LEVEL II SCOUR ANALYSIS FOR BRIDGE 34 (SHERUS00040034) ON US ROUTE 4, CROSSING THE OTTAUQUECHEE RIVER, SHERBURNE, VERMONT

U.S. Geological Survey
Open-File Report 97-9

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

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By ROBERT H. FLYNN AND TIMOTHY SEVERANCE

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Pembroke, New Hampshire

1997

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 34 (SHERUS00040034) ON US ROUTE 4, CROSSING THE OTTAUQUECHEE RIVER, SHERBURNE, VERMONT

By **Robert H. Flynn and Timothy Severance**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure SHERUS00040034 on US Route 4 crossing the Ottauquechee River, Sherburne, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in central Vermont. The 25.8-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture upstream of the bridge while the immediate banks have dense woody vegetation. Downstream of the bridge, the banks are forested.

In the study area, the Ottauquechee River has an incised, straight channel with a slope of approximately 0.028 ft/ft, an average channel top width of 66 ft and an average channel depth of 5 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 118.1 mm (0.387 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 25, 1995, indicated that the reach was stable.

The US Route 4 crossing of the Ottauquechee River is a 187-ft-long, two-lane bridge consisting of three steel-beam spans (Vermont Agency of Transportation, written communication, March 14, 1995). The bridge is supported by vertical, concrete abutments above spill-through stone fill (< 36 inches diameter). The channel is skewed approximately 60 degrees to the opening while the opening-skew-to-roadway is 60 degrees. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows was 0.0 ft. Abutment scour ranged from 4.7 to 7.4 ft. The worst-case abutment scour occurred at the left abutment for the 500-year discharge. Pier scour ranged from 7.5 to 11.4 ft. The worst-case pier scour occurred at the incipient-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 others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Killington Peak, VT. Quadrangle, 1:24,000, 1961
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 SHERUS00040034 ***Stream*** Ottauquechee River

County Rutland ***Road*** US 4 ***District*** 3

Description of Bridge

Bridge length 187 ***ft*** ***Bridge width*** 35.2 ***ft*** ***Max span length*** 75 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 09/25/95

Description of stone fill Type-3, on spill-through slope of abutments is in good condition.

The abutments and two piers are concrete.

Brief description of piers/abutments

Y

Is bridge skewed to flood flow according to ***survey?*** ***Angle*** 60 N

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

09/25/95

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	0	0	09/25/
Level II	95	0	0

Potential for debris Low. There is some debris caught on boulders on the upstream right bank.

Describe any features near or at the bridge that may affect flow (include observation date)

Some trees with exposed roots and boulders in the channel and along upstream banks may eventually affect flow (observed 09/25/95).

Description of the Geomorphic Setting

General topography The channel is located within a 280 foot-wide, flat to slightly irregular flood plain with steep valley walls on both sides.

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

Date of inspection 09/25/95

DS left: Steep channel bank.

DS right: Moderately sloped overbank.

US left: Moderately sloped overbank.

US right: Moderately sloped overbank.

Description of the Channel

Average top width 66 ***ft*** ***Average depth*** 5 ***ft***

Predominant bed material Boulder/ Bedrock ***Bank material*** Boulder/Cobble

Straight and stable with non-alluvial channel boundaries and little to no flood plain.

09/25/95

Vegetative co

Trees and brush

DS left: Trees

DS right: Trees

US left: Trees.

US right:

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

The assessment of 09/25/95 noted some debris on boulders along the upstream right bank channel.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 25.8 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
Green Mountain	100

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: There are some houses along the downstream left overbank

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 5,810 ***ft³/s*** ***Q500*** 8,800 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(25.8/23.1)exp 0.5] with bridge number 28 in Sherburne. Bridge number 28 crosses the Ottauquechee River upstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 28 is 23.1 square miles.

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 Yes. USGS survey elevations adjusted to VTAOT plans based on USLAB Bridge seat elevation.

Description of reference marks used to determine USGS datum.
RM1 is a chiseled X on top of curbing on the downstream end of the right abutment (elev. 1095.42 ft, arbitrary survey datum). RM2 is a brass survey disk on top of curbing on the upstream end of the left abutment (elev. 1104.18 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-113	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	33	1	Road Grade section
APPRO	155	2	Modelled Approach section (Templated from APTEM)
APTEM	186	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 0.047 to 0.055, and overbank "n" values ranged from 0.075 to 0.100.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0276 ft/ft which was determined from surveyed thalweg and water surface points downstream of the bridge.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0353 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

For the 100-year, 500-year and incipient-overtopping discharge, WSPRO assumes critical depth at the exit and full valley sections. Supercritical models were developed for these discharges. Analyzing both the supercritical and subcritical profiles for each discharge, it can be determined that the water surface profile is just below critical at the exit and full valley sections. Thus, the assumptions of critical depth are satisfactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 1099.1 ***ft***
Average low steel elevation 1096.1 ***ft***

100-year discharge 5,810 ***ft^3/s***
Water-surface elevation in bridge opening 1091.1 ***ft***
Road overtopping? N ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 476 ***ft^2***
Average velocity in bridge opening 12.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.4 ***ft/s***

Water-surface elevation at Approach section with bridge 1093.9
Water-surface elevation at Approach section without bridge 1093.4
Amount of backwater caused by bridge 0.5 ***ft***

500-year discharge 8,800 ***ft^3/s***
Water-surface elevation in bridge opening 1096.1 ***ft***
Road overtopping? Y ***Discharge over road*** 2,750
Area of flow in bridge opening 706 ***ft^2***
Average velocity in bridge opening 8.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.5 ***ft/s***

Water-surface elevation at Approach section with bridge 1097.9
Water-surface elevation at Approach section without bridge 1095.2
Amount of backwater caused by bridge 2.7

Incipient overtopping discharge 6,600 ***ft^3/s***
Water-surface elevation in bridge opening 1091.6 ***ft***
Area of flow in bridge opening 519 ***ft^2***
Average velocity in bridge opening 12.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.9 ***ft/s***

Water-surface elevation at Approach section with bridge 1094.4
Water-surface elevation at Approach section without bridge 1093.9
Amount of backwater caused by bridge 0.5 ***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 others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

Contraction scour was computed by use of Laursen’s live-bed contraction scour equation (Richardson and others, 1995, p. 32, equation 20) for the 100-year discharge and incipient road-overflow models. The 500-year discharge 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 the 500-year discharge was computed by the Chang equation (Richarson and others, 1995, p. 145-146) . The results of Laursen's equation for the 500-year event were also computed and can be found in appendix F.

Abutment scour for the left and right abutments was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping. Because scour processes on the spill-through embankment material is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, the total scour depths were applied for the entire spill-through embankment below the elevation at the toe of each embankment and extended to the vertical concrete abutment wall as shown in figure 8.

Pier scour was computed based on an equation developed by Colorado State University (CSU) (Richardson and others, 1995, p. 36, equation 21). The variables used by the CSU equation include pier dimensions, flow approach depth and velocity, Froude number, and multiplicative factors for pier shape, attack angle, bed conditions, and armoring (see Appendix F).

