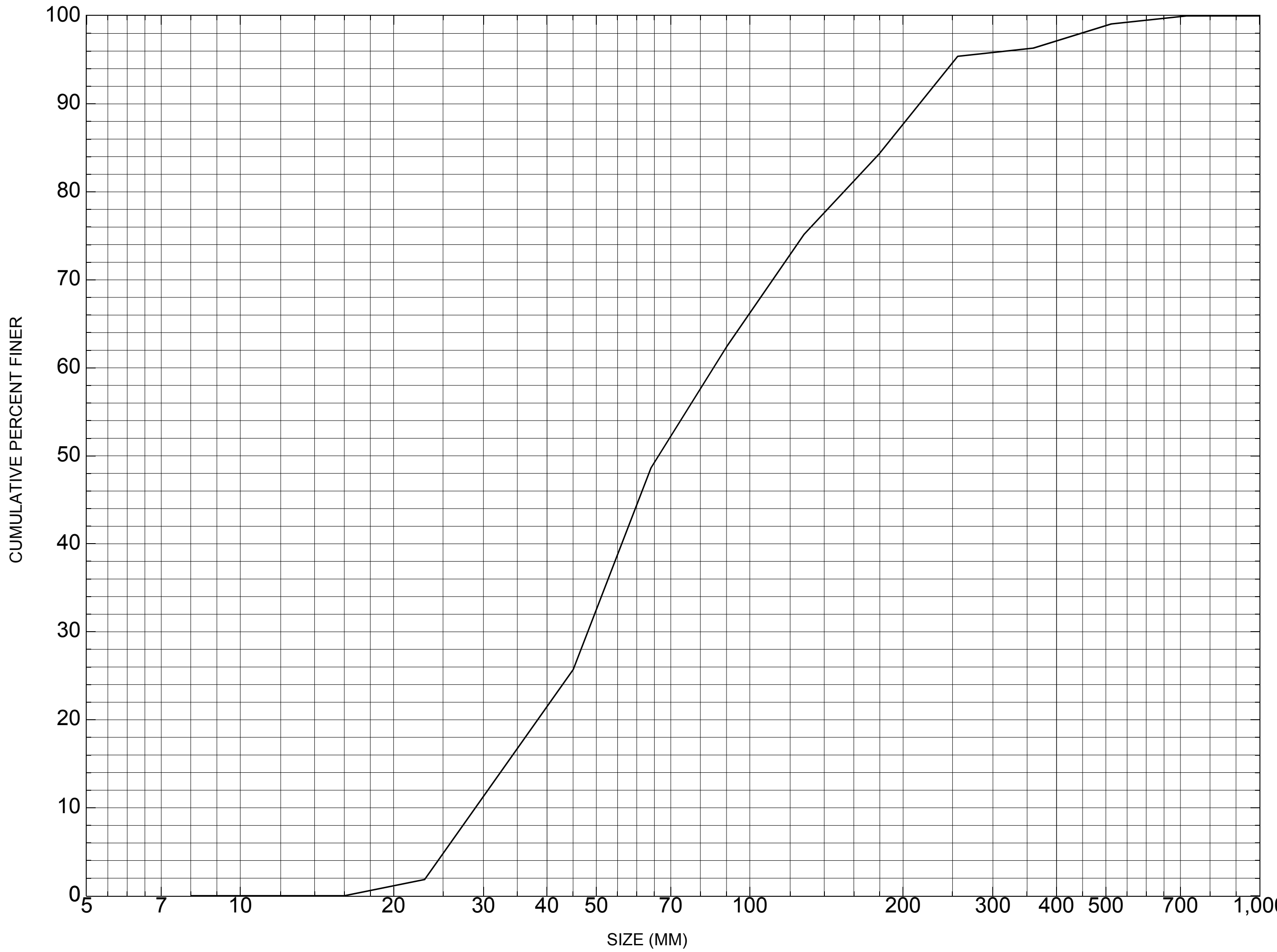
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -1.    26.   19025.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    491.55    0.90  486.88  535.19************  1.49  493.33  491.84
   FULLV:FV    492.70    0.94  488.03  536.34  1.08  0.05  1.59  494.47  492.88
   BRIDG:BR    493.37    1.00  488.09  497.89************  2.21  495.58  493.37
   RDWAY:RG  ****************  497.82  549.68**********************************
   APPRO:AS    493.55    0.32  489.27  554.41  0.15  1.83  0.28  497.56  497.28
  ER
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure SHEFTH00320015, in Sheffield, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number SHEFTH00320015

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 28 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 64075

