LEVEL II SCOUR ANALYSIS FOR BRIDGE 33 (CASTTH00050033) on TOWN HIGHWAY 5, crossing the CASTLETON RIVER, CASTLETON, VERMONT

Open-File Report 98-542

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

U.S. Department of the Interior
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LEVEL II SCOUR ANALYSIS FOR BRIDGE 33 (CASTTH00050033) on TOWN HIGHWAY 5, crossing the CASTLETON RIVER, CASTLETON, VERMONT

By ERICK M. BOEHMLER AND TIMOTHY SEVERANCE

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Pembroke, New Hampshire

1998

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	Max	maximum
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
LOB	left overbank	yr	year

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 33 (CASTTH00050033) ON TOWN HIGHWAY 5, CROSSING THE CASTLETON RIVER, CASTLETON, VERMONT

By **Erick M. Boehmler and Timothy Severance**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CASTTH00050033 on Town Highway 5 crossing the Castleton River, Castleton, 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 (FHWA, 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 Champlain section of the St. Lawrence Valley physiographic province in west-central Vermont. However, the majority of the drainage area is occupied in the Taconic section of the New England province. The 36.9-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the setting is suburban. Surface cover consists of shrubs and brush with a railroad, a residential roadway, and a house with a grass lawn along the left bank. The right bank upstream is a grass lawn bordering a cemetery and is categorized as pasture. The right bank downstream surface cover is forest.

In the study area, the Castleton River has a sinuous channel with a slope of approximately 0.003 ft/ft, an average channel top width of 76 ft and an average bank height of 9 ft. The channel bed material ranges from silt and clay to cobbles with a median grain size (D_{50}) of 19.4 mm (0.064 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 20, 1995, indicated that the reach was stable.

The Town Highway 5 crossing of the Castleton River is a 41-ft-long, one-lane bridge consisting of one 37-foot steel-beam span (Vermont Agency of Transportation, written communication, March 20, 1995). The opening length of the structure parallel to the bridge face is 34 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 40 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 2.5 ft deeper than the mean thalweg depth was observed in the center of the channel under the bridge and up to 0.75 feet of scour was observed along the right abutment and the upstream right wingwall during the Level I assessment. The scour protection measure at the site included type-1 (less than 12 inches diameter), type-2 (less than 36 inches diameter) and type-3 (less than 48 inches diameter) stone fill. The type-1 stone fill was observed on the abutments and the upstream right wingwall. Type-2 stone fill was observed on the upstream right bank and the upstream left wingwall. Type-3 stone fill was observed along both banks 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 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 0.7 to 7.0 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 14.9 to 20.1 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and 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.

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 CASTTH00050033 ***Stream*** Castleton River

County Rutland ***Road*** TH 5 ***District*** 3

Description of Bridge

Bridge length 41 ***ft*** ***Bridge width*** 14.5 ***ft*** ***Max span length*** 37 ***ft***

Alignment of bridge to road (on curve or straight) Curved right and straight left

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

Stone fill on abutment? Yes ***Date of inspection*** 9/20/95

Description of stone fill Type-1 at the downstream end of the right abutment, the entire base length of the left abutment, and the upstream end of the upstream right wingwall, and type-2 along the entire base length of the upstream left wingwall.

Brief description of piers/abutments The right abutment is concrete and the left abutment is a stone wall. The upstream and downstream right wingwalls are concrete and the upstream left wingwall is a stone wall.

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

Is bridge skewed to flood flow according to survey? Yes ***Angle*** 40

There is a moderate channel bend in the upstream reach. A scour hole has developed in the location where the bend impacts the upstream right wingwall.

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	9/20/95	0	0
Level II	9/20/95	0	0

Potential for debris Low.

Describe any features near or at the bridge that may affect flow (include observation date) None were observed on 9/20/95.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley, with irregular and narrow over-banks and moderately sloping valley walls on both sides.

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

Date of inspection 9/20/95

DS left: Steep channel bank (railroad embankment) to a flat overbank.

DS right: Steep channel bank to an irregular overbank.

US left: Steep channel bank (railroad embankment) to a flat overbank.

US right: Steep channel bank to an irregular overbank and steep valley wall.

Description of the Channel

Average top width 76 ***ft*** ***Average depth*** 9 ***ft***

Predominant bed material Sand to Cobbles ***Bank material*** Silt/Clay and Boulders

Perennial and sinuous with semi-alluvial channel boundaries and narrow point bars.

9/20/95

Vegetative co Shrubs, brush and a few trees

DS left: Trees with some shrubs and brush

DS right: Trees, shrubs, and brush

US left: Short grass

US right:

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

None were observed on 9/20/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 36.9 ***mi***^{2}

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
St. Lawrence Valley / Champlain	5
New England / Taconic	95

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: While the drainage area is rural the site is suburban. A railway, cemetery, and residential houses are located in the vicinity of the site.

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi***^{2}

Is there a lake/ No

-

Calculated Discharges

Q100 4,200 ***ft***^{3}***/s*** ***Q500*** 5,800 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on flood frequency estimates available from the VTAOT database records (written communication, May, 1995) for this site. The VTAOT values 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). Each curve was extended graphically to the 500-year event.

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. Add 91.9 feet to the USGS' survey to obtain the National Geodetic Vertical Datum of 1929.

Description of reference marks used to determine USGS datum. RM1 is a National Geodetic Survey Benchmark engraved "L25" on top of the upstream right wingwall at the upstream end (elev. 497.49 ft, arbitrary survey datum). RM2 is the top nut on a fire hydrant on the upstream side of TH 5 and 105 feet left of the left abutment (elev. 502.54 arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	0	1	Exit section
FULLV	13	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	13	1	Bridge section
RDWAY	20	1	Road Grade section
APPRO	64	1	Approach section

[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. Also, flow was assumed to align with the abutments in the opening. 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 0.035 to 0.050, and overbank "n" values ranged from 0.035 to 0.065.

The starting water surface elevations for the 100- and 500-year discharges were obtained from the water surface profile at cross section "N" provided in the Flood Insurance Study (FIS) for the Town of Castleton (FEMA, 1984). For the incipient roadway-overtopping discharge, the starting water surface elevation was obtained based on a rating of the discharges and water surface elevations computed at cross section N. Each water surface elevation at section "N" from the FIS was assumed to be a satisfactory starting water surface elevation at the exit section (EXITX), which was surveyed for this hydraulic evaluation.

The approach section (APPRO) was surveyed 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 499.3 *ft*
Average low steel elevation 497.6 *ft*

100-year discharge 4,200 *ft³/s*
Water-surface elevation in bridge opening 497.8 *ft*
Road overtopping? Yes *Discharge over road* 958 *ft³/s*
Area of flow in bridge opening 325 *ft²*
Average velocity in bridge opening 10.0 *ft/s*
Maximum WSPRO tube velocity at bridge 12.2 *ft/s*

Water-surface elevation at Approach section with bridge 500.9
Water-surface elevation at Approach section without bridge 499.5
Amount of backwater caused by bridge 1.4 *ft*

500-year discharge 5,800 *ft³/s*
Water-surface elevation in bridge opening 497.8 *ft*
Road overtopping? Yes *Discharge over road* 2,474 *ft³/s*
Area of flow in bridge opening 325 *ft²*
Average velocity in bridge opening 10.2 *ft/s*
Maximum WSPRO tube velocity at bridge 12.5 */s*

Water-surface elevation at Approach section with bridge 502.0
Water-surface elevation at Approach section without bridge 500.9
Amount of backwater caused by bridge 1.1 *ft*

Incipient overtopping discharge 2,380 *ft³/s*
Water-surface elevation in bridge opening 497.1 *ft*
Area of flow in bridge opening 307 *ft²*
Average velocity in bridge opening 7.8 *ft/s*
Maximum WSPRO tube velocity at bridge 10.3 *ft/s*

Water-surface elevation at Approach section with bridge 497.9
Water-surface elevation at Approach section without bridge 497.9
Amount of backwater caused by bridge 0.0 *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 submerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146).