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
	0.0	0.0	0.0
Live-bed scour			
	---	--	--
Clear-water scour			
	11.2	0.4	12.7
Depth to armoring			
	--	--	--
Left overbank			
	--	--	--
Right overbank			

Local scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
Abutment scour	6.6	7.4	7.0
Left abutment	4.7	6.9	5.5
Right abutment			
Pier scour	10.9	7.5	11.4
Pier 1	10.9	7.5	11.4
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
	2.0	2.5	2.1
Abutments:			
	2.0	2.5	2.1
Left abutment			
Right abutment			
	2.2	0.8	2.4
Piers:			
	2.2	0.8	2.4
Pier 1			
	--	--	--
Pier 2			

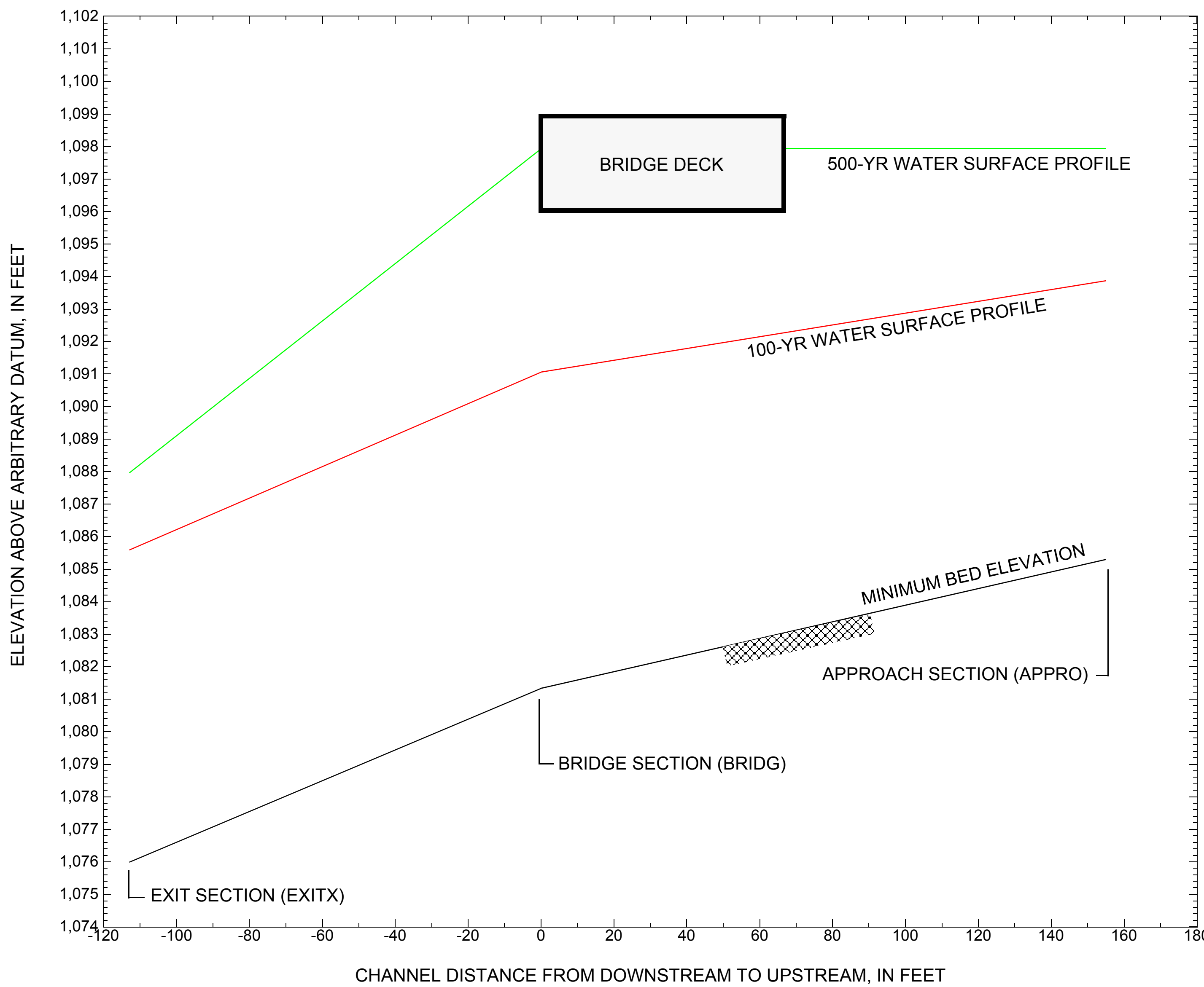

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure SHERUS00040034 on US Route 4, crossing Ottauquechee River, Sherburne, Vermont.

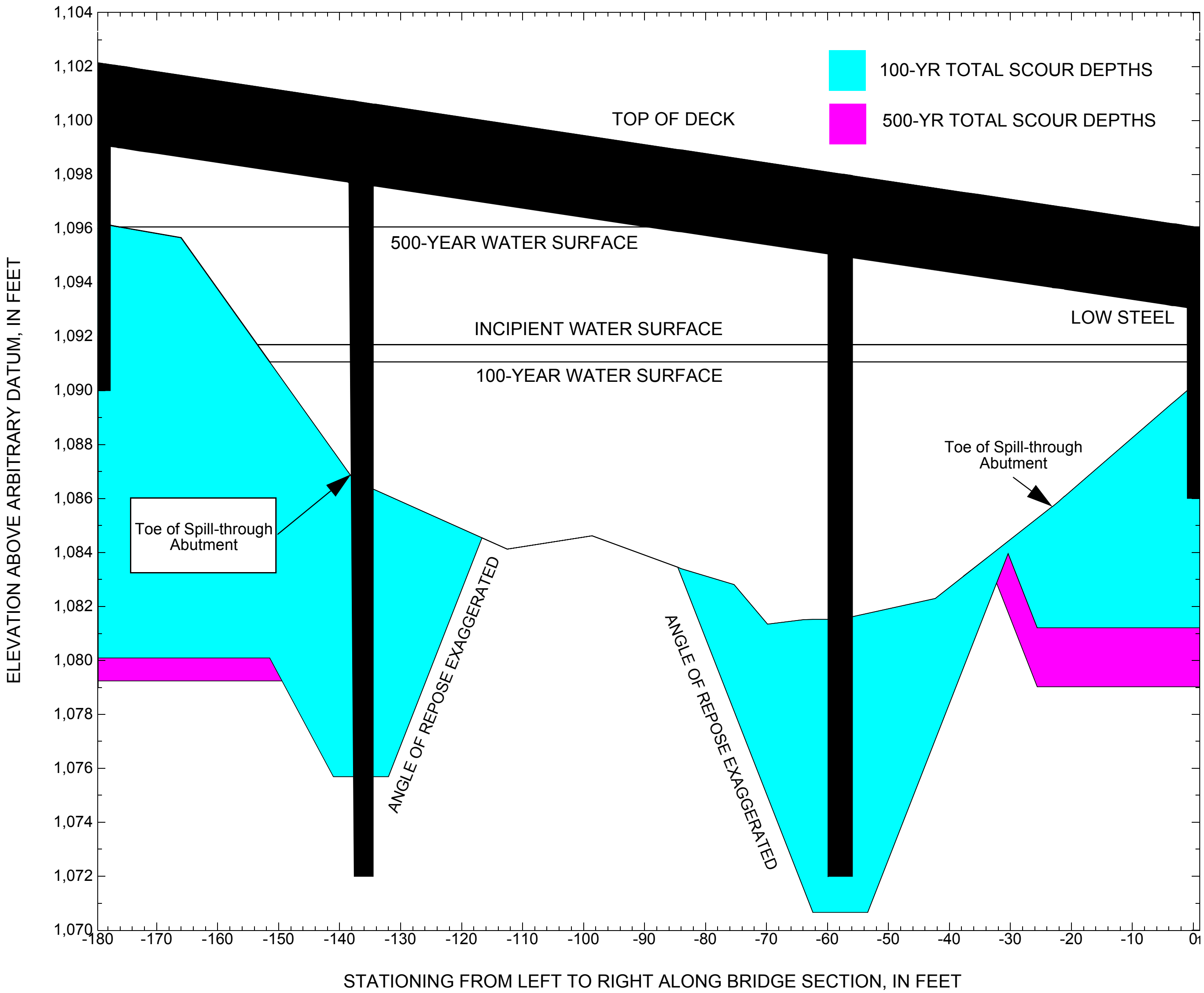

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure SHERUS00040034 on US Route 4, crossing Ottauquechee River, Sherburne, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure SHERUS00040034 on US Route 4, crossing Ottauquechee River, Sherburne, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 5,810 cubic-feet per second											
Left abutment	-178.6	1099.3	1099.3	1090.0	1096.2	0.0	--	--	--	--	-9.9
Toe of LABUT	-137.6	--	--	--	1086.7	0.0	6.6	--	6.6	1080.1	--
Left Pier	-136.5	--	--	1072.0	1086.6	0.0	--	10.9	10.9	1075.7	3.7
Right Pier	-57.9	--	--	1072.0	1081.5	0.0	--	10.9	10.9	1070.6	-1.4
Toe of RABUT	-22.1	--	--	--	1085.9	0.0	4.7	--	4.7	1081.2	--
Right abutment	0.0	1092.8	1092.8	1086.0	1090.2	0.0	--	--	--	--	-4.8