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

Waterway *(I - 6)* BRANCH OF MILLER RUN

Road Name *(I - 7):* -

Route Number TH032

Vicinity *(I - 9)* AT JCT OF TH 32 & TH 33

Topographic Map Lyndonville

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44361

Longitude *(i - 17; nnnnn.n)* 72073

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10031200150312

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

Maximum span length *(I - 48; nnnn)* 0027

Year built *(I - 27; YYYY)* 1982

Structure length *(I - 49; nnnnnn)* 000031

Average daily traffic, ADT *(I - 29; nnnnnn)* 000050

Deck Width *(I - 52; nn.n)* 253

Year of ADT *(I - 30; YY)* 92

Channel & Protection *(I - 61; n)* 7

Opening skew to Roadway *(I - 34; nn)* 35

Waterway adequacy *(I - 71; n)* 7

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

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

Structure type *(I - 43; nnn)* 101

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 029.0

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

Vertical clearance from streambed (*nnn.n ft*) 008.5

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

Waterway of full opening (*nnn.n ft*^{2}) 187.0

Comments:

The structural inspection report of 10/31/94 indicates that the structure is a concrete slab bridge. The bridge was built in 1982 and has no indications of significant structural problems. The abutment walls and wingwalls are constructed of concrete, which have reports of a few minor cracks. Boulder fill is noted as placed around the ends of the wingwalls and partially along the embankments. Debris accumulation and point bar development are noted as minor at this site. Part of the flow is reported to impact the upstream end of the right abutment.

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: **6.1**

Terrain character: **Mountainous**

Stream character & type: **Steep, mountainous tributary to Miller Run**

Streambed material: **Boulders and some gravel**

Discharge Data *(cfs)*: $Q_{2.33}$ **530** Q_{10} **820** Q_{25} **1120**

Q_{50} **1400** Q_{100} **1740** Q_{500} **-**

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

Estimated Discharge *(cfs)*: **-** Velocity at Q **25** *(ft/s)*: **12.4**

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

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

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

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

Watershed storage area (*in percent*): **1** %

The watershed storage area is: **1** (*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*)	493.7	494.5	495.7	496.8	498.2
Velocity (*ft / sec*)	9.6	11.2	12.4	13.3	14.3

Long term stream bed changes: **Estimated scour expected is + / - 1.0 feet**

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): **N** Frequency: **Q70**

Relief Elevation (*ft*): **497.0** Discharge over roadway at Q_{100} (*ft^3/ sec*): **-**

Are there other structures nearby? (*Yes, No, Unknown*): **Y** *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*): 0.5 Town: Sheffield Year Built: 1963
Highway No. : TH32 Structure No. : 16 Structure Type: -
Clear span (*ft*): 51.0 Clear Height (*ft*): 9.0 Full Waterway (ft^2): 459.0

Comments:
Hydraulics report indicates that class III stone fill should be used to protect the banks and bridge.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 6.10 mi^2 Lake/pond/swamp area 0.02 mi^2
Watershed storage *(ST)* 0.3 %
Bridge site elevation 976 ft Headwater elevation 2720 ft
Main channel length 4.69 mi
10% channel length elevation 1053 ft 85% channel length elevation 2441 ft
Main channel slope *(S)* 394.65 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? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: 07 / 1981

Project Number BRZ1447(7) Minimum channel bed elevation: 487.4

Low superstructure elevation: USLAB 494.65* DSLAB - USRAB - DSRAB -

Benchmark location description:

There were no specific benchmarks provided on the plans. Other points shown on the plans with elevations are: 1) The point on top of the concrete upstream right wingwall at the streamward edge where the concrete slope changes from horizontal to downward, elevation 498.10, and 2) the point at the same location but on the upstream left wingwall, elevation 499.61.

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

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

If 1: Footing Thickness 2.0 Footing bottom elevation: 481.5

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:

-

Comments:

*** The low superstructure elevation given above is a minimum value for the overall structure. Other elevation points are the wingwall tops: upstream left 499.61 right 498.10 and downstream left 498.76 right 497.27.**

Cross-sectional Data

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

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

Comments: **There are several channel cross sections printed and kept with the plans that may be retrieved. However, due to the difference between the USGS and VTAOT survey techniques there are no reproducible bridge cross sections.**

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments: -

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 03/18/96
Computerized by: EW Date: 03/18/96
Reviewd by: LKS Date: 01/27/98

Structure Number SHEFTH00320015

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. DEGAN   Date *(MM/DD/YY)* 07 / 31 / 1995
2. Highway District Number 07   Mile marker -
   County Caledonia (005)   Town Sheffield (64075)
   Waterway *(I - 6)* Unnamed Tributary of Miller Run   Road Name -
   Route Number TH032   Hydrologic Unit Code: 01080102
3. Descriptive comments:
The bridge is a concrete slab bridge. It is located at the junction of TH 32 and TH 33.