For comparison, contraction scour for the discharges resulting in orifice flow also was computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Results from these computations are presented 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	6.4	7.0	0.7
Depth to armoring	N/A	N/A	3.5
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	*100-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
Abutment scour			
Left abutment	16.6	20.0	14.9
Right abutment	19.2	20.1	16.1
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	1.9	2.0	1.1
Right abutment	1.9	2.0	1.1
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

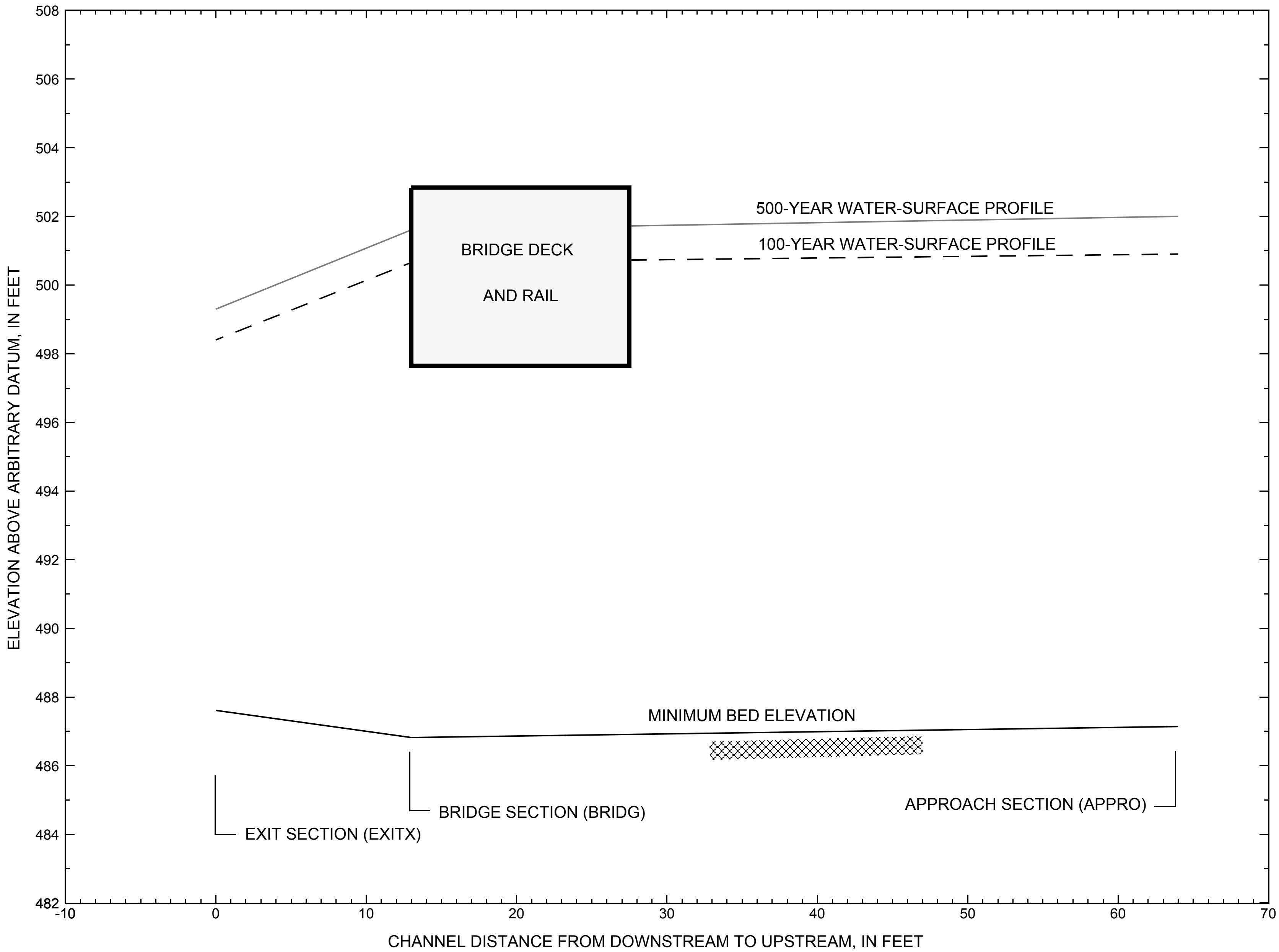

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure CASTTH00050033 on Town Highway 5, crossing the Castleton River, Castleton, Vermont.