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure SHERUS00040034 on US Route 4, crossing Ottauquechee River, Sherburne, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 8,800 cubic-feet per second											
Left abutment	-178.6	1099.3	1099.3	1090.0	1096.2	0.0	--	--	--	--	-10.8
Toe of LABUT	-137.6	--	--	--	1086.7	0.0	7.4	--	7.4	1079.3	--
Left Pier	-136.5	--	--	1072.0	1086.6	0.0	--	7.5	7.5	1079.1	7.1
Right Pier	-57.9	--	--	1072.0	1081.5	0.0	--	7.5	7.5	1074.0	2.0
Toe of RABUT	-22.1	--	--	--	1085.9	0.0	6.9	--	6.9	1079.0	--
Right abutmen	0.0	1092.8	1092.8	1086.0	1090.2	0.0	--	--	--	--	-7.0

1.Measured along the face of the most constricting side of the bridge.

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U.S. Geological Survey, 1961, Killington Peak, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File sher034.wsp
T2        Hydraulic analysis for structure SHERUS00040034   Date: 26-SEP-96
T3        Bridge #34 over Ottauquechee River. RHF
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           5810.0   8800.0   6600.0
SK          0.0276   0.0276   0.0276
*
XS   EXITX   -113          0.
GR         -331.2,1098.31   -317.0,1093.90   -243.0,1094.86   -108.9,1093.09
GR          -81.9,1091.79    -69.0,1084.71    -55.3,1077.81    -50.0,1076.11
GR          -42.3,1075.99    -35.1,1076.23    -29.4,1076.91    -25.7,1077.91
GR          -17.6,1080.33    -12.4,1084.50      0.0,1089.80     24.4,1092.89
GR           45.8,1093.16     65.2,1092.35     86.7,1090.71    116.9,1091.55
GR          161.5,1095.38
*
N           0.085    0.055    0.100
SA              -81.9        0
*
XS   FULLV      0  * * *   0.0276
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0   1096.06      60.0
GR         -178.6,1099.33   -178.5,1099.06   -178.4,1096.15   -166.0,1095.66
GR         -137.6,1086.67   -125.6,1085.44   -112.5,1084.12    -98.6,1084.62
GR          -84.0,1083.40    -75.3,1082.81    -69.8,1081.34    -63.9,1081.51
GR          -57.4,1081.54    -42.3,1082.30    -22.1,1085.88      0.0,1090.20
GR            0.0,1092.78   -178.6,1099.33
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV
CD           3      65.3     2.1    1100.7
N           0.047
*
PW         1081.54,4 1085.44,4 1085.44,8 1094.89,8 1094.89,4 1097.39,4 1097.39,0
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     33      35.2     1
GR         -376.3,1102.68   -366.5,1100.16   -336.3,1100.95   -264.1,1100.77
GR         -250.2,1101.14   -244.0,1103.65   -221.7,1103.88   -215.2,1103.65
GR         -215.0,1104.45   -185.7,1102.47    -20.2,1099.27    -18.3,1096.92
GR          -18.2,1096.03      0.0,1095.72     49.7,1094.84     83.2,1094.44
GR          118.3,1096.41    180.0,1099.87
*
*           EXPECTED SRD =  155 AT ONE BR. LENGTH BUT COMPUTED SRD =  176
*
XT   APTEM    186           0.
GR         -253.6,1106.95   -194.7,1106.32   -167.2,1106.48   -112.6,1103.95
GR          -93.5,1103.08    -82.8,1096.82    -74.8,1091.86    -57.3,1088.28
GR          -49.9,1087.38    -44.8,1086.56    -40.1,1085.65    -33.6,1085.30
GR          -28.2,1085.75    -23.1,1087.38    -15.6,1089.17     -7.7,1092.73
GR            0.0,1093.88     17.8,1107.33     34.4,1106.75     57.2,1106.39
GR           62.8,1107.74     80.8,1108.21     93.3,1108.65    110.1,1114.04
GR          118.6,1119.98
*
AS   APPRO    155 * * * 0.0353
GT
N           0.100        0.051       0.075
SA                 -93.5       17.8
*
HP 1 BRIDG    1091.06 1 1091.06
HP 2 BRIDG    1091.06 * * 5810
HP 1 APPRO    1093.87 1 1093.87
HP 2 APPRO    1093.87 * * 5810
*
HP 1 BRIDG    1096.06 1 1096.06
HP 2 BRIDG    1096.06 * * 6047
HP 1 APPRO    1097.93 1 1097.93
HP 2 APPRO    1097.93 * * 8800
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V090192            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File sher034.wsp
        Hydraulic analysis for structure SHERUS00040034   Date: 26-SEP-96
        Bridge #34 over Ottauquechee River. RHF
           *** RUN DATE & TIME: 10-31-96  16:04
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     476.  49472.    76.    80.                        6768.
  1091.06          476.  49472.    76.    80.  1.00  -151.     0.   6768.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
      1091.06  -151.5     0.0   475.8   49472.    5810.  12.21

X STA.      -151.5     -127.8     -118.5     -111.0     -104.0      -96.8
  A(I)            39.2       27.4       25.0       23.5       23.8
  V(I)            7.40      10.61      11.64      12.34      12.22

X STA.       -96.8      -90.2      -84.4      -78.9      -73.9      -69.5
  A(I)            22.7       21.4       21.3       20.5       20.2
  V(I)           12.82      13.55      13.64      14.19      14.35

X STA.       -69.5      -65.6      -61.6      -57.6      -53.5      -49.2
  A(I)            19.1       18.9       19.0       19.5       19.7
  V(I)           15.24      15.39      15.26      14.92      14.72

X STA.       -49.2      -44.5      -39.5      -33.2      -24.4        0.0
  A(I)            21.1       21.8       24.0       28.1       39.7
  V(I)           13.79      13.32      12.09      10.35       7.32


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     155.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     480.  44611.    81.    84.                        6611.
  1093.87          480.  44611.    81.    84.  1.00   -80.     1.   6611.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     155.

         WSEL     LEW     REW    AREA        K        Q    VEL
      1093.87   -79.8     1.4   479.6   44611.    5810.  12.12

X STA.       -79.8      -66.7      -61.3      -57.2      -53.9      -50.8
  A(I)            39.7       28.9       25.3       23.3       22.2
  V(I)            7.33      10.05      11.49      12.49      13.09

X STA.       -50.8      -48.0      -45.4      -43.1      -40.9      -38.9
  A(I)            21.5       20.8       20.1       19.4       19.0
  V(I)           13.53      13.95      14.44      14.95      15.30

X STA.       -38.9      -36.9      -34.8      -32.9      -30.8      -28.6
  A(I)            19.0       19.2       18.9       19.8       20.1
  V(I)           15.31      15.14      15.35      14.68      14.42

X STA.       -28.6      -26.3      -23.5      -20.0      -15.4        1.4
  A(I)            21.2       23.1       25.2       28.8       44.2
  V(I)           13.73      12.60      11.55      10.07       6.58
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File sher034.wsp
        Hydraulic analysis for structure SHERUS00040034   Date: 26-SEP-96
        Bridge #34 over Ottauquechee River. RHF
           *** RUN DATE & TIME: 10-31-96  16:04
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     802.  81229.    43.   140.                       19569.
  1096.06          802.  81229.    43.   140.  1.00  -176.     0.  19569.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
      1096.06  -176.1     0.0    706.   81229.    6047.   8.57

X STA.      -176.1     -139.4     -131.2     -124.6     -118.8     -113.5
  A(I)            62.5       39.3       34.0       32.2       30.5
  V(I)            4.83       7.69       8.89       9.40       9.93

X STA.      -113.5     -108.5     -103.6      -98.4      -93.4      -88.1
  A(I)            29.4       28.9       29.9       29.0       32.0
  V(I)           10.29      10.45      10.10      10.43       9.45

X STA.       -88.1      -81.7      -75.5      -69.5      -64.0      -58.2
  A(I)            40.0       39.4       40.0       37.7       39.5
  V(I)            7.57       7.67       7.56       8.02       7.65

X STA.       -58.2      -51.9      -45.0      -37.1      -26.2        0.0
  A(I)            40.9       43.4       46.7       53.1       73.4
  V(I)            7.40       6.97       6.47       5.70       4.12

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     155.
    WSEL  SA#    AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
      2     834.  100830.    93.    99.                      14139.
  1097.93          834.  100830.    93.    99.  1.00   -87.     7.  14139.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     155.