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 2   UB 2   DS 2   *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 31 *(feet)*   Span length 27 *(feet)*   Bridge width 25.3 *(feet)*

Road approach to bridge:

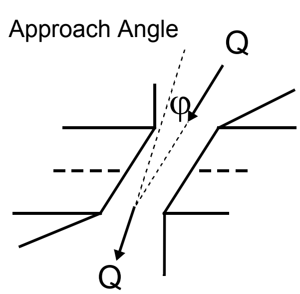
8. LB 2   RB 1   *(**0** even, **1-** lower, **2-** higher)*
9. LB 2   RB 2   *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
    US left --   US right --

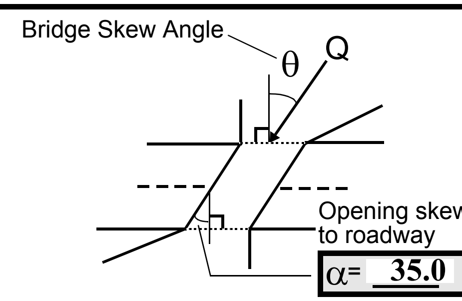
	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	0	-	0	0
RBUS	0	-	0	0
RBDS	0	-	0	0
LBDS	0	-	0	0

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

Channel approach to bridge (BF):

15. Angle of approach: 0   16. Bridge skew: 35



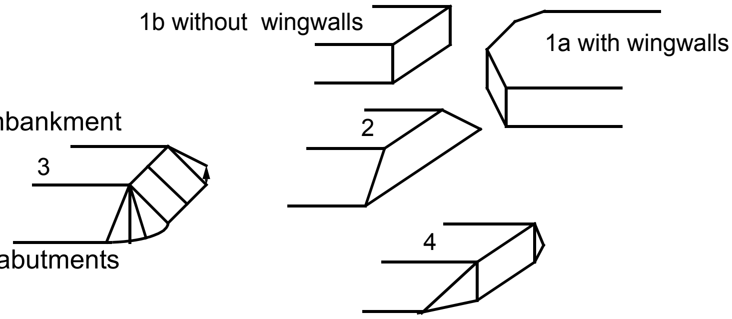


α= 35.0

17. Channel impact zone 1:   Exist? Y *(Y or N)*
    Where? RB *(LB, RB)*   Severity 1
    Range? 3 feet US *(US, UB, DS)* to 0 feet US
    Channel impact zone 2:   Exist? N *(Y or N)*
    Where? - *(LB, RB)*   Severity -
    Range? - feet - *(US, UB, DS)* to - feet -

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

18. Bridge Type: **1a**



1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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

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

#4: The upstream and downstream left banks are residential. There is a house and TH 33, which runs parallel to the channel, on the downstream right bank.

#7: Bridge dimensions are from VTAOT. Field measured values are bridge length = 31 ft, span length = 29 ft, bridge width = 25 ft.

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
33.5	**8.5**			**8.0**	**2**	**1**	**5432**	**5432**	**0**	**0**

23. Bank width **30.0** 24. Channel width **25.0** 25. Thalweg depth **54.5** 29. Bed Material **543**

30 .Bank protection type: LB **3** RB **3** 31. Bank protection condition: LB **1** RB **1**

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

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

The left bank protection extends from the end of the upstream left wingwall to 60 feet upstream. The right bank protection extends from the end of the upstream right wingwall to 70 feet downstream.

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.):

There are no pointbars upstream at this site.

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.):

There are no cut-banks upstream at this site. Beyond two bridge lengths, a severe cut-bank exists at 100 ft upstream on the right bank.

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.):

There is no channel scour upstream at this site.

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):

There are no major confluences upstream at this site.

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
23.0		0.5		2	7	7	-

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

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

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

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

5432

-

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

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

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

70. Debris and Ice Comments:

1

-

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		0	90	2	0	0	0	90.0
RABUT	1	0	90			2	0	22.0

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

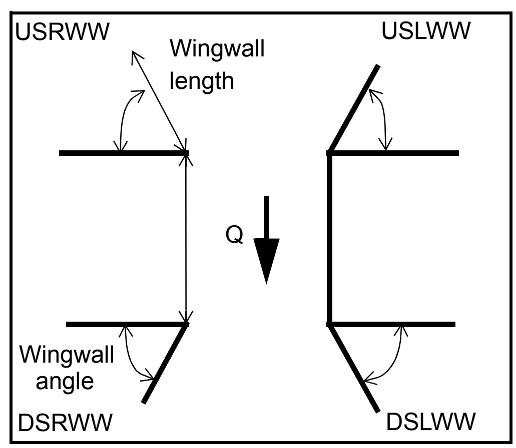
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0
0
1
The RABUT and LABUT protrude past the bottom of the bank.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						22.0	
USRWW:	Y		1		0	0.0	
DSLWW:	0		0		Y	33.5	
DSRWW:	1		1		0.5	34.5	