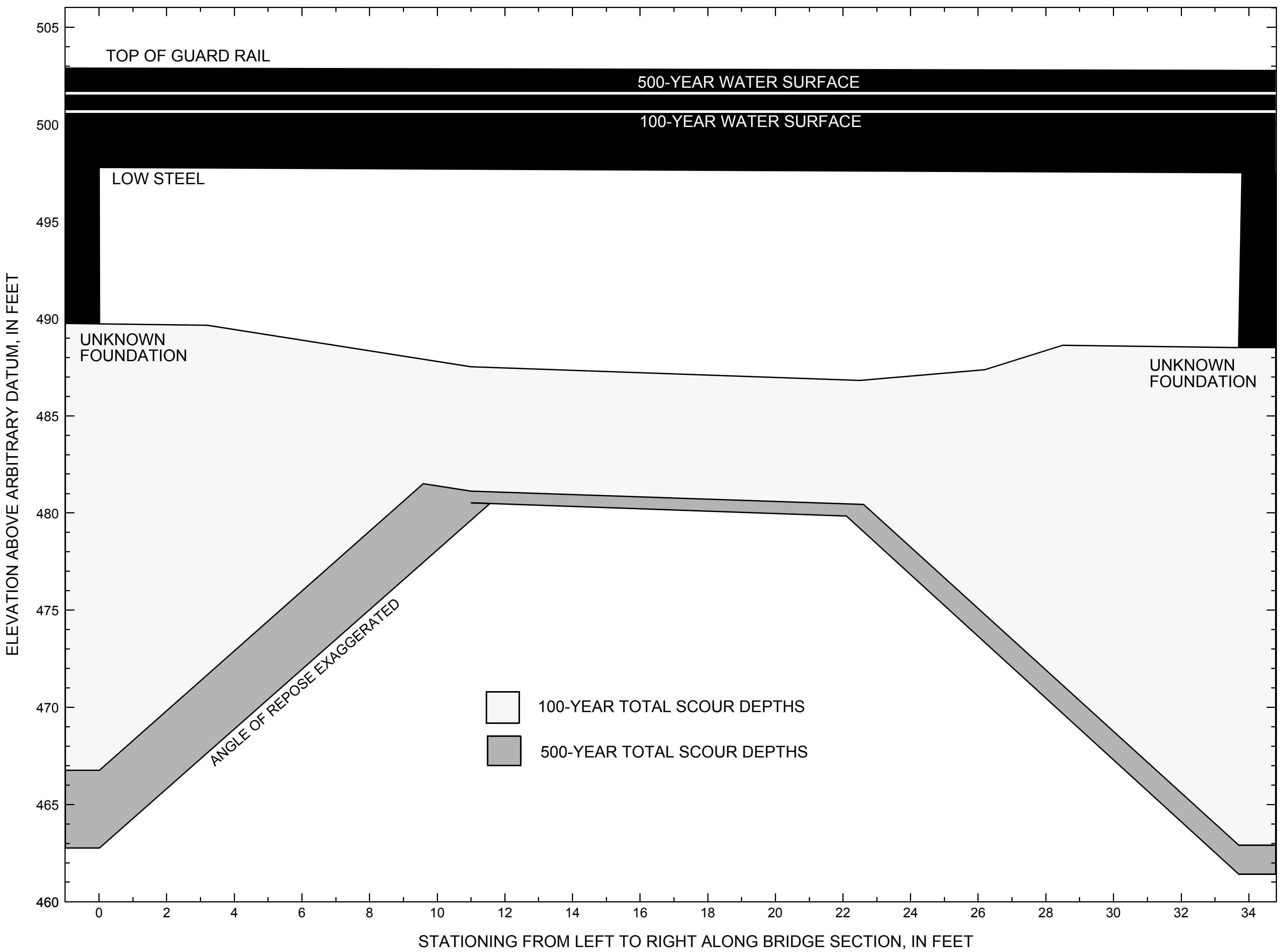

Figure 8. Scour elevations for the 100- and 500-year discharges at structure CASTTH00050033 on Town Highway 5, crossing the Castleton River, Castleton, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CASTTH00050033 on Town Highway 5, crossing the Castleton River, Castleton, 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 4,200 cubic-feet per second											
Left abutment	0.0	--	497.8	--	489.8	6.4	16.6	--	23.0	466.8	--
Right abutment	33.8	--	497.5	--	488.5	6.4	19.2	--	25.6	462.9	--

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 CASTTH00050033 on Town Highway 5, crossing the Castleton River, Castleton, 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 5,800 cubic-feet per second											
Left abutment	0.0	--	497.8	--	489.8	7.0	20.0	--	27.0	462.8	--
Right abutment	33.8	--	497.5	--	488.5	7.0	20.1	--	27.1	461.4	--

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, 1964, Poultney, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photorevised 1972, Contour Interval, 20 feet, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File cast033.wsp
T2        Hydraulic analysis for structure CASTTH00050033   Date: 25-MAR-98
T3        Town Highway 5 (Cemetary Road) over the Castleton River, Castleton, VT
*         * * This file was generated by AWISPP v3.0.5 * *
*             AWISPP - Automated WSPRO Input and Survey Processing Program
*
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           4200.0   5800.0   2380.0
WS          498.4    499.3    497.2
*           0.0033   0.0033
*
XS   EXITX      0
GR          -89.7, 503.58    -82.7, 498.14    -68.3, 499.12    -25.3, 501.06
GR          -23.5, 500.34    -11.6, 495.92     -6.4, 493.17     -4.4, 493.24
GR            0.0, 489.82      5.8, 488.87      9.5, 487.84     13.6, 487.61
GR           18.3, 488.14     23.2, 489.89     29.5, 493.43     45.2, 498.97
GR           81.4, 499.84     90.4, 498.95    100.6, 495.40    114.3, 495.47
GR          137.3, 495.72    152.8, 500.67    170.8, 510.93
*
N           0.050        0.050        0.065
SA                 -23.5         45.2
*
XS   FULLV      13   * * *   0.0
*
*             SRD     LSEL    XSSKEW
BR   BRIDG    13     497.65      0.0
GR            0.0, 497.78      0.0, 489.76      3.2, 489.66     11.0, 487.52
GR           22.5, 486.82     26.2, 487.37     28.5, 488.63     33.7, 488.51
GR           33.8, 497.51      0.0, 497.78
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      29.4 * *     61.3      8.5
N           0.035
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     20      14.5     2
GR          -89.7, 503.58    -82.7, 498.14    -68.3, 499.12    -28.8, 501.00
GR          -20.7, 501.04     -4.1, 499.99     -3.1, 499.65     -2.9, 502.99
GR            0.0, 502.90     23.8, 502.78     36.8, 502.36     37.3, 498.93
GR           62.2, 499.46    118.3, 499.81    162.5, 501.09    168.5, 500.36
GR          178.4, 501.21    196.4, 511.47
*
AS   APPRO     64           0.
GR          -92.5, 503.58    -85.5, 498.14    -71.1, 499.12    -31.6, 501.10
GR          -29.6, 500.35    -21.9, 496.99    -14.4, 492.14    -11.3, 491.70
GR           -9.1, 491.55     -5.8, 490.64      0.0, 492.46      6.0, 493.02
GR           12.8, 492.15     16.2, 489.85     18.8, 488.41     22.7, 488.31
GR           27.7, 488.39     35.6, 487.14     37.0, 487.34     42.3, 489.86
GR           49.8, 494.19     56.4, 498.44    115.9, 499.02    158.2, 500.71
GR          191.9, 502.75    212.6, 512.59
*
N           0.035        0.050        0.040
SA                 -31.6         56.4
*
HP 1 BRIDG 497.78 1 497.78
HP 2 BRIDG 497.78 * * 3242
HP 2 RDWAY 500.66 * *  958
HP 1 APPRO 500.90 1 500.90
HP 2 APPRO 500.90 * * 4200
*
HP 1 BRIDG 497.78 1 497.78
HP 2 BRIDG 497.78 * * 3324
HP 2 RDWAY 501.61 * * 2474
HP 1 APPRO 502.00 1 502.00
HP 2 APPRO 502.00 * * 5800
*
HP 1 BRIDG 497.11 1 497.11
HP 2 BRIDG 497.11 * * 2380
HP 1 APPRO 497.87 1 497.87
HP 2 APPRO 497.87 * * 2380
*
EX
ER
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File cast033.wsp
        Hydraulic analysis for structure CASTTH00050033   Date: 25-MAR-98
        Town Highway 5 (Cemetary Road) over the Castleton River, Castleton, VT
           *** RUN DATE & TIME: 07-14-98  13:54

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =      13.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     325.  33840.     0.    85.                             0.
   497.78          325.  33840.     0.    85.  1.00     0.    34.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =      13.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.78     0.0    33.8   325.4   33840.    3242.   9.96

X STA.         0.0        4.6        6.3        7.9        9.4       10.8
  A(I)            37.0       15.3       14.3       14.6       13.7
  V(I)            4.38      10.60      11.36      11.11      11.84

X STA.        10.8       12.1       13.5       14.8       16.1       17.4
  A(I)            13.7       14.0       13.6       13.6       13.7
  V(I)           11.79      11.57      11.89      11.95      11.87

X STA.        17.4       18.7       20.0       21.3       22.5       23.8
  A(I)            13.7       13.8       13.6       13.3       13.3
  V(I)           11.80      11.73      11.93      12.17      12.23

X STA.        23.8       25.1       26.4       28.0       29.6       33.8
  A(I)            13.8       13.7       14.7       14.5       37.4
  V(I)           11.73      11.81      11.04      11.19       4.33

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      20.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.66   -85.9   172.0   170.2    4317.     958.   5.63

X STA.       -85.9      -81.8      -79.8      -77.4      -74.8      -71.7
  A(I)             6.3        4.9        5.3        5.4        5.8
  V(I)            7.63       9.75       9.00       8.83       8.30