         WSEL     LEW     REW    AREA        K        Q    VEL
      1097.93   -86.6     6.8   833.8  100830.    8800.  10.55

X STA.       -86.6      -70.9      -65.2      -60.7      -56.8      -53.2
  A(I)            70.9       49.1       43.3       40.8       39.2
  V(I)            6.21       8.95      10.16      10.77      11.23

X STA.       -53.2      -50.0      -46.9      -44.1      -41.4      -38.9
  A(I)            37.0       35.9       34.8       34.5       33.6
  V(I)           11.88      12.26      12.63      12.75      13.10

X STA.       -38.9      -36.4      -34.0      -31.5      -29.0      -26.2
  A(I)            33.5       33.8       33.1       34.5       36.4
  V(I)           13.14      13.01      13.30      12.76      12.10

X STA.       -26.2      -23.1      -19.5      -15.3       -9.3        6.8
  A(I)            37.5       39.9       43.7       50.3       72.0
  V(I)           11.73      11.02      10.08       8.74       6.11

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      33.

         WSEL     LEW     REW    AREA        K        Q    VEL
      1097.93   -19.1   145.4   388.4   10938.    2752.   7.09

X STA.       -19.1      -10.9       -4.8        1.4       10.6       18.7
  A(I)            15.0       12.6       13.4       21.3       20.1
  V(I)            9.18      10.89      10.27       6.47       6.85

X STA.        18.7       26.1       33.0       39.5       45.6       51.4
  A(I)            19.3       18.9       18.4       18.2       17.7
  V(I)            7.12       7.27       7.46       7.55       7.77

X STA.        51.4       57.1       62.6       68.1       73.4       78.7
  A(I)            17.9       17.7       17.9       17.8       18.2
  V(I)            7.70       7.78       7.68       7.74       7.58

X STA.        78.7       84.1       90.1       98.0      108.7      145.4
  A(I)            18.6       19.8       22.5       25.4       37.8
  V(I)            7.41       6.95       6.11       5.43       3.64
```

```
        U.S. Geological Survey WSPRO Input File sher034.wsp
        Hydraulic analysis for structure SHERUS00040034   Date: 26-SEP-96
        Bridge #34 over Ottauquechee River. RHF
           *** RUN DATE & TIME: 10-31-96  16:04
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     519.   56457.    77.    82.                        7670.
  1091.63          519.   56457.    77.    82.  1.00  -153.     0.   7670.


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

         WSEL     LEW     REW    AREA        K        Q    VEL
      1091.63  -153.3     0.0   519.3   56457.    6600.  12.71

X STA.      -153.3     -129.1     -119.4     -111.8     -104.9      -97.8
  A(I)            42.3       30.8       27.2       25.4       25.4
  V(I)            7.80      10.71      12.13      12.99      12.99

X STA.       -97.8      -91.0      -85.0      -79.4      -74.3      -69.7
  A(I)            25.0       23.6       23.4       22.4       22.0
  V(I)           13.21      13.99      14.10      14.72      15.03

X STA.       -69.7      -65.7      -61.6      -57.4      -53.1      -48.7
  A(I)            21.0       20.7       20.9       21.4       21.7
  V(I)           15.75      15.91      15.77      15.43      15.21

X STA.       -48.7      -43.9      -38.7      -32.1      -23.4        0.0
  A(I)            22.6       23.8       26.8       29.3       43.6
  V(I)           14.61      13.88      12.30      11.25       7.57

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     155.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     526.   51160.    83.    86.                        7509.
  1094.43          526.   51160.    83.    86.  1.00   -81.     2.   7509.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     155.

         WSEL     LEW     REW    AREA        K        Q    VEL
      1094.43   -80.7     2.2   525.5   51160.    6600.  12.56

X STA.       -80.7      -67.3      -62.0      -57.8      -54.3      -51.2
  A(I)            44.0       30.6       27.9       25.7       24.5
  V(I)            7.49      10.77      11.84      12.83      13.46

X STA.       -51.2      -48.3      -45.7      -43.3      -41.0      -38.9
  A(I)            23.6       22.2       22.3       21.5       21.0
  V(I)           13.96      14.85      14.82      15.36      15.72

X STA.       -38.9      -36.8      -34.7      -32.6      -30.5      -28.2
  A(I)            20.9       21.1       20.8       21.7       22.1
  V(I)           15.80      15.63      15.87      15.19      14.93

X STA.       -28.2      -25.8      -22.8      -19.3      -14.5        2.2
  A(I)            23.0       25.7       26.9       31.6       48.3
  V(I)           14.33      12.84      12.25      10.46       6.84
```

```
U.S. Geological Survey WSPRO Input File sher034.wsp
Hydraulic analysis for structure SHERUS00040034   Date: 26-SEP-96
Bridge #34 over Ottauquechee River. RHF

===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                            WSI,CRWS =  1085.41    1085.59

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

EXITX:XS   ******   -71.     400.  3.29 ***** 1088.88 1085.59   5810. 1085.59
     -113. ******   -10.   36286.  1.00 ***** *******    1.00   14.54

===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.04    1088.51    1088.73

===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =  1085.09    1101.43    0.50

===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =  1085.09    1101.43    1088.73

===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 =  1088.73    1101.43    1088.73

FULLV:FV     113.   -71.     401.  3.27 ***** 1092.00 1088.73   5810. 1088.73
        0.   113.   -10.   36405.  1.00 ***** *******    1.00   14.50
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.10    1092.97    1093.36

===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =  1088.23    1118.89    0.50

===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =  1088.23    1118.89    1093.36

===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =  1093.36    1118.89    1093.36

APPRO:AS     155.   -79.     439.  2.73 ***** 1096.09 1093.36   5810. 1093.36
      155.   155.     1.   39014.  1.00 ***** *******    1.00   13.24
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    5810.    1091.06

            <<<<<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     113.  -151.     476.  2.47 ***** 1093.53 1091.06   5810. 1091.06
        0.   113.     0.   49463.  1.07 ***** *******    0.89   12.21

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   1.  0.968  0.127 1096.06 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      33.        <<<<<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      90.   -80.     480.  2.28  1.52 1096.15 1093.36   5810. 1093.87
      155.    90.     1.   44623.  1.00  1.10    0.00    0.88   12.11

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.000  0.000   44629.  -123.    29.  1091.84

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -113.    -71.   -10.   5810.   36286.     400.   14.54 1085.59
   FULLV:FV       0.    -71.   -10.   5810.   36405.     401.   14.50 1088.73
   BRIDG:BR       0.  -151.     0.   5810.   49463.     476.   12.21 1091.06
   RDWAY:RG      33.**************      0.*****************     1.00********
   APPRO:AS     155.    -80.     1.   5810.   44623.     480.   12.11 1093.87

   XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS    -123.    29.   44629.
```

WSPRO OUTPUT FILE (continued)