Wingwall materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	0	0	Y	0	1	1	-	-
Condition	Y	0	1	0	2	2	-	-
Extent	1	0	0	3	3	0	0	0

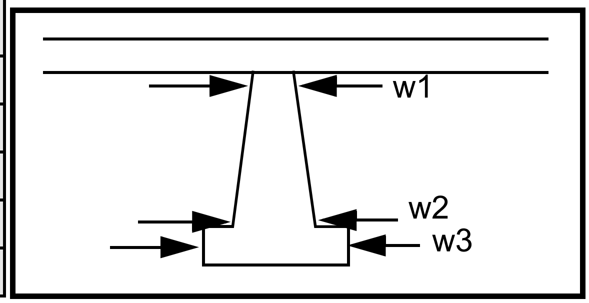
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
0
-
-
2
1
2
3
1
1

Piers:

84. Are there piers? **Th** (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				**25.0**	**23.5**	**60.0**
Pier 2				**10.5**	**55.0**	**13.0**
Pier 3			**-**	**10.0**	**18.0**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e**	**ever,**	**tion**	**33.**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**strea**	**there**	**serve**	**The**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**m**	**is no**	**s as**	**stone**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**impa**	**foot-**	**road**	**fill**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**cts**	**ing**	**emb**	**pro-**	*Y- yes; N- no*
91. Attack ∠ (BF)	**the**	**expo**	**ank-**	**tec-**	
92. Pushed	**upst**	**sed.**	**ment**	**tion**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**ream**	**The**	**pro-**	**on**	
95. Cross-members	**right**	**right**	**tec-**	**all**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**wing**	**bank**	**tion**	**the**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**wall;**	**pro-**	**for**	**wing**	
98. Exposure depth	**how-**	**tec-**	**TH**	**walls**	

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

extends along the base to the top corner.

N

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 - Thalweg depth - Bed Material -

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

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

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

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

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

105. Drop structure comments (eg. downstream scour depth):
-
-
-
-
-
-

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

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

Material: -____

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

-
-
-
-

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

Cut bank extent: **no** feet **pie** *(US, UB, DS)* to **rs.** feet ____ *(US, UB, DS)*

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

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

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

Scour dimensions: Length ______ Width **2** Depth: **1** Positioned **543** %LB to **2** %RB

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

5432
0
0
543

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

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

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

Confluence comments (eg. confluence name):

extends from the DS end of the RABUT to 50 feet DS. LB protection extends from the DS end of the LABUT to 40 feet DS. Bank erosion is evident DS from stone fill protection extending to the cut-bank area.

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)*:

N

109. G. Plan View Sketch

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:	SHEFTH00320015	Town:	SHEFFIELD
Road Number:	TH 32	County:	CALEDONIA
Stream:	BRANCH OF MILLER RUN		

Initials LKS Date: 08/01/97 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	1740	2750	1150
Main Channel Area, ft2	356	421	273
Left overbank area, ft2	0	1	0
Right overbank area, ft2	44	132	0
Top width main channel, ft	53	55	50
Top width L overbank, ft	0	4	0
Top width R overbank, ft	47	102	0
D50 of channel, ft	0.2173	0.2173	0.2173
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.7	7.7	5.5
y1, average depth, LOB, ft	ERR	0.3	ERR
y1, average depth, ROB, ft	0.9	1.3	ERR
Total conveyance, approach	31097	44083	20124
Conveyance, main channel	29705	38879	20124
Conveyance, LOB	0	14	0
Conveyance, ROB	1392	5190	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1662.1	2425.4	1150.0
Ql, discharge, LOB, cfs	0.0	0.9	0.0
Qr, discharge, ROB, cfs	77.9	323.8	0.0
Vm, mean velocity MC, ft/s	4.7	5.8	4.2
Vl, mean velocity, LOB, ft/s	ERR	0.9	ERR
Vr, mean velocity, ROB, ft/s	1.8	2.5	ERR
Vc-m, crit. velocity, MC, ft/s	9.3	9.5	8.9
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)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	1740	2750	1150
(Q) discharge thru bridge, cfs	1518	1760	1150
Main channel conveyance	10018	11139	5615
Total conveyance	10018	11139	5615
Q2, bridge MC discharge,cfs	1518	1760	1150
Main channel area, ft2	179	175	97
Main channel width (normal), ft	21.9	21.9	21.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	21.9	21.9	21.6
y_bridge (avg. depth at br.), ft	8.16	7.98	4.47
Dm, median (1.25*D50), ft	0.271625	0.271625	0.271625
y2, depth in contraction,ft	6.79	7.71	5.42
ys, scour depth (y2-ybridge), ft	-1.37	-0.27	**0.95**