X STA.       -71.7      -67.9      -63.0      -55.8       39.2       42.0
  A(I)             6.2        6.9        8.0       17.3        4.6
  V(I)            7.73       6.91       5.98       2.78      10.42

X STA.        42.0       45.8       50.5       56.0       62.6       69.7
  A(I)             6.1        7.1        7.6        8.2        8.4
  V(I)            7.88       6.71       6.26       5.82       5.69

X STA.        69.7       77.5       85.9       95.0      105.5      172.0
  A(I)             8.8        9.1        9.3       10.0       24.8
  V(I)            5.46       5.28       5.13       4.78       1.93

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      69.    3454.    53.    54.                           447.
             2     766.   92231.    87.    94.                         12869.
             3     173.    9008.   105.   105.                          1263.
   500.90         1009.  104693.   246.   254.  1.21   -89.   161.  10521.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.90   -89.1   161.3  1008.6  104693.    4200.   4.16

X STA.       -89.1      -12.7       -8.4       -4.5        0.1        5.5
  A(I)           149.0       39.8       39.1       41.7       44.4
  V(I)            1.41       5.27       5.37       5.03       4.73

X STA.         5.5       10.9       15.6       18.8       21.5       24.0
  A(I)            43.7       43.8       37.5       33.6       31.7
  V(I)            4.80       4.79       5.60       6.24       6.62

X STA.        24.0       26.7       29.6       32.2       34.9       37.4
  A(I)            33.5       35.9       35.1       35.3       34.1
  V(I)            6.27       5.86       5.99       5.96       6.16

X STA.        37.4       40.1       43.7       48.9       80.9      161.3
  A(I)            35.2       39.5       45.8       93.8      115.9
  V(I)            5.96       5.32       4.58       2.24       1.81
```

WSPRO OUTPUT FILE (continued)

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File cast033.wsp
        Hydraulic analysis for structure CASTTH00050033   Date: 25-MAR-98
        Town Highway 5 (Cemetary Road) over the Castleton River, Castleton, VT
           *** RUN DATE & TIME: 07-14-98  13:54

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =      13.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     325.   33840.     0.    85.                            0.
   497.78          325.   33840.     0.    85.  1.00     0.    34.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =      13.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.78     0.0    33.8   325.4   33840.    3324.  10.22

X STA.         0.0        4.6        6.3        7.9        9.4       10.8
  A(I)             37.0       15.3       14.3       14.6       13.7
  V(I)             4.49      10.87      11.65      11.39      12.14

X STA.        10.8       12.1       13.5       14.8       16.1       17.4
  A(I)             13.7       14.0       13.6       13.6       13.7
  V(I)            12.09      11.87      12.19      12.25      12.17

X STA.        17.4       18.7       20.0       21.3       22.5       23.8
  A(I)             13.7       13.8       13.6       13.3       13.3
  V(I)            12.10      12.02      12.23      12.48      12.54

X STA.        23.8       25.1       26.4       28.0       29.6       33.8
  A(I)             13.8       13.7       14.7       14.5       37.4
  V(I)            12.03      12.11      11.32      11.47       4.44

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      20.

         WSEL     LEW     REW    AREA        K        Q    VEL
       501.61   -87.2   179.1   373.1   13298.    2474.   6.63

X STA.       -87.2      -80.6      -76.9      -72.7      -67.6      -61.4
  A(I)             14.7       11.9       12.4       13.4       14.4
  V(I)             8.40      10.38      10.01       9.24       8.60

X STA.       -61.4      -53.4      -40.9       -8.5       41.3       46.4
  A(I)             15.7       18.5       27.3       19.6       12.8
  V(I)             7.86       6.69       4.53       6.32       9.66

X STA.        46.4       52.9       60.3       68.7       77.1       86.1
  A(I)             15.8       16.8       17.9       17.5       18.3
  V(I)             7.81       7.34       6.90       7.06       6.76

X STA.        86.1       95.6      105.5      116.1      128.3      179.1
  A(I)             18.6       19.0       19.6       20.5       48.4
  V(I)             6.66       6.52       6.30       6.05       2.56

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     133.    9569.    59.    60.                         1131.
             2     863.  111996.    88.    95.                        15335.
             3     299.   20073.   123.   123.                         2639.
   502.00         1294.  141638.   270.   278.  1.19   -90.   180.  14712.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.00   -90.5   179.5  1294.4  141638.    5800.   4.48

X STA.       -90.5      -58.2      -12.4       -7.7       -3.2        2.2
  A(I)             91.2      145.6       49.4       49.6       52.6
  V(I)             3.18       1.99       5.87       5.85       5.51

X STA.         2.2        8.3       13.9       18.2       21.4       24.4
  A(I)             55.4       54.8       50.8       43.4       41.0
  V(I)             5.24       5.29       5.71       6.69       7.07

X STA.        24.4       27.6       30.8       33.9       36.8       40.1
  A(I)             44.1       44.8       43.8       43.0       46.4
  V(I)             6.57       6.47       6.62       6.74       6.24

X STA.        40.1       44.1       51.0       76.1      103.1      179.5
  A(I)             48.9       62.5       96.6       87.7      142.9
  V(I)             5.92       4.64       3.00       3.31       2.03
```

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File cast033.wsp
        Hydraulic analysis for structure CASTTH00050033   Date: 25-MAR-98
        Town Highway 5 (Cemetary Road) over the Castleton River, Castleton, VT
           *** RUN DATE & TIME: 07-14-98  13:54

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =      13.

     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1     307.  43698.    34.    50.                        5258.
   497.11          307.  43698.    34.    50.  1.00     0.    34.   5258.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =      13.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.11     0.0    33.8   307.3   43698.    2380.   7.75

X STA.         0.0         5.7         7.3         8.7        10.1        11.3
  A(I)            43.5        12.7        12.6        12.6        12.1
  V(I)            2.74        9.40        9.44        9.47        9.82

X STA.        11.3        12.6        13.8        15.0        16.3        17.5
  A(I)            11.8        12.0        12.2        12.1        12.2
  V(I)           10.07        9.95        9.79        9.83        9.76

X STA.        17.5        18.7        19.9        21.0        22.2        23.4
  A(I)            12.0        12.1        11.9        11.9        11.7
  V(I)            9.94        9.86       10.03       10.01       10.15

X STA.        23.4        24.5        25.7        27.0        28.4        33.8
  A(I)            11.6        11.7        12.5        13.0        45.3
  V(I)           10.26       10.14        9.52        9.18        2.63

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             2     513.  50378.    79.    86.                        7388.
   497.87          513.  50378.    79.    86.  1.00    -24.    56.   7388.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.87   -23.9    55.5   512.6   50378.    2380.   4.64

X STA.       -23.9        -9.5        -5.9        -2.2         3.0         9.1
  A(I)            55.2        24.3        24.7        28.7        30.7
  V(I)            2.16        4.89        4.83        4.14        3.88

X STA.         9.1        14.2        17.4        19.6        21.7        23.6
  A(I)            28.9        24.4        20.6        19.6        18.5
  V(I)            4.11        4.89        5.77        6.08        6.44

X STA.        23.6        25.7        27.9        30.0        32.1        34.0
  A(I)            19.6        20.8        20.8        20.5        20.1
  V(I)            6.06        5.71        5.72        5.81        5.91

X STA.        34.0        35.8        37.7        39.9        42.4        55.5
  A(I)            19.3        19.7        20.9        22.0        53.3
  V(I)            6.18        6.05        5.70        5.40        2.23
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WSPRO OUTPUT FILE (continued)