```
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS   1085.59    1.00 1075.99 1098.31************  3.29 1088.88 1085.59
   FULLV:FV   1088.73    1.00 1079.11 1101.43************  3.27 1092.00 1088.73
   BRIDG:BR   1091.06    0.89 1081.34 1099.33************  2.47 1093.53 1091.06
   RDWAY:RG  *************** 1094.44 1104.45*********************************
   APPRO:AS   1093.36    0.88 1084.21 1118.89  1.52  1.10  2.28 1096.15 1093.87


        U.S. Geological Survey WSPRO Input File sher034.wsp
        Hydraulic analysis for structure SHERUS00040034   Date: 26-SEP-96
        Bridge #34 over Ottauquechee River. RHF
           *** RUN DATE & TIME: 10-31-96  16:04

 ===015 WSI IN WRONG FLOW REGIME AT SECID “EXITX”:  USED WSI = CRWS.
                              WSI,CRWS =  1087.57    1087.96

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

EXITX:XS   ******   -75.     555.  3.91 ***** 1091.87 1087.96   8800. 1087.96
     -113. ******    -4.   56555.  1.00 ***** *******    1.00   15.86

 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.06    1090.68    1091.08

 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =  1087.46    1101.43    0.50

 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =  1087.46    1101.43    1091.08

 ===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 =  1091.08    1101.43    1091.08

FULLV:FV     113.   -75.     555.  3.91 ***** 1094.99 1091.08   8800. 1091.08
        0.   113.    -4.   56555.  1.00 ***** *******    1.00   15.86
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID “APPRO”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.05    1094.97    1095.20

 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =  1090.58    1118.89    0.50

 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =  1090.58    1118.89    1095.20

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID “APPRO”
                  WSBEG,WSEND,CRWS =  1095.20    1118.89    1095.20

APPRO:AS     155.   -82.     591.  3.45 ***** 1098.66 1095.20   8800. 1095.20
      155.   155.     3.   60857.  1.00 ***** *******    1.00   14.90
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =  1096.01       0.00    1092.98    1094.44

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =  1101.19         0.      8800.

 ===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     113.  -176.     706.  1.14 ***** 1097.20 1091.24   6047. 1096.06
        0. ******     0.   81229.  1.00 ***** *******    0.76    8.57

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   5.  0.477  0.120 1096.06 ****** ****** ******


    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      33.   120.  0.91  1.73 1098.75    0.00   2752. 1097.93
```

```
           Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
 LT:      0.   151.  -370.   -70.   0.8   0.2   5.7  24.3   1.5   3.0
 RT:   2752.   137.   -18.   118.   3.5   2.7   8.6   7.5   3.5   3.1

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

APPRO:AS      90.   -87.     834.  1.73  0.60 1099.66 1095.20   8800. 1097.93
      155.    90.      7.  100868.  1.00  0.00    0.00    0.62   10.55

      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    -113.   -75.    -4.   8800.   56555.     555.   15.86 1087.96
   FULLV:FV      0.   -75.    -4.   8800.   56555.     555.   15.86 1091.08
   BRIDG:BR      0.  -176.     0.   6047.   81229.     706.    8.57 1096.06
   RDWAY:RG     33.*******     0.   2752.        0.*********    1.00 1097.93
   APPRO:AS    155.   -87.     7.   8800.  100868.     834.   10.55 1097.93

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File sher034.wsp
        Hydraulic analysis for structure SHERUS00040034   Date: 26-SEP-96
        Bridge #34 over Ottauquechee River. RHF
           *** RUN DATE & TIME: 10-31-96  16:04
  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS   1087.96    1.00 1075.99 1098.31************  3.91 1091.87 1087.96
   FULLV:FV   1091.08    1.00 1079.11 1101.43************  3.91 1094.99 1091.08
   BRIDG:BR   1091.24    0.76 1081.34 1099.33************  1.14 1097.20 1096.06
   RDWAY:RG  **************** 1094.44 1104.45  0.91******  1.73 1098.75 1097.93
   APPRO:AS   1095.20    0.62 1084.21 1118.89  0.60  0.00  1.73 1099.66 1097.93

  ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                              WSI,CRWS =  1086.04    1086.28

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

EXITX:XS   ******   -72.     442.  3.47 ***** 1089.74 1086.28   6600. 1086.28
     -113. ******    -8.   41609.  1.00 ***** *******    1.00   14.93

  ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.05    1089.13    1089.39

  ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =  1085.78    1101.43    0.50

  ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =  1085.78    1101.43    1089.39

  ===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 =  1089.39    1101.43    1089.39

FULLV:FV     113.   -72.     442.  3.47 ***** 1092.86 1089.39   6600. 1089.39
        0.   113.    -8.   41610.  1.00 ***** *******    1.00   14.93
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.08    1093.53    1093.88

  ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =  1088.89    1118.89    0.50

  ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =  1088.89    1118.89    1093.88

  ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                   WSBEG,WSEND,CRWS =  1093.88    1118.89    1093.88
```

```
 APPRO:AS      155.   -80.     481.  2.93 ***** 1096.82 1093.88   6600. 1093.88
       155.   155.     1.   44779.  1.00 ***** *******    1.00   13.73
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                    SECID "BRIDG"     Q,CRWS =    6600.    1091.63

             <<<<<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      113.  -153.     519.  2.69 ***** 1094.32 1091.63   6600. 1091.63
         0.   113.     0.   56437.  1.07 ***** *******    0.89   12.71

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        3.   0.   1.  0.967  0.125 1096.06 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR      Q    WSEL
    RDWAY:RG      33.        <<<<<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       90.   -81.     526.  2.45  1.48 1096.88 1093.88   6600. 1094.43
       155.    90.     2.   51194.  1.00  1.07   -0.01    0.88   12.55

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.000  0.000   51372.  -124.    30.  1092.46

                       <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File sher034.wsp
         Hydraulic analysis for structure SHERUS00040034   Date: 26-SEP-96
         Bridge #34 over Ottauquechee River. RHF
            *** RUN DATE & TIME: 10-31-96  16:04
   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS    -113.   -72.    -8.   6600.   41609.     442.   14.93 1086.28
    FULLV:FV       0.   -72.    -8.   6600.   41610.     442.   14.93 1089.39
    BRIDG:BR       0.  -153.     0.   6600.   56437.     519.   12.71 1091.63
    RDWAY:RG      33.**************      0.******************     1.00********
    APPRO:AS     155.   -81.     2.   6600.   51194.     526.   12.55 1094.43

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS    -124.    30.   51372.
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