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	1518	1760	1150
Main channel area (DS), ft2	116	146	96.5
Main channel width (normal), ft	21.9	21.9	21.6
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	21.9	21.9	21.6
D90, ft	0.7063	0.7063	0.7063
D95, ft	0.8289	0.8289	0.8289
Dc, critical grain size, ft	0.8464	0.6504	0.7580
Pc, Decimal percent coarser than Dc	0.046	0.126	0.078
Depth to armoring, ft	**N/A**	**13.57**	**26.92**

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	1740	2750	1150
Q, thru bridge MC, cfs	1518	1760	1150
Vc, critical velocity, ft/s	9.26	9.46	8.94
Va, velocity MC approach, ft/s	4.67	5.76	4.21
Main channel width (normal), ft	21.9	21.9	21.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	21.9	21.9	21.6
qbr, unit discharge, ft2/s	69.3	80.4	53.2
Area of full opening, ft2	178.8	174.8	96.5
Hb, depth of full opening, ft	8.16	7.98	4.47
Fr, Froude number, bridge MC	0.58	0.69	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	116	146	0
**Hb, depth at downstream face, ft	5.30	6.67	0.00
**Fr, Froude number at DS face	1.00	0.82	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	497.15	497.15	0
Elevation of Bed, ft	488.99	489.17	-4.47
Elevation of Approach, ft	498.88	500.09	0
Friction loss, approach, ft	0.11	0.14	0
Elevation of WS immediately US, ft	498.77	499.95	0.00
ya, depth immediately US, ft	9.78	10.78	4.47
Mean elevation of deck, ft	498.72	498.72	0
w, depth of overflow, ft (>=0)	0.05	1.23	0.00
Cc, vert contrac correction (<=1.0)	0.96	0.96	1.00
**Cc, for downstream face (<=1.0)	0.8144	0.907454	0
Ys, scour w/Chang equation, ft	**-0.34**	**0.90**	N/A
Ys, scour w/Umbrell equation, ft	-1.05	0.21	N/A

**=for UNsubmerged orifice flow using estimated downstream bridge face properties.

**Ys, scour w/Chang equation, ft	3.90	2.69	N/A

**Ys, scour w/Umbrell equation, ft	1.82	1.52	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	6.79	7.71	5.42
WSEL at downstream face, ft	494.27	495.66	--
Depth at downstream face, ft	5.30	6.67	0.00
Ys, depth of scour (Laursen), ft	1.50	1.05	N/A

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	1740	2750	1150	1740	2750	1150
a', abut.length blocking flow, ft	16.5	21.2	13.6	61.8	116.9	14.4
Ae, area of blocked flow ft2	74.47	88.58	51.33	68.26	86.4	53.71
Qe, discharge blocked abut.,cfs	203	--	129.38	--	--	136.56
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.73	3.59	2.52	2.83	3.37	2.54
ya, depth of f/p flow, ft	4.51	4.18	3.77	1.10	0.74	3.73
--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	55	55	55	125	125	125
K2	0.94	0.94	0.94	1.04	1.04	1.04
Fr, froude number f/p flow	0.226	0.296	0.229	0.358	0.426	0.232
ys, scour depth, ft	**10.07**	**11.16**	**8.42**	**7.58**	**8.27**	**9.04**

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)	16.5	21.2	13.6	61.8	116.9	14.4
y1 (depth f/p flow, ft)	4.51	4.18	3.77	1.10	0.74	3.73
a'/y1	3.66	5.07	3.60	55.95	158.17	3.86
Skew correction (p. 49, fig. 16)	0.87	0.87	0.87	1.08	1.08	1.08
Froude no. f/p flow	0.23	0.30	0.23	0.36	0.43	0.23
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	6.17	4.37	ERR
vertical w/ ww's	ERR	ERR	ERR	5.06	3.59	ERR
spill-through	ERR	ERR	ERR	3.39	2.40	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)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	1	0.82	1	1	0.82	1
y, depth of flow in bridge, ft	5.30	6.67	4.41	5.30	6.67	4.41
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	**2.22**	**2.64**	**1.84**	**2.22**	**2.64**	**1.84**