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File cast033.wsp
        Hydraulic analysis for structure CASTTH00050033   Date: 25-MAR-98
        Town Highway 5 (Cemetary Road) over the Castleton River, Castleton, VT
           *** RUN DATE & TIME: 07-14-98  13:54

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

EXITX:XS   ******   -83.     505.  1.32 *****  499.72  497.57   4200.  498.40
        0. ******   146.   40722.  1.23 ***** *******    0.79    8.31

FULLV:FV      13.   -83.     545.  1.14  0.13  499.86 *******   4200.  498.72
       13.    13.   147.   44330.  1.23  0.00    0.01    0.73    7.71
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  1.66

APPRO:AS      51.   -87.     715.  0.60  0.28  500.13 *******   4200.  499.53
       64.    51.   129.   73666.  1.12  0.00    0.00    0.55    5.88
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                         WS3N,LSEL =    498.72     497.65

            <<<<<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      13.     0.     325.  1.54 *****  499.32  494.60   3242.  497.78
       13. ******    34.   33840.  1.00 ***** *******    0.57    9.96

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.65 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.    37.  0.06  0.33  501.17    0.00    958.  500.66

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    357.    62.   -86.    -3.   2.5   1.0   5.7   5.7   1.5   3.1
   RT:    601.   117.    37.   172.   1.7   0.9   5.4   5.6   1.4   3.0

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

APPRO:AS      22.   -89.    1009.  0.33  0.10  501.23  495.59   4200.  500.90
       64.    25.   161.  104690.  1.21  0.00    0.00    0.40    4.16

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS       0.    -83.   146.   4200.   40722.     505.    8.31  498.40
   FULLV:FV      13.    -83.   147.   4200.   44330.     545.    7.71  498.72
   BRIDG:BR      13.      0.    34.   3242.   33840.     325.    9.96  497.78
   RDWAY:RG      20.*******   357.    958.******************    2.00  500.66
   APPRO:AS      64.    -89.   161.   4200.  104690.    1009.    4.16  500.90

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    497.57    0.79  487.61  510.93************  1.32  499.72  498.40
   FULLV:FV  ********    0.73  487.61  510.93  0.13  0.00  1.14  499.86  498.72
   BRIDG:BR    494.60    0.57  486.82  497.78************  1.54  499.32  497.78
   RDWAY:RG  ****************  498.14  511.47  0.06******  0.33  501.17  500.66
   APPRO:AS    495.59    0.40  487.14  512.59  0.10  0.00  0.33  501.23  500.90
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WSPRO OUTPUT FILE (continued)

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File cast033.wsp
        Hydraulic analysis for structure CASTTH00050033   Date: 25-MAR-98
        Town Highway 5 (Cemetary Road) over the Castleton River, Castleton, VT
           *** RUN DATE & TIME: 07-14-98  13:54

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

EXITX:XS   ******   -84.     627.  1.76 *****  501.06  498.72   5800.  499.30
        0. ******   149.   50864.  1.32 ***** *******    0.95    9.25

 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.91     499.72     498.72

 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   498.80     510.93    0.50

 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   498.80     510.93     498.72

FULLV:FV      13.   -85.     702.  1.50  0.15  501.22  498.72   5800.  499.72
       13.    13.   150.   56406.  1.41  0.00    0.01    0.91    8.26
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             “APPRO”     KRATIO =  1.84

APPRO:AS      51.   -89.    1000.  0.63  0.29  501.50 *******   5800.  500.87
       64.    51.   161.  103775.  1.21  0.00   -0.01    0.56    5.80
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   499.72     497.65

            <<<<<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      13.     0.     325.  1.62 *****  499.40  494.71   3324.  497.78
       13. ******    34.   33840.  1.00 ***** *******    0.58   10.22

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.65 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.    37.  0.06  0.37  502.31    0.00   2474.  501.61

              Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    912.    84.   -87.    -3.   3.5   1.6   7.0   6.7   2.3   3.1
   RT:   1562.   142.    37.   179.   2.7   1.7   7.0   6.6   2.4   3.0

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

APPRO:AS      22.   -90.    1294.  0.37  0.12  502.37  496.78   5800.  502.00
       64.    27.   179.  141522.  1.20  0.00    0.00    0.39    4.48

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS       0.   -84.   149.   5800.   50864.     627.    9.25  499.30
   FULLV:FV      13.   -85.   150.   5800.   56406.     702.    8.26  499.72
   BRIDG:BR      13.     0.    34.   3324.   33840.     325.   10.22  497.78
   RDWAY:RG      20.*******   912.   2474.*****************    2.00  501.61
   APPRO:AS      64.   -90.   179.   5800.  141522.    1294.    4.48  502.00