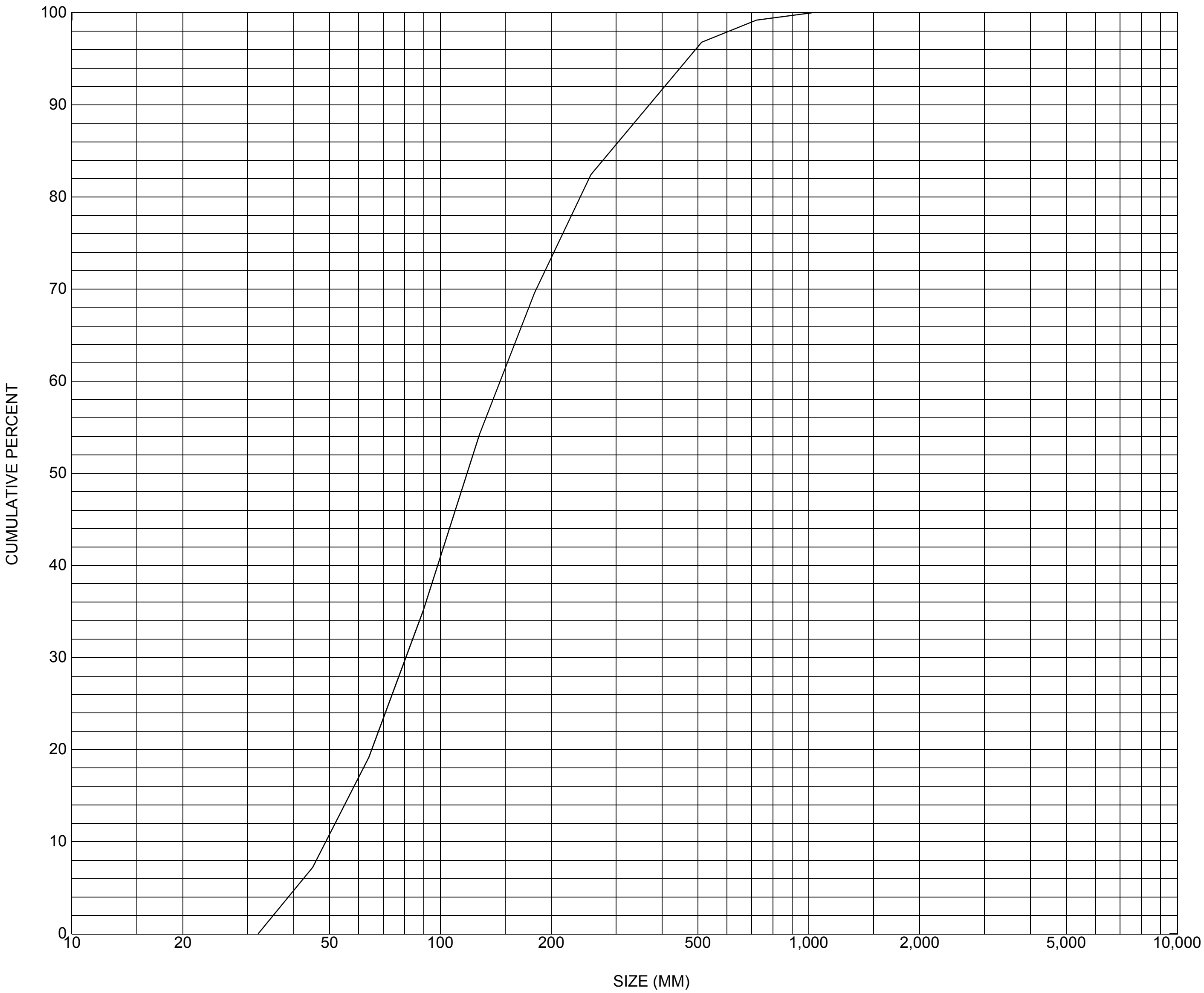
         U.S. Geological Survey WSPRO Input File sher034.wsp
         Hydraulic analysis for structure SHERUS00040034   Date: 26-SEP-96
         Bridge #34 over Ottauquechee River. RHF
            *** RUN DATE & TIME: 10-31-96  16:04
  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXITX:XS   1086.28    1.00 1075.99 1098.31************  3.47 1089.74 1086.28
    FULLV:FV   1089.39    1.00 1079.11 1101.43************  3.47 1092.86 1089.39
    BRIDG:BR   1091.63    0.89 1081.34 1099.33************  2.69 1094.32 1091.63
    RDWAY:RG  *************** 1094.44 1104.45**********************************
    APPRO:AS   1093.88    0.88 1084.21 1118.89  1.48  1.07  2.45 1096.88 1094.43
   ER

1  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure SHERUS00040034, in Sherburne, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number SHERUS00040034

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 14 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 64825

Mile marker *(I - 11; nnn.nnn)* 008240

Waterway *(I - 6)* OTTAUQUECHEE RIVER

Road Name *(I - 7):* -

Route Number US004

Vicinity *(I - 9)* 0.3 MI W JCT. VT.100 S

Topographic Map Killington Peak

Hydrologic Unit Code: 01080106

Latitude *(I - 16; nnnn.n)* 43364

Longitude *(i - 17; nnnnn.n)* 72450

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20002000341121

Maintenance responsibility *(I - 21; nn)* 01

Maximum span length *(I - 48; nnnn)* 0075

Year built *(I - 27; YYYY)* 1961

Structure length *(I - 49; nnnnnn)* 000187

Average daily traffic, ADT *(I - 29; nnnnnn)* 006153

Deck Width *(I - 52; nn.n)* 352

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

Channel & Protection *(I - 61; n)* 8

Opening skew to Roadway *(I - 34; nn)* 60

Waterway adequacy *(I - 71; n)* 8

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

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

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

Year Reconstructed *(I - 106)* 1991

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

Clear span (*nnn.n ft*) 040.8

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

Vertical clearance from streambed (*nnn.n ft*) 014.0

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

Waterway of full opening (*nnn.n ft*^{2}) 570.0

Comments:

The structural inspection report of 10/8/93 indicates the structure is a three span rolled steel beam type bridge. The left abutment wall is reported as having some minor cracking. The left pier has areas of cracking. The right pier (#2) has some concrete cracking and a small area of spalling. The right abutment wall, like the left, has some minor cracking and scaling noted. Both abutments are protected with heavy stone fill (riprap). The channel proceeds straight through the bridge with the predominant flow through the middle span (#2). The channel bed is reported as being composed of boulders and bed rock. Vegetation is noted as growing on the embankments both up and downstream.

Bridge Hydrologic Data

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

Terrain character: **Hilly**

Stream character & type: -

Streambed material: **Boulders and bedrock**

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)* : **light** Debris *(Heavy, Moderate, Light)*: **light**

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

The stream response is (*Flashy, Not 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:

Some hydrologic information is printed on the plans which is shown above. The plans also show a drainage area equal to 17,538 acres.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **25.845** mi^2

Lake and pond area **0.385** mi^2

Watershed storage *(ST)* **1.49** %

Bridge site elevation **1090** ft

Headwater elevation **2782** ft

Main channel length **10.473** mi

10% channel length elevation **1135** ft

85% channel length elevation **1472** ft

Main channel slope *(S)* **42.9** 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)*: 08 / 1958

Project Number F 020-2(2) Minimum channel bed elevation: 1080.5

Low superstructure elevation: USLAB 1099.06 DSLAB 1097.20 USRAB 1092.49 DSRAB 1090.62

Benchmark location description:

No benchmark information is provided on the plans. However, a couple points shown with elevations are: 1) the highest of three concrete step-like posts at the upstream end of the left abutment on the streamward edge midway across the post width, elevation 1107.08, and 2) the point at the same location as in (1) but on the upstream right abutment side, elevation 1100.67.

Reference Point (*MSL, Arbitrary, Other*): MSL Datum (*NAD27, NAD83, Other*): NGVD1929

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

If 1: Footing Thickness 3.0 Footing bottom elevation: 1086.*

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? Y *If no, type ctrl-n bi* Number of borings taken: 4

Foundation Material Type: 1 (*1-regolith, 2-bedrock, 3-unknown*)

Briefly describe material at foundation bottom elevation or around piles:

The left abutment is set in mainly a gravel and boulder material with some sand. The right abutment is set in gravel and stones. Both pier footings are set in hard, compact gravel with some sand.

Comments:

***Footing bottom elevation left: 1090.0 and right: 1086.0. The plans show a flow through abutment type. The footings on each abutment wall are only 2.0 feet thick while those on the piers are 3.0 feet thick. The bottom of the footing on each pier is shown at 1072.0 feet AMSL. The low superstructure elevations for the piers: pier 1(left) upstream end 1097.27(left), 1096.65(right) downstream end 1095.40(left), 1094.78(right); pier 2(right) upstream end 1094.08(left), 1094.29(right) downstream end 1092.21(left), 1092.42(right). The piers are 53 feet long and 4 feet wide.**

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: RB Date: 2/20/96
Computerized by: RB Date: 2/20/96
Reviewd by: RF Date: 10/17/96

Structure Number SHERUS00040034

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* T. SEVERANCE Date *(MM/DD/YY)* 09 / 25 / 1995

2. Highway District Number 3 Mile marker 008240

County RUTLAND 021 Town SHERBURNE 64825

Waterway *(I - 6)* ______ Road Name -

Route Number US0004 Hydrologic Unit Code: 01080106

3. Descriptive comments:

.3 MI with junction VT 100S. Just west of the Bridgewater border and junction with VT 100, (VT100 and US4 run together here and go N/W). The Hadley Hill Road intersection is just S/E of the bridge and the Johnson Road intersection is just N/W of the bridge. There are two piers and all the flow is between them at this time. The bridge is made of steel beams with a concrete deck and asphalt top. There is granite / concrete curbing with steel rail.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 6 LBDS 65 RBDS 6 Overall 6
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US 2 UB 2 DS 2 *(**1**- pool; **2**- riffle)*

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

7. Bridge length 187 *(feet)* Span length 225 *(feet)* Bridge width 35.2 *(feet)*

Road approach to bridge:

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

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

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

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

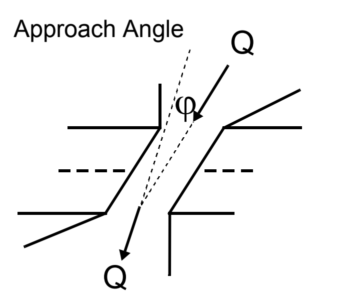
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

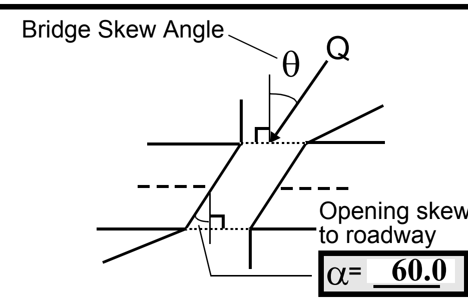
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

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

Channel approach to bridge (BF):

15. Angle of approach: 0 16. Bridge skew: 60





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

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: **1b**

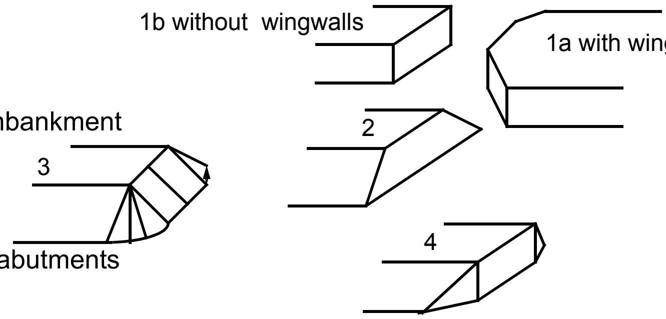
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

7. Values are from the VT AOT.
Measured bridge length is 187 feet, span length is 187.3 feet, and bridge width is 35 feet

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
122.5	5.0			3.5	4	4	5	5	1	1

23. Bank width **30.0** 24. Channel width **25.0** 25. Thalweg depth **75.0** 29. Bed Material **543**

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

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

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

30. Boulders exist naturally along both banks.
There are some trees with exposed roots, boulders and cobbles have been left behind on the banks.
The stream is seperated US and rejoins 275 feet US.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 87 35. Mid-bar width: 24

36. Point bar extent: 27 feet UB (US, UB) to 155 feet US (US, UB, DS) positioned 0 %LB to 75 %RB

37. Material: 543

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

A small portion of the flow trickles over the bar at mid-bar and rejoins the main flow 15 feet DS.

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

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

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

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

NO CUT BANKS

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

47. Scour dimensions: Length - Width - Depth : - Position - %LB to - %RB

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

NO CHANNEL SCOUR
Some local scouring not due to bridge.

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

51. Confluence 1: Distance >250 52. Enters on RB (LB or RB) 53. Type 1 (*1*- perennial; *2*- ephemeral)

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

54. Confluence comments (eg. confluence name):

Where the confluence enters it is the same width as our 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
59.5		2.0		2	5	5	0

58. Bank width (BF) - 59. Channel width (Amb) - 60. Thalweg depth (Amb) 90.0 63. Bed Material 0

*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.):

45
All of the flow is currently passing between the piers.

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

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

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

70. Debris and Ice Comments:

1

The channel is wide beneath the bridge, there is no debris at the US ends of the piers. Some debris (log) is on the US right bank lodged in/on the protection.

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	0	0	-	-	90.0
RABUT	1	0	90			0	0	89.5

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

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

-

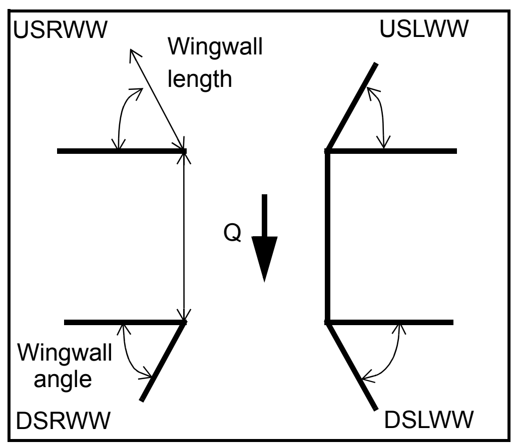
-

1

72. There is a 45 degree slope angle of the stone fill which is piled to within 2 feet of the steel on both abutments.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						89.5	
USRWW:	N		-		-	1.5	
DSLWW:	-		-		N	66.0	
DSRWW:	-		-		-	65.0	



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

82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	-	N	-	-	-	1	1
Condition	N	-	-	-	-	-	1	1
Extent	-	-	-	-	-	3	3	-

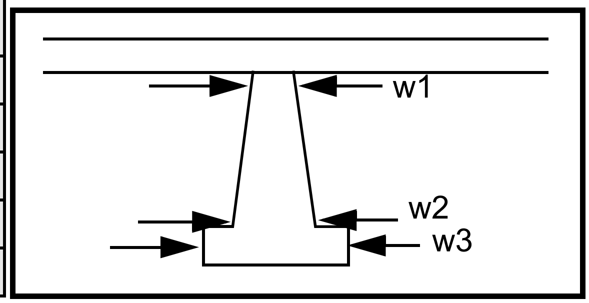
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	-	-	-	-	-	-
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	ncret	piled	With	is the	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	e	at	in	rema	1- Solid pier, 2- column, 3- bent
88. Material	wing	the	half	ins	1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	walls	four	a	of an	1- Round; 2- Square; 3- Pointed
90. Inclined?	do	cor-	brid	old	Y- yes; N- no
91. Attack ∠ (BF)	not	ners	ge	abut	
92. Pushed	exist,	wher	lengt	ment	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	but	e the	h on	.	
95. Cross-members	there	wing	the	Ther	0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	is	walls	DS	e is	0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	stone	woul	left	stone	
98. Exposure depth	fill	d be.	bank	fill	

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

piled between this abutment and the bridge.

Y

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
-	-			-	**LB**	**1**	**2**	**1**	**N**	**0**

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

Bank protection type (Qmax): LB - RB **0** Bank protection condition: LB **0** 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.):

-
RB
1
2
1
N
0
-
-
0
0
-
-
-
-

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? e (LB or RB) Mid-bank distance: pier

Cut bank extent: s feet con (US, UB, DS) to sist feet of3 (US, UB, DS)

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

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

umns each. Between the columns, walls have been poured. No scour is evident at the piers. The left pier is on the bankward side of the left bank point bar (previously described). Some water is pooled around the US end of the right pier but it does not travel through, all the flow passes along the left side of the right pier. Gravel, cobble, and several boulders line the streamward side of the right pier.

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

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

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

3
54
54
1

Are there major confluences? 1 (Y or if N type ctrl-n mc) How many? 543

Confluence 1: Distance 0 Enters on 0 (LB or RB) Type - (**1**- perennial; **2**- ephemeral)

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

Confluence comments (eg. confluence name):

1 bridge length there is stone fill along the right bank where the wingwall would be and an old abutment on the left bank. There is a narrow point bar along the right bank and minor cut bank along the left bank with

F. Geomorphic Channel Assessment

107. Stage of reach evolution tre

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)*:

e roots exposed. There is a lot of cobble and boulders left behind on both DS banks, just as with the US banks.