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    498.72    0.95  487.61  510.93************  1.76  501.06  499.30
   FULLV:FV    498.72    0.91  487.61  510.93  0.15  0.00  1.50  501.22  499.72
   BRIDG:BR    494.71    0.58  486.82  497.78************  1.62  499.40  497.78
   RDWAY:RG  ***************  498.14  511.47  0.06******  0.37  502.31  501.61
   APPRO:AS    496.78    0.39  487.14  512.59  0.12  0.00  0.37  502.37  502.00
```
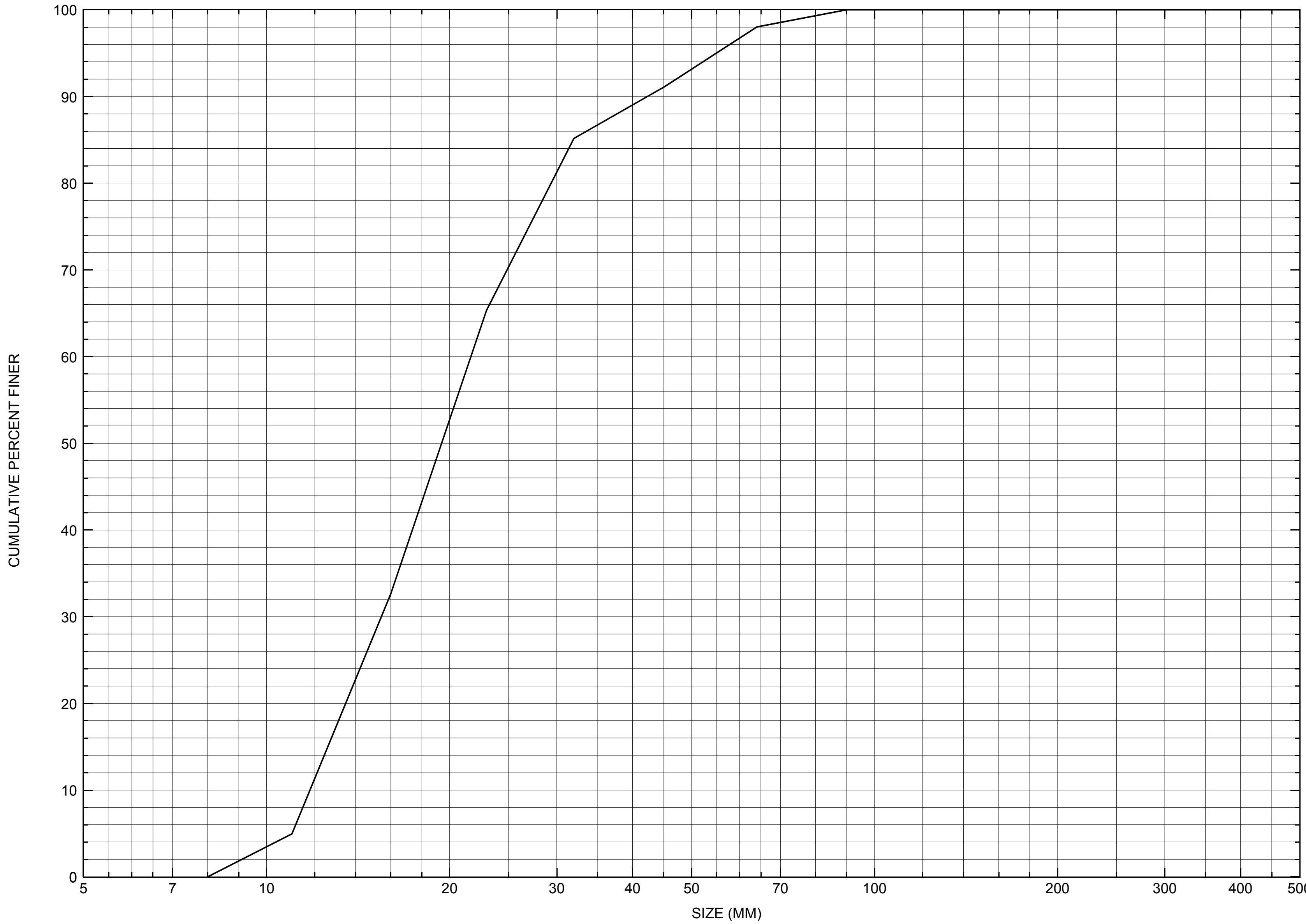

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File cast033.wsp
        Hydraulic analysis for structure CASTTH00050033   Date: 25-MAR-98
        Town Highway 5 (Cemetary Road) over the Castleton River, Castleton, VT
           *** RUN DATE & TIME: 07-14-98  13:54

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

EXITX:XS   ******   -15.     374.  0.77 *****  497.97  495.02   2380.  497.20
        0. ******   142.   29097.  1.22 ***** *******    0.65    6.36

FULLV:FV      13.   -15.     390.  0.71  0.08  498.06 *******   2380.  497.36
       13.     13.   142.   30463.  1.22  0.00    0.01    0.61    6.10
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  1.67

APPRO:AS      51.   -24.     517.  0.33  0.19  498.25 *******   2380.  497.92
       64.     51.    56.   50945.  1.00  0.00    0.00    0.32    4.61
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   497.11     497.79     497.87     497.65

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

 ===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                        YU/Z,WSIU,WS = 1.10     498.61     498.68

 ===270 REJECTED 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      13.     0.     307.  0.93  0.07  498.04  493.37   2380.  497.11
       13.     13.    34.   43677.  1.00  0.00    0.00    0.45    7.75

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  497.65 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.         <<<<<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      22.   -24.     513.  0.34  0.08  498.21  493.95   2380.  497.87
       64.     25.    56.   50390.  1.00  0.09    0.00    0.32    4.64

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.576  0.304   35052.     6.    40.   497.79

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS       0.   -15.   142.   2380.   29097.     374.    6.36  497.20
   FULLV:FV      13.   -15.   142.   2380.   30463.     390.    6.10  497.36
   BRIDG:BR      13.     0.    34.   2380.   43677.     307.    7.75  497.11
   RDWAY:RG      20.**************      0.*********       0.    2.00********
   APPRO:AS      64.   -24.    56.   2380.   50390.     513.    4.64  497.87

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       6.    40.   35052.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX     HF    HO   VHD      EGL    WSEL
   EXITX:XS    495.02    0.65  487.61  510.93************  0.77  497.97  497.20
   FULLV:FV  ********    0.61  487.61  510.93   0.08  0.00  0.71  498.06  497.36
   BRIDG:BR    493.37    0.45  486.82  497.78   0.07  0.00  0.93  498.04  497.11
   RDWAY:RG  ****************  498.14  511.47************  0.26  498.88********
   APPRO:AS    493.95    0.32  487.14  512.59   0.08  0.09  0.34  498.21  497.87
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CASTTH00050033, in Castleton, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CASTTH00050033

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 20 / 95

Highway District Number *(I - 2; nn)* 03

County *(FIPS county code; I - 3; nnn)* 021

Town *(FIPS place code; I - 4; nnnnn)* 11950

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

Waterway *(I - 6)* CASTLETON RIVER

Road Name *(I - 7)*: -

Route Number TH005

Vicinity *(I - 9)* 0.15 MI TO JCT W TH1

Topographic Map Poultney

Hydrologic Unit Code: 02010001

Latitude *(I - 16; nnnn.n)* 43367

Longitude *(i - 17; nnnnn.n)* 73112

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10110300331103

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

Maximum span length *(I - 48; nnnn)* 0037

Year built *(I - 27; YYYY)* 1908

Structure length *(I - 49; nnnnnn)* 000041

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

Deck Width *(I - 52; nn.n)* 145

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

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

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

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

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

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*) 034.0

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

Vertical clearance from streambed (*nnn.n ft*) 010.0

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

Waterway of full opening (*nnn.n* ft^2) 340.0

Comments:

The structural inspection report of 7/13/94 indicates the structure is a single span, steel beam type bridge. The right abutment and its wingwalls are concrete while the left abutment is "laid-up" cut-stone blocks. The right abutment is reported as having areas of spalling and heavy concrete scaling along the bottom of the wall. The left abutment has cracks, breaks, voids, and displacement of the stone reported. Settlement of the left abutment has occurred, reportedly. Its wingwalls are in a condition similar to that of the abutment concrete. The report notes scour along the left abutment, which has created a 3 foot long segment where the stone blocks have fallen out from the wall. Furthermore, scour is reported **(Continued, page 33)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

through the bridge along the centerline of the stream. The streambed is composed of stones and silt. There is a log across part of the channel upstream from the structure and another tree is hanging over the channel downstream. The majority of the flow is noted to proceed along the upstream right wingwall, and then makes a sharp bend through the structure impacting the left abutment.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **36.87** mi^2 Lake/pond/swamp area **0.29** mi^2

Watershed storage *(ST)* **1.1** %

Bridge site elevation **400** ft Headwater elevation **2726** ft

Main channel length **8.46** mi

10% channel length elevation **440** ft 85% channel length elevation **1180** ft

Main channel slope *(S)* **116.69** 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? **Yes** *If no, type ctrl-n xs*

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

Comments: **The elevation and station measurements are in feet. This cross section was dated 7/7/92 and attached to a bridge inspection report. The elevation coordinate was taken from the surveyed points used in this report. They line-up at the low chord points.**

Station	0	10	17.33	23.66	34.00	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	497.79	497.71	497.65	497.60	497.51	-	-	-	-	-	-
Bed elevation	490.04	487.29	487.15	487.10	488.43	-	-	-	-	-	-