109. G. Plan View Sketch

N

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: SHERUS00040034 Town: SHERBURNE
Road Number: US 4 County: RUTLAND
Stream: OTTAUQUECHEE RIVER

Initials RF Date: 11/07/96 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	5810	8800	6600
Main Channel Area, ft2	479.6	833.8	525.5
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	81.2	93.4	82.9
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.3874	0.3874	0.3874
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	5.9	8.9	6.3
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	44611	100830	51160
Conveyance, main channel	44611	100830	51160
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	5810.0	8800.0	6600.0
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	12.1	10.6	12.6
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	11.0	11.8	11.1
Vc-l, crit. velocity, LOB, ft/s	N/A	N/A	N/A
Vc-r, crit. velocity, ROB, ft/s	N/A	N/A	N/A

Results

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

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour
y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)
ys=y2-y_bridge
(Richardson and others, 1995, p. 30, eq. 17 and 18)

	Approach			Bridge		
Characteristic	100 yr	500 yr	Other Q	100 yr	500 yr	Other Q
Q1, discharge, cfs	5810	8800	6600	5810	6047	6600
Total conveyance	44611	100830	51160	49472	81229	56457
Main channel conveyance	44611	100830	51160	49472	81229	56457
Main channel discharge	5810	8800	6600	5810	6047	6600
Area - main channel, ft2	479.6	833.8	525.5	475.8	801.8	519.3
(W1) channel width, ft	81.2	93.4	82.9	75.75	88.05	76.65
(Wp) cumulative pier width, ft	0	0	0	8	8	8
W1, adjusted bottom width(ft)	81.2	93.4	82.9	67.75	80.05	68.65
D50, ft	0.3874	0.3874	0.3874	0.3874	0.3874	0.3874
w, fall velocity, ft/s (p. 32)	2	2	2	2	2	2
y, ave. depth flow, ft	5.91	8.93	6.34	7.02	10.02	7.56
S1, slope EGL	0.026	0.024	0.025			
P, wetted perimeter, MC, ft	84	99	86			
R, hydraulic Radius, ft	5.710	8.422	6.110			

V*, shear velocity, ft/s	2.186	2.551	2.218
V*/w	1.093	1.276	1.109
Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)			
k1	0.64	0.64	0.64
y2,depth in contraction, ft	6.63	7.14	7.15
ys, scour depth, ft (y2-y_bridge)	-0.39	-2.87	-0.41

ARMORING

D90	1.20444	1.20444	1.20444
D95	1.5382	1.5382	1.5382
Critical grain size,Dc, ft	0.8264	0.2687	0.8649
Decimal-percent coarser than Dc	0.1819	0.6923	0.1698
depth to armoring, ft	11.15	0.36	12.69

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	479.6	833.8	525.5
Main channel width, ft	81.2	93.4	82.9
y1, main channel depth, ft	5.91	8.93	6.34

Bridge Section

(Q) total discharge, cfs	5810	8800	6600
(Q) discharge thru bridge, cfs		6047	
Main channel conveyance		81229	
Total conveyance		81229	
Q2, bridge MC discharge,cfs	ERR	6047	ERR
Main channel area, ft2	0	802	0
Main channel width (skewed), ft	0.0	88.1	0.0
Cum. width of piers in MC, ft	0.0	8.0	0.0
W, adjusted width, ft	0	80.05	0
y_bridge (avg. depth at br.), ft	ERR	10.02	ERR
Dm, median (1.25*D50), ft	0.48425	0.48425	0.48425
y2, depth in contraction,ft	ERR	6.20	ERR
ys, scour depth (y2-ybridge), ft	N/A	-3.82	N/A

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	0	8800	0
Q, thru bridge, cfs	0	6047	0
Total Conveyance, bridge	0	81229	0
Main channel(MC) conveyance, bridge	0	81229	0
Q, thru bridge MC, cfs	ERR	6047	ERR
Vc, critical velocity, ft/s	10.98701	11.77004	11.11719
Vc, critical velocity, m/s	3.348676	3.587334	3.388355
Main channel width (skewed), ft	0	88.05	0
Cum. width of piers in MC, ft	0	8	0
W, adjusted width, ft	0	80.05	0
qbr, unit discharge, ft^2/s	ERR	75.54029	ERR
qbr, unit discharge, m^2/s	N/A	7.017237	N/A
Area of full opening, ft^2	0	801.8	0
Hb, depth of full opening, ft	ERR	10.01624	ERR
Hb, depth of full opening, m	N/A	3.052801	N/A
Fr, Froude number, bridge MC	1	0.76	1
Cf, Fr correction factor (<=1.0)	1.5	1	1.5
ya, depth immediately upstream, ft	0	11.29	0
w, depth of overflow, ft	0	0	0
Cc, vert contrac correction (<=1.0)	ERR	0.970881	ERR
Ys, ft	N/A	-3.40573	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	5810	8800	6600	5810	8800	6600
a', abut.length blocking flow, ft	4	2.5	4	1.4	2.8	2.2
Ae, area of blocked flow ft2	12.12	11.29	13.13	3.68	1.47	6.36
Qe, discharge blocked abut.,cfs	88.7	70.06	98.51	24.21	76.52	43.47
(If using Qtotal_overbank to obtain Ve, le						
Ve, (Qe/Ae), ft/s	7.32	6.21	7.50	6.58	52.05	6.83
ya, depth of f/p flow, ft	3.03	4.52	3.28	2.63	0.53	2.89
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	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	0.741	0.515	0.730	0.715	12.660	0.708
ys, scour depth, ft	6.58	7.43	6.96	4.67	6.86	5.49

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.89	0.76	0.89	0.89	0.76	0.89
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5.48	7.964	5.925	5.48	7.964	5.925
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	2.84	ERR	ERR	2.84	ERR
Fr>0.8 (vertical abut.)	2.22	ERR	2.40	2.22	ERR	2.40
Fr<=0.8 (spillthrough abut.)	ERR	2.48	ERR	ERR	2.48	ERR
Fr>0.8 (spillthrough abut.)	1.96	ERR	2.12	1.96	ERR	2.12

Pier Scour(both live-bed and clear water scour)

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

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

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

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

K4, corr. factor for armoring (the following equations are in Si units)
K4=[1-0.89*(1-Vr)^2]^0.5
Vr=(V1-Vi)/(Vc90-Vi)
V1=0.645*((D50/a)^0.053)*Vc50
Vc=6.19*(y^1/6)*(Dc^1/3)

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

Piers 1 AND 2	Q100	Q500	Qother
Area of WSPRO flow tube, ft2	15.39	28.9	20.7
Skewed width of flow tube, ft	2	2.45	2.05
y1, pier approach depth, ft	7.70	11.80	10.10
y1 in meters	2.345	3.595	3.078
V1, pier approach velocity, ft/s	15.39	10.45	15.91
a, pier width, ft	4	4	4
L, pier length, ft	53	53	53
Fr1, Froude number at pier	0.978	0.536	0.882

Pier attack angle, degrees	0	0	0
K1, shape factor	1	1	1
K2, attack factor	1.00	1.00	1.00
K3, bed condition factor	1.1	1.1	1.1
D50, ft	0.3874	0.3874	0.3874
D50, m	0.118074	0.118074	0.118074
D90, ft	1.20444	1.20444	1.20444
D90, m	0.367095	0.367095	0.367095
Vc50,critical velocity(D50),m/s	3.500	3.759	3.662
Vc90,critical velocity(D90),m/s	5.109	5.486	5.345
Vi,incipient velocity,m/s	1.995	2.142	2.087
Vr, velocity ratio	0.866	0.312	0.848
K4, armor factor	0.99	0.76	0.99
ys, scour depth (K4 applicable) ft	10.87	7.48	11.41
ys, scour depth (K4 not applied)ft	ERR	ERR	ERR

Piers 1 and 2	Q100	Q500	Qother
K, pier shape coeff.	1.5	1.5	1.5
V, char. aver. velocity, ft/s	12.21	7.54	12.71
D50, median stone diameter, ft	2.18	0.83	2.37