Low chord to bed	7.75	10.42	10.50	10.50	9.08	-	-	-	-	-	-

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: **MAI** Date: **10/25/95**
Computerized by: **MAI** Date: **10/25/95**
Reviewd by: **EMB** Date: **4/29/98**

Structure Number **CASTTH00050023**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **T**. **Severance** Date *(MM/DD/YY)* **09** / **20** / 19**95**

2. Highway District Number **03** Mile marker **0**

County **Rutland (021)** Town **Castleton (11950)**

Waterway *(I - 6)* **Castleton River** Road Name **Cemetery Road**

Route Number **TH 5** Hydrologic Unit Code: **02010001**

3. Descriptive comments:
This bridge is located 0.15 mile from the junction of Town Highway 1.

B. Bridge Deck Observations

4. Surface cover... LBUS **2** RBUS **2** LBDS **2** RBDS **6** 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 **1** UB **1** DS **1** *(**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 **41.0** *(feet)* Span length **37.0** *(feet)* Bridge width **14.5** *(feet)*

Road approach to bridge:

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

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

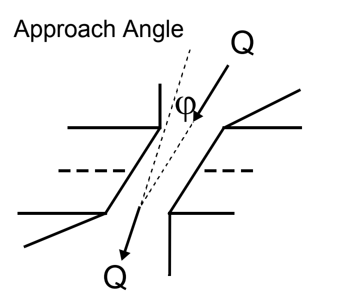
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

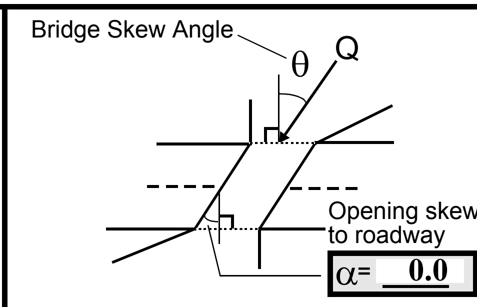
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	0	-	2	1
RBDS	0	-	2	1
LBDS	0	-	2	1

*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: **40** 16. Bridge skew: **40**





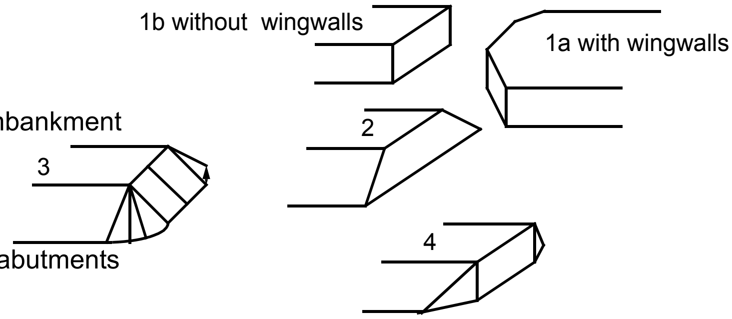
17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **0** feet **US** *(US, UB, DS)* to **60** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **0** feet **US** *(US, UB, DS)* to **60** feet **DS**

*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 surface cover generally is suburban. A railroad bed follows the left bank of the river near this site. In addition to the railroad downstream, the surface cover consists primarily of shrubs and brush. A cemetary and TH 5 occupy the upstream right overbank. On the upstream left overbank, a residential neighborhood was observed with a house and a local roadway following the river. Forest covers the downstream right over-bank.
7. The span length and deck width measured were 36.0 feet and 15.0 feet, respectively.
13. Some slumping is evident at the base of the up- and downstream left road embankments.

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
38.0	**9.0**			**8.5**	**1**	**1**	**13**	**13**	**1**	**1**

23. Bank width **25.0** 24. Channel width **30.0** 25. Thalweg depth **83.0** 29. Bed Material **3**

30 .Bank protection type: LB **0** RB **2** 31. Bank protection condition: LB **-** 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.):
27. Silty / clay in upper layer with gravel below.
30. Right bank protection extends 65 feet upstream of the upstream right wingwall.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **96** 35. Mid-bar width: **5**

36. Point bar extent: **88** feet **US** (US, UB) to **116** feet **US** (US, UB, DS) positioned **80** %LB to **100** %RB

37. Material: **32**

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

This is a gravel point bar with more sand at the US end. A second point bar is located along the right bank from 133 to 167 feet US. The width is 5 feet at the mid-bar distance of 153 feet US and the bar is positioned 80% left to 100% right banks. There is grass covering the bar.

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

41. Mid-bank distance: **95** 42. Cut bank extent: **50** feet **US** (US, UB) to **130** feet **US** (US, UB, DS)

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

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

Tree roots are exposed with a number of smaller trees leaning into the channel. Much of the finer material has been washed away, leaving gravel along the base of the left bank.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **18**

47. Scour dimensions: Length **82** Width **12** Depth : **2** Position **50** %LB to **100** %RB

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

The bed is primarily gravel with little (0.2 feet) to no penetration along the scoured section. A mucky layer overlies the gravel along the left bank. There is 1 foot of penetration in areas before hitting gravel; material washes into the channel from the bank and confluence.

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

51. Confluence 1: Distance **14** 52. Enters on **LB** (LB or RB) 53. Type **1** (**1**- perennial; **2**- ephemeral)

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

54. Confluence comments (eg. confluence name):

A ditch enters 10 feet US of the US end of the US left wingwall. The ditch runs along and between the railroad embankment and stream channel.

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
53.5		**2.5**		**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.):

21

A scour-hole is positioned along the right half of the channel and bed material is composed of fine gravel and course sand. Bed material on the left half of the channel consists of more silt with a penetration of 0.5 feet. The stone protection under the bridge encroaches on the center of the channel. The scour depth under the bridge is 2.5 feet at 8 feet under the bridge and to the right of the center of the channel.

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

There is debris located US along the left bank. A fallen tree mentioned in the structural inspection dated 7/13/94 has been removed.

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		**40**	**90**	**2**	**0**	**-**	**-**	**90.0**
RABUT	**2**	**0**	**90**			**2**	**2**	**34.0**

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.):

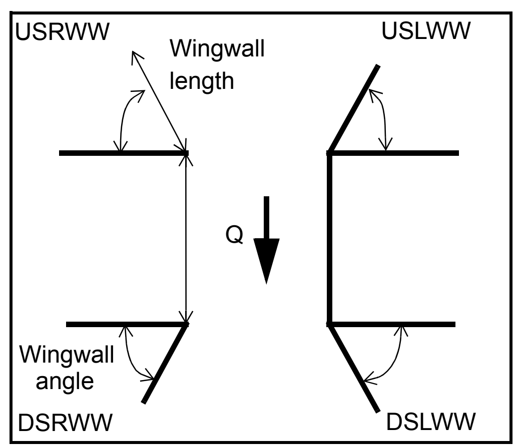
0.5
1.2
1

74. The right abutment footing is exposed at the downstream end. Beyond 2 feet in either direction the footing is covered by stone fill. The downstream end of the right wingwall is met by bank protection covered with sand.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**34.0**	
USRWW:	**Y**		**2**		**0**	**3.0**	
DSLWW:	**-**		**-**		**Y**	**16.5**	
DSRWW:	**1**		**2**		**0.75**	**16.5**	

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



82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	**1.25**	**-**	**Y**	**-**	**2**	**2**	**2**	**2**
Condition	**N**	**-**	**1**	**-**	**1**	**2**	**1**	**3**
Extent	**-**	**-**	**0**	**2**	**1**	**1**	**1**	**-**

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

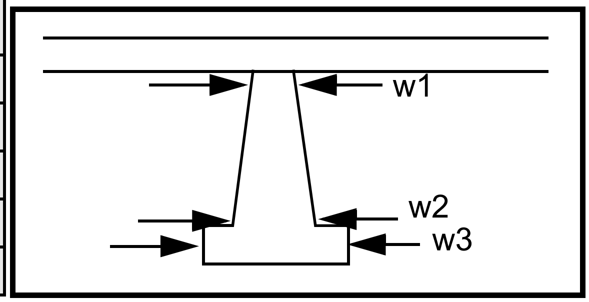
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
0
-
-
0
-
-

Piers:

84. Are there piers? **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				**90.0**	**14.5**	**35.0**
Pier 2		**-**		**20.0**	**-**	**30.0**
Pier 3	**8.0**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e**	**cov-**	**wall**	**detect**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**upst**	**ered**	**has**	**pro-**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**ream**	**by**	**par-**	**tec-**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**left**	**slum**	**tially**	**tion.**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**wing**	**ped**	**falle**	**DS**	*Y- yes; N- no*
91. Attack ∠ (BF)	**wall**	**eart**	**n**	**right**	
92. Pushed	**pro-**	**h/**	**into**	**wing**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**tec-**	**grass**	**the**	**wall-**	
95. Cross-members	**tion**	**.**	**chan**	**no**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**is**	**DS**	**nel-**	**pro-**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**most**	**left**	**unab**	**tec-**	
98. Exposure depth	**ly**	**wing**	**le to**	**tion**	

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

detected, but unable to penetrate hard earth (road wash path) some slate (flat) pieces line the surface and are reducing and eliminating road wash effects below the road surface.

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? N____ *(Y or if N type ctrl-n cb)* Where? O____ *(LB or RB)* Mid-bank distance: PIE_

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

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

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

Is channel scour present? _____ *(Y or if N type ctrl-n cs)* Mid-scour distance: 1______

Scour dimensions: Length 2_____ Width 5_____ Depth: 5_____ Positioned 0____ %LB to 0____ %RB

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

432
3
3
1

Are there major confluences? 1____ *(Y or if N type ctrl-n mc)* How many? Ther

Confluence 1: Distance e is_ Enters on ston_ *(LB or RB)* Type e fill_ *(**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):

along both left and right banks for greater than 100 feet downstream.
Stone fill lines the channel bed from 0 to 70 feet DS.

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: CASTTH00050033 Town: Castleton
Road Number: TH 5 (Cemetary Road) County: Rutland
Stream: Castleton River

Initials EMB Date: 4/29/98 Checked: MAI

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	4200	5800	2380
Main Channel Area, ft2	766	863	513
Left overbank area, ft2	69	133	0
Right overbank area, ft2	173	299	0
Top width main channel, ft	87	88	79
Top width L overbank, ft	53	59	0
Top width R overbank, ft	105	123	0
D50 of channel, ft	0.0636	0.0636	0.0636
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.8	9.8	6.5
y1, average depth, LOB, ft	1.3	2.3	ERR
y1, average depth, ROB, ft	1.6	2.4	ERR
Total conveyance, approach	104693	141638	50378
Conveyance, main channel	92231	111996	50378
Conveyance, LOB	3454	9569	0
Conveyance, ROB	9008	20073	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	3700.1	4586.2	2380.0
Ql, discharge, LOB, cfs	138.6	391.8	0.0
Qr, discharge, ROB, cfs	361.4	822.0	0.0
Vm, mean velocity MC, ft/s	4.8	5.3	4.6
Vl, mean velocity, LOB, ft/s	2.0	2.9	ERR
Vr, mean velocity, ROB, ft/s	2.1	2.7	ERR
Vc-m, crit. velocity, MC, ft/s	6.4	6.5	6.1
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

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	3242	3324	2380
Main channel area (DS), ft2	325.4	325.4	307.3
Main channel width (normal), ft	33.8	33.8	33.8
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	33.8	33.8	33.8
D90, ft	0.1387	0.1387	0.1387
D95, ft	0.1801	0.1801	0.1801
Dc, critical grain size, ft	0.2204	0.2317	0.1355
Pc, Decimal percent coarser than Dc	0.017	0.014	0.104
Depth to armoring, ft	N/A	N/A	3.50

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	4200	5800	2380
(Q) discharge thru bridge, cfs	3242	3324	2370
Main channel conveyance	33840	33840	43698
Total conveyance	33840	33840	43698
Q2, bridge MC discharge,cfs	3242	3324	2370
Main channel area, ft2	325	325	307
Main channel width (normal), ft	33.8	33.8	33.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	33.8	33.8	33.8
y_bridge (avg. depth at br.), ft	9.63	9.63	9.09
Dm, median (1.25*D50), ft	0.0795	0.0795	0.0795
y2, depth in contraction,ft	12.75	13.03	9.75
ys, scour depth (y2-ybridge), ft	3.12	3.40	**0.66**

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	4200	5800	2380
Q, thru bridge MC, cfs	3242	3324	2380
Vc, critical velocity, ft/s	6.43	6.55	6.11
Va, velocity MC approach, ft/s	4.83	5.31	4.64
Main channel width (normal), ft	33.8	33.8	33.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	33.8	33.8	33.8
qbr, unit discharge, ft2/s	95.9	98.3	70.4
Area of full opening, ft2	325.4	325.4	307.3
Hb, depth of full opening, ft	9.63	9.63	9.09
Fr, Froude number, bridge MC	0.57	0.58	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	N/A	N/A	N/A
**Hb, depth at downstream face, ft	N/A	N/A	N/A
**Fr, Froude number at DS face	ERR	ERR	ERR
**Cf, for downstream face (<=1.0)	N/A	N/A	N/A
Elevation of Low Steel, ft	497.65	497.65	0
Elevation of Bed, ft	488.02	488.02	-9.09
Elevation of Approach, ft	500.9	502	0
Friction loss, approach, ft	0.1	0.12	0
Elevation of WS immediately US, ft	500.80	501.88	0.00
ya, depth immediately US, ft	12.78	13.86	9.09
Mean elevation of deck, ft	502.67	502.67	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.93	0.91	1.00
**Cc, for downstream face (<=1.0)	ERR	ERR	ERR
Ys, scour w/Chang equation, ft	**6.43**	**6.95**	N/A
Ys, scour w/Umbrell equation, ft	2.22	3.84	N/A

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

**Ys, scour w/Chang equation, ft	N/A	N/A	N/A
**Ys, scour w/Umbrell equation, ft	N/A	N/A	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	12.75	13.03	9.75
WSEL at downstream face, ft	--	--	--
Depth at downstream face, ft	N/A	N/A	N/A
Ys, depth of scour (Laursen), ft	N/A	N/A	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	4200	5800	2380	4200	5800	2380
a', abut.length blocking flow, ft	31.6	31.6	23.9	22.6	22.6	21.7
Ae, area of blocked flow ft2	147.6	191.21	116.3	164.4	177.8	137.3
Qe, discharge blocked abut.,cfs	--	--	407.4	--	--	607.5
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.11	3.63	3.50	3.55	3.85	4.42
ya, depth of f/p flow, ft	4.67	6.05	4.87	7.27	7.87	6.33
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.316	0.318	0.280	0.363	0.356	0.310
ys, scour depth, ft	16.62	19.95	14.94	19.16	20.14	16.12

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

a'(abut length blocked, ft)	31.6	31.6	23.9	22.6	22.6	21.7
y1 (depth f/p flow, ft)	4.67	6.05	4.87	7.27	7.87	6.33
a'/y1	6.77	5.22	4.91	3.11	2.87	3.43
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.32	0.32	0.28	0.36	0.36	0.31
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	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)

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.57	0.58	0.45	0.57	0.58	0.45
y, depth of flow in bridge, ft	9.63	9.63	9.09	9.63	9.63	9.09
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	1.93	2.00	1.14	1.93	2.00	1.14
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR