LEVEL II SCOUR ANALYSIS FOR BRIDGE 23 (WEELTH00210023) on TOWN HIGHWAY 21, crossing MILLER RUN, WHEELOCK, VERMONT

Open-File Report 97-795

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

U.S. Department of the Interior
U.S. Geological Survey

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By ROBERT H. FLYNN AND ERICK M. BOEHMLER

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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 23 (WEELTH00210023) ON TOWN HIGHWAY 21, CROSSING MILLER RUN, WHEELOCK, VERMONT

By **Robert H. Flynn and Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WEELTH00210023 on Town Highway 21 crossing Miller Run, Wheelock, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in northeastern Vermont. The 28.3-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest on the upstream and downstream right banks while the surface cover on the upstream and downstream left banks consists primarily of short grass and buildings with shrubs, brush and trees along the immediate banks.

In the study area, Miller Run has an incised, straight channel with a slope of approximately 0.003 ft/ft, an average channel top width of 76 ft and an average bank height of 6 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 67.5 mm (0.221 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 2, 1995, indicated that the reach was stable.

The Town Highway 21 crossing of Miller Run is a 46-ft-long, one-lane bridge consisting of one 43-foot steel-beam span with a wooden deck (Vermont Agency of Transportation, written communication, April 5, 1995). The opening length of the structure parallel to the bridge face is 42.1 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 20 degrees to the opening while the computed opening-skew-to-roadway is 25 degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed under the bridge, along the center of the channel, during the Level I assessment. The scour protection measures at the site included type-2 stone fill (less than 36 inches diameter) along the downstream left bank and along the entire base length of the upstream and downstream right wingwalls. Type-3 stone fill (less than 48 inches diameter) protection was observed along the upstream end of the upstream left wingwall and randomly scattered along the left abutment. Type-4 stone fill (less than 60 inches diameter) protection was observed along the entire base length of the downstream left wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge is 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 was computed to be zero ft. Abutment scour ranged from 9.1 to 10.8 ft along the right abutment and from 9.8 to 12.3 ft along the left abutment. 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.

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.

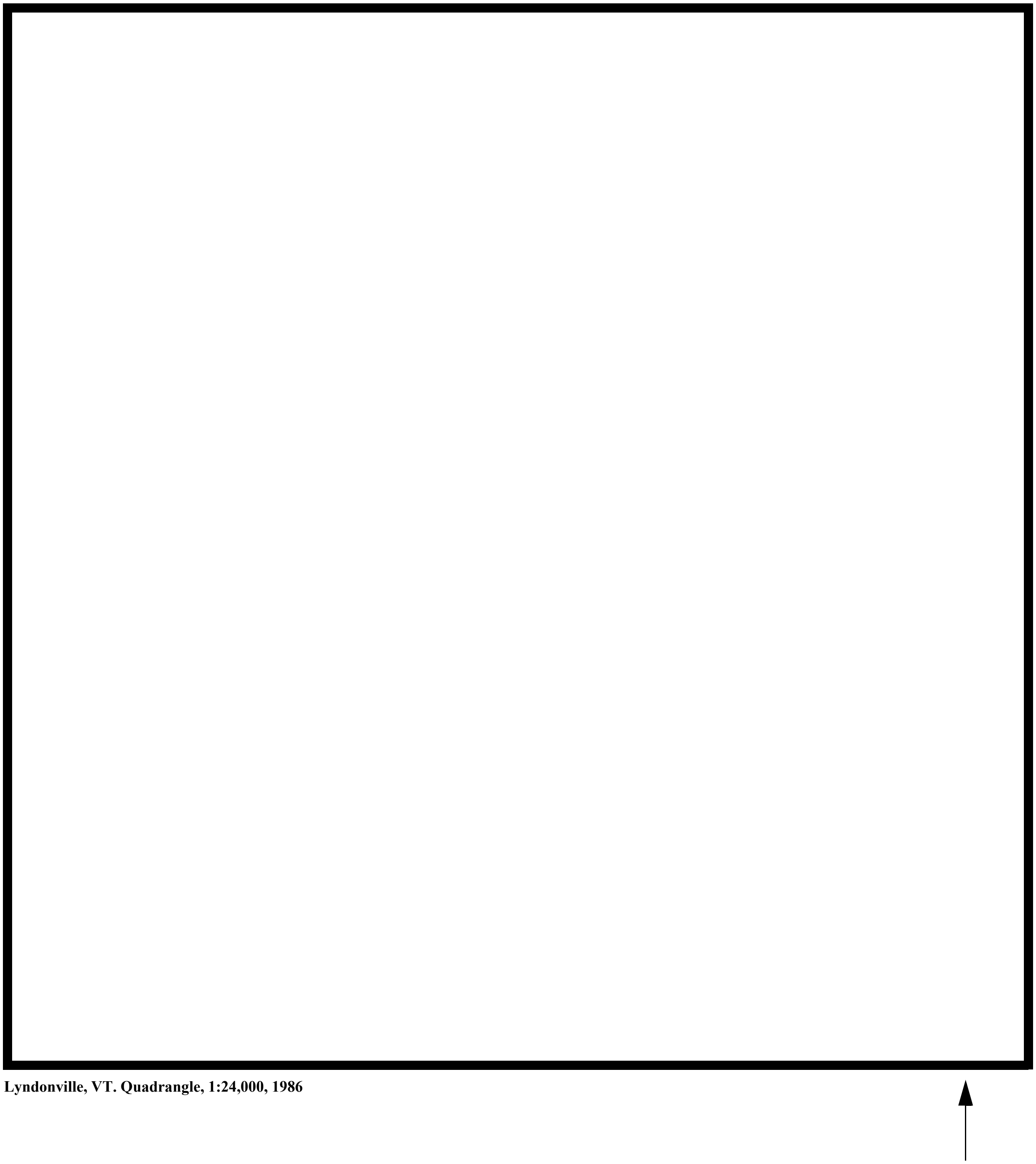

Figure 1. Location of study area on USGS 1:24,000 scale map.

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

LEVEL II SUMMARY

Structure Number WEELTH00210023 ***Stream*** Miller Run

County Caledonia ***Road*** TH21 ***District*** 7

Description of Bridge

Bridge length 46 ***ft*** ***Bridge width*** 14.4 ***ft*** ***Max span length*** 43 ***ft***

Alignment of bridge to road (on curve or straight) Curve, right ; Straight, left

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

Stone fill on abutment? Yes ***Date of inspection*** 8/2/95

Description of stone fill Type-2 stone fill along the entire base length of the USRWW and DSRWW. Type-3 stone fill along the upstream end of the USLWW and randomly scattered along the LABUT. Type-4 stone fill along the entire base length of the DSLWW.

Brief description of piers/abutments The abutments and wingwalls are concrete. There is a one foot deep scour hole under the bridge, along the center of the channel.

Is bridge skewed to flood flow according to [Level I] survey? Yes ***Angle*** 20

Is bridge located on a bend in channel? No ***If so, describe (mild, moderate, severe)***

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	8/2/95	0	0
Level II	8/2/95	0	0

Potential for debris Low. Currently, there is no debris in the channel near the bridge and the channel is laterally stable and straight.

Describe any features near or at the bridge that may affect flow (include observation date) A perennial stream enters Miller Run approximately 100 ft upstream on the left bank. Observed on 8/2/95.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley setting with a flat to slightly irregular flood plain.

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

Date of inspection 8/2/95

DS left: Steeply sloping channel bank to moderately sloping overbank and Rte. 122.

DS right: Steeply sloping channel bank to TH 21 and steep valley wall.

US left: Steeply sloping channel bank to moderately sloping overbank and Rte. 122.

US right: Steeply sloping channel bank and valley wall

Description of the Channel

Average top width 76 ft ***Average depth*** 6 ft

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

Straight and stable with semi-alluvial channel boundaries and a narrow flood plain.

8/2/95

Vegetative co Shrubs, brush and trees with grass on the overbank.

DS left: Trees, shrubs and brush.

DS right: Shrubs, brush and trees with grass on the overbank.

US left: Trees, shrubs and brush.

US right:

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

None as of 8/2/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 28.3 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: There are houses and other buildings on the upstream and downstream left overbank area.

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 4,500 ***ft³/s*** ***Q500*** 6,250 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency estimates computed by use of the FHWA empirical method (Federal Highway Administration, 1983). These values were selected due to the central tendency of the discharge frequency curve with others which were developed from empirical relationships and extended to the 500-year discharge (Benson, 1962; Johnson and Tasker, 1974; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled "X" on top of the upstream end of the left abutment (elev. 502.15 ft, arbitrary survey datum). RM2 is a chiseled "X" on top of the downstream end of the left abutment (elev. 502.16 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	-43	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	7	1	Road Grade section
APPRO	53	2	Modelled Approach section (Templated from APTEM)
APTEM	82	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.060, and overbank "n" values ranged from 0.045 to 0.060.

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 0.0027 ft/ft, which was determined from surveyed downstream thalweg points.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.018 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 502.3 *ft*
Average low steel elevation 499.4 *ft*

100-year discharge 4,500 *ft^3/s*
Water-surface elevation in bridge opening 499.5 *ft*
Road overtopping? Yes *Discharge over road* 2,330 *ft^3/s*
Area of flow in bridge opening 288 *ft^2*
Average velocity in bridge opening 7.6 *ft/s*
Maximum WSPRO tube velocity at bridge 8.8 *ft/s*

Water-surface elevation at Approach section with bridge 505.2
Water-surface elevation at Approach section without bridge 504.1
Amount of backwater caused by bridge 1.1 *ft*

500-year discharge 6,250 *ft^3/s*
Water-surface elevation in bridge opening 499.5 *ft*
Road overtopping? Yes *Discharge over road* 4,480 *ft^3/s*
Area of flow in bridge opening 288 *ft^2*
Average velocity in bridge opening 6.2 *ft/s*
Maximum WSPRO tube velocity at bridge 7.2 *ft/s*

Water-surface elevation at Approach section with bridge 506.3
Water-surface elevation at Approach section without bridge 505.7
Amount of backwater caused by bridge 0.6 *ft*

Incipient overtopping discharge 2,210 *ft^3/s*
Water-surface elevation in bridge opening 499.5 *ft*
Area of flow in bridge opening 288 *ft^2*
Average velocity in bridge opening 7.7 *ft/s*
Maximum WSPRO tube velocity at bridge 8.9 *ft/s*

Water-surface elevation at Approach section with bridge 502.2
Water-surface elevation at Approach section without bridge 501.0
Amount of backwater caused by bridge 1.2 *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 100- and 500-year scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

At this site, the 100-year, 500-year and incipient roadway-overtopping discharges resulted in 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 others, 1995, p. 145-146). Results of this scour analysis are shown in tables 1 and 2 and figure 8.

For comparison, estimates of contraction scour for the discharges resulting in orifice flow were also computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and presented in Appendix F. Furthermore, for those discharges resulting in unsubmerged orifice flow, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions also are provided in Appendix F.

Abutment scour for the right abutment 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.

Scour at the left abutment was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	0.0
Depth to armoring	0.9	0.3	0.9
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	11.7	12.3	9.8
Right abutment	10.4	10.8	9.1
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	1.2	0.8	1.3
Right abutment	1.2	0.8	1.3
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

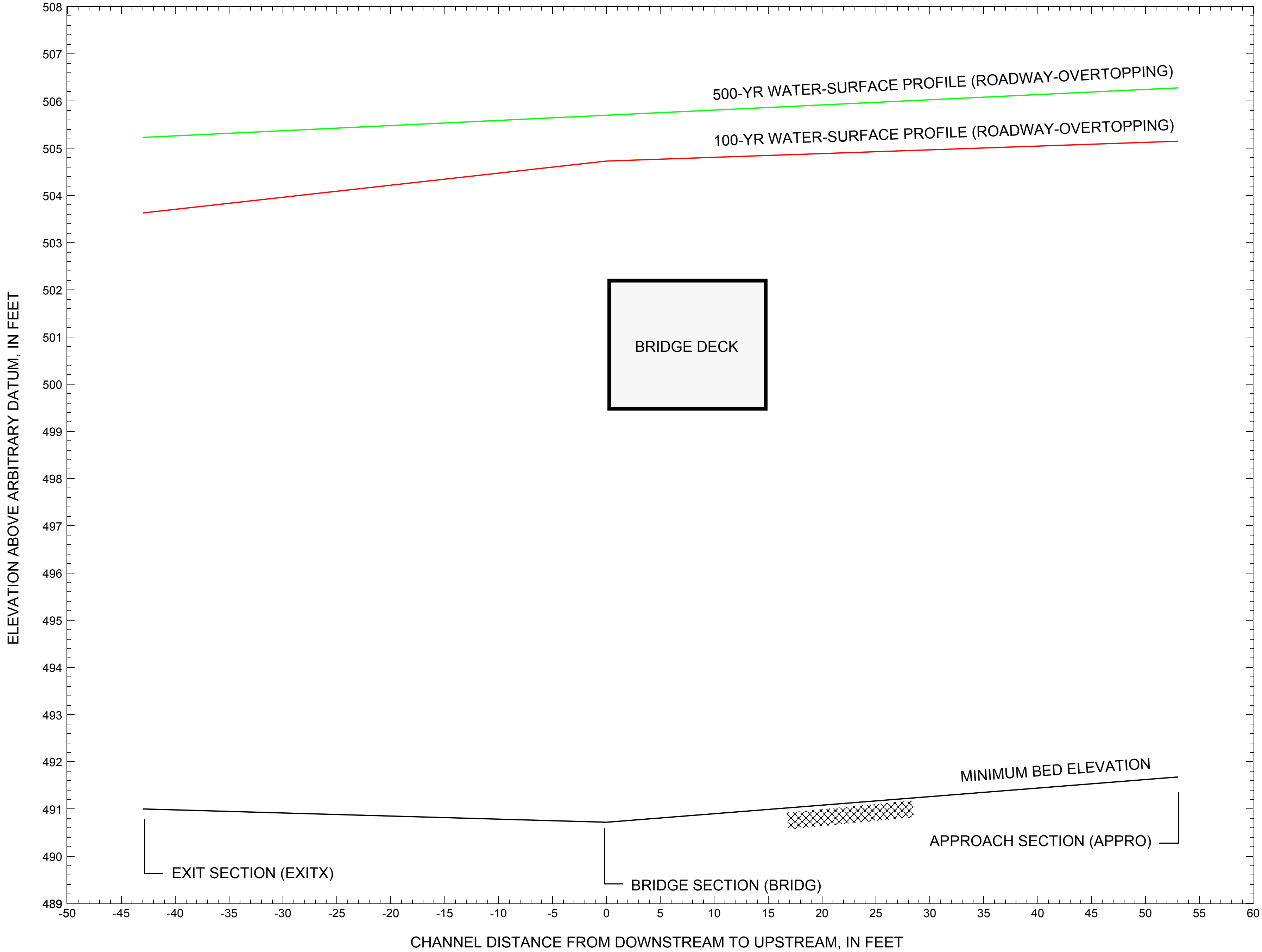

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure WEELTH00210023 on Town Highway 21, crossing Miller Run, Wheelock, Vermont.

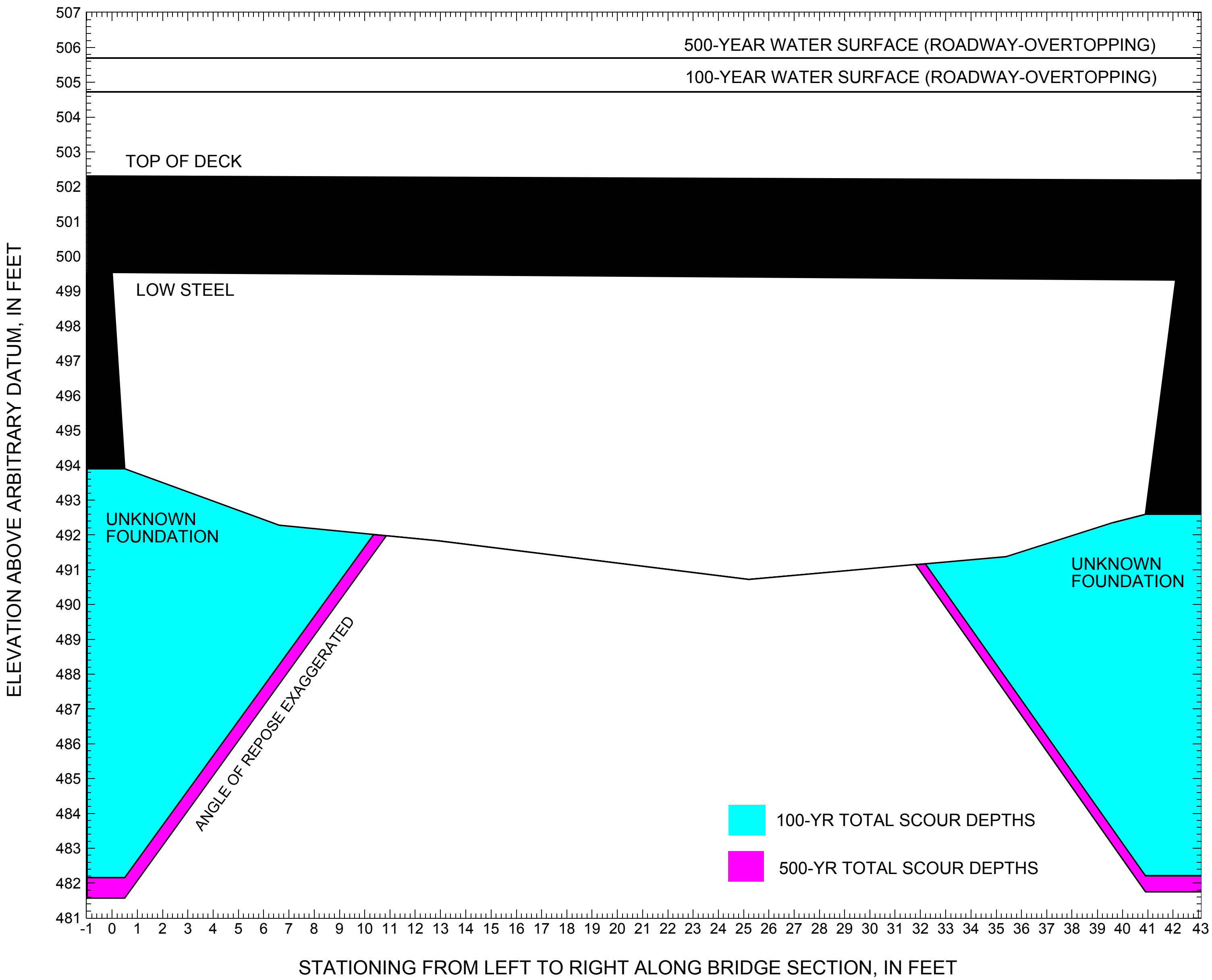

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure WEELTH00210023 on Town Highway 21, crossing Miller Run, Wheelock, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WEELTH00210023 on Town Highway 21, crossing Miller Run, Wheelock, 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-yr. discharge is 4,500 cubic-feet per second											
Left abutment	0.0	--	499.5	--	493.9	0.0	11.7	--	11.7	482.2	--
Right abutment	42.1	--	499.3	--	492.6	0.0	10.4	--	10.4	482.2	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure WEELTH00210023 on Town Highway 21, crossing Miller Run, Wheelock, 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-yr. discharge is 6,250 cubic-feet per second											
Left abutment	0.0	--	499.5	--	493.9	0.0	12.3	--	12.3	481.6	--
Right abutment	42.1	--	499.3	--	492.6	0.0	10.8	--	10.8	481.8	--

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

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File weel023.wsp
T2        Hydraulic analysis for structure WEELTH00210023   Date: 09-SEP-97
T3        Bridge #23 on Town Highway 21 over Miller Run in Wheelock, Vt. RHF
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           4500.0   6250.0   2210.0
SK          0.0027   0.0027   0.0027
*
XS   EXITX    -43           0.
GR         -266.1, 508.68
GR          -87.2, 504.12    -51.6, 500.67    -36.0, 500.27     -8.5, 499.22
GR            0.0, 492.77      1.5, 492.36      7.5, 492.00     17.7, 491.00
GR           28.5, 491.43     34.4, 492.18     42.0, 493.31     52.6, 497.15
GR           65.4, 500.97     71.1, 502.78     80.8, 503.44     87.5, 504.67
GR           93.0, 507.12    117.7, 511.95
*
N           0.050       0.060       0.060
SA                  -8.5         71.1
*
XS   FULLV      0  * * *   0.0
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    499.43      25.0
GR            0.0, 499.54      0.5, 493.90      6.6, 492.28     12.9, 491.83
GR           25.2, 490.72     35.4, 491.38     39.6, 492.35     40.9, 492.59
GR           42.1, 499.32      0.0, 499.54
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      21.9 * *    57.7      3.8
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      7      14.4     2
GR         -425.1, 515.26   -395.7, 516.48   -382.1, 516.66   -370.5, 515.94
GR         -328.6, 511.99   -266.1, 508.68   -186.7, 506.19    -72.4, 503.02
GR          -47.3, 502.61      0.0, 502.31     40.7, 502.19     62.1, 502.87
GR           80.2, 503.51     91.1, 504.88    100.4, 506.38    117.7, 511.95
*
XT   APTEM     82           0.
GR         -266.1, 508.68   -150.4, 502.93   -125.8, 501.44    -62.3, 499.54
GR          -38.9, 499.77    -16.8, 498.02     -4.4, 493.53      0.0, 492.95
GR            7.3, 492.60     14.8, 492.33     23.0, 492.20     29.3, 492.41
GR           34.0, 493.11     39.4, 493.79     50.5, 499.01     54.6, 500.02
GR           68.3, 500.54     76.0, 501.15     86.9, 504.96    117.7, 511.95
*
AS   APPRO     53 * * * 0.018
GT
N           0.045       0.060       0.060
SA                 -16.8         54.6
*
HP 1 BRIDG  499.54 1 499.54
HP 2 BRIDG  499.54 * * 2173
HP 2 RDWAY  504.73 * * 2332
HP 1 APPRO  505.15 1 505.15
HP 2 APPRO  505.15 * * 4500
*
HP 1 BRIDG  499.54 1 499.54
HP 2 BRIDG  499.54 * * 1771
```

APPENDIX B:

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File weel023.wsp
        Hydraulic analysis for structure WEELTH00210023   Date: 09-SEP-97
        Bridge #23 on Town Highway 21 over Miller Run in Wheelock, Vt. RHF

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      288     21009      0     88                            0
   499.54           288     21009      0     88  1.00      0     42        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.54     0.0    42.1   287.5   21009.    2173.   7.56

X STA.         0.0        4.3        6.9        9.1       11.1       13.2
  A(I)            22.4       16.2       14.9       13.6       14.1
  V(I)            4.85       6.72       7.28       7.96       7.72

X STA.        13.2       15.0       16.9       18.7       20.4       22.0
  A(I)            13.1       13.3       12.9       12.7       12.5
  V(I)            8.29       8.17       8.43       8.54       8.66

X STA.        22.0       23.7       25.2       26.9       28.5       30.2
  A(I)            12.5       12.4       12.7       12.4       12.8
  V(I)            8.66       8.79       8.55       8.73       8.48

X STA.        30.2       31.9       33.7       35.6       37.9       42.1
  A(I)            13.0       13.5       13.9       15.4       23.0
  V(I)            8.35       8.05       7.81       7.03       4.72


    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       7.

         WSEL     LEW     REW    AREA        K        Q    VEL
       504.73  -134.1    89.9   390.0   15735.    2332.   5.98

X STA.      -134.1      -84.0      -68.9      -57.6      -48.2      -39.8
  A(I)            34.8       24.1       21.0       18.9       18.0
  V(I)            3.35       4.83       5.56       6.16       6.46

X STA.       -39.8      -31.8      -24.5      -17.3      -10.5       -3.3
  A(I)            17.5       16.5       16.3       15.9       17.2
  V(I)            6.65       7.07       7.16       7.34       6.76

X STA.        -3.3        4.0       11.2       18.3       25.2       32.1
  A(I)            17.5       17.7       17.4       17.1       17.3
  V(I)            6.66       6.60       6.70       6.82       6.75

X STA.        32.1       39.0       46.1       54.5       65.2       89.9
  A(I)            17.5       17.7       18.7       20.6       28.3
  V(I)            6.66       6.60       6.25       5.65       4.12


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      781     66602    189    189                         9015
             2      820    101477     71     74                        15758
             3      141      8636     35     36                         1591
   505.15          1741    176714    296    299  1.14   -205     90    22474

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

         WSEL     LEW     REW    AREA        K        Q    VEL
       505.15  -205.6    90.0  1741.4  176714.    4500.   2.58

X STA.      -205.6     -123.4      -99.1      -79.6      -63.9      -49.0
  A(I)           171.8      113.2      103.8       91.8       90.5
  V(I)            1.31       1.99       2.17       2.45       2.49

X STA.       -49.0      -34.2      -22.2      -11.8       -4.7        0.8
  A(I)            88.6       81.2       83.0       75.9       68.4
  V(I)            2.54       2.77       2.71       2.96       3.29

X STA.         0.8        5.9       10.8       15.7       20.5       25.3
  A(I)            65.7       64.8       65.2       64.0       64.4
  V(I)            3.42       3.47       3.45       3.52       3.49

X STA.        25.3       30.2       35.7       42.0       53.8       90.0
  A(I)            65.9       69.4       73.9       94.4      145.5
  V(I)            3.42       3.24       3.04       2.38       1.55
```

```
      U.S. Geological Survey WSPRO Input File weel023.wsp
      Hydraulic analysis for structure WEELTH00210023   Date: 09-SEP-97
      Bridge #23 on Town Highway 21 over Miller Run in Wheelock, Vt. RHF

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

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      288     21009      0     88                             0
 499.54           288     21009      0     88  1.00      0     42         0

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     499.54     0.0    42.1   287.5   21009.    1771.   6.16

X STA.         0.0       4.3        6.9        9.1       11.1       13.2
  A(I)             22.4       16.2       14.9       13.6       14.1
  V(I)             3.95       5.48       5.93       6.49       6.30

X STA.        13.2      15.0       16.9       18.7       20.4       22.0
  A(I)             13.1       13.3       12.9       12.7       12.5
  V(I)             6.75       6.66       6.87       6.96       7.06

X STA.        22.0      23.7       25.2       26.9       28.5       30.2
  A(I)             12.5       12.4       12.7       12.4       12.8
  V(I)             7.06       7.17       6.97       7.12       6.91

X STA.        30.2      31.9       33.7       35.6       37.9       42.1
  A(I)             13.0       13.5       13.9       15.4       23.0
  V(I)             6.80       6.56       6.37       5.73       3.85


  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       7.

       WSEL     LEW     REW    AREA        K        Q    VEL
     505.70  -169.0    96.2   627.3   31257.    4482.   7.14

X STA.      -169.0    -103.8      -84.4      -70.8      -59.6      -49.6
  A(I)             59.0       40.2       34.6       31.3       29.7
  V(I)             3.80       5.57       6.48       7.15       7.55

X STA.       -49.6     -40.6      -32.1      -23.8      -16.0       -8.5
  A(I)             27.9       27.0       26.7       25.4       25.0
  V(I)             8.03       8.31       8.41       8.83       8.98

X STA.        -8.5      -0.2        8.1       16.2       24.1       32.0
  A(I)             27.9       28.2       27.7       27.2       27.4
  V(I)             8.04       7.95       8.08       8.24       8.17

X STA.        32.0      39.9       48.1       57.7       69.2       96.2
  A(I)             27.8       27.8       29.8       32.0       44.7
  V(I)             8.07       8.05       7.51       6.99       5.01


  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1     1007     94324    212    212                         12472
           2      900    118666     71     74                         18141
           3      184     12319     40     41                          2219
 506.28          2091    225310    323    327  1.13   -227     95     28442

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

       WSEL     LEW     REW    AREA        K        Q    VEL
     506.28  -228.3    95.0  2091.1  225310.    6250.   2.99

X STA.      -228.3    -136.8     -111.7      -91.4      -74.8      -60.0
  A(I)            209.0      133.7      124.0      109.9      105.5
  V(I)             1.50       2.34       2.52       2.84       2.96

X STA.       -60.0     -45.8      -32.1      -20.5      -10.2       -3.1
  A(I)            101.9       98.1       92.7       98.3       88.1
  V(I)             3.07       3.18       3.37       3.18       3.55

X STA.        -3.1       2.7        8.3       13.7       19.0       24.4
  A(I)             79.7       79.2       77.0       77.7       78.3
  V(I)             3.92       3.95       4.06       4.02       3.99

X STA.        24.4      29.8       35.7       42.9       56.7       95.0
  A(I)             78.1       82.1       91.5      116.7      169.5
  V(I)             4.00       3.81       3.42       2.68       1.84
```

```
        U.S. Geological Survey WSPRO Input File weel023.wsp
        Hydraulic analysis for structure WEELTH00210023   Date: 09-SEP-97
        Bridge #23 on Town Highway 21 over Miller Run in Wheelock, Vt. RHF

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      288     21009      0     88                            0
   499.54           288     21009      0     88  1.00      0     42        0
1
    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.54     0.0    42.1   287.5   21009.    2210.   7.69

 X STA.         0.0        4.3        6.9        9.1       11.1       13.2
   A(I)            22.4       16.2       14.9       13.6       14.1
   V(I)            4.93       6.84       7.40       8.10       7.86

 X STA.        13.2       15.0       16.9       18.7       20.4       22.0
   A(I)            13.1       13.3       12.9       12.7       12.5
   V(I)            8.43       8.31       8.58       8.69       8.81

 X STA.        22.0       23.7       25.2       26.9       28.5       30.2
   A(I)            12.5       12.4       12.7       12.4       12.8
   V(I)            8.81       8.94       8.70       8.88       8.62

 X STA.        30.2       31.9       33.7       35.6       37.9       42.1
   A(I)            13.0       13.5       13.9       15.4       23.0
   V(I)            8.49       8.18       7.94       7.15       4.80


    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      317     18908    131    131                         2798
             2      612     62338     71     74                        10164
             3       52      2065     26     26                          423
   502.24           981     83311    228    231  1.19   -147     81    10561

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      53.

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.24  -147.6    80.6   981.2   83311.    2210.   2.25

 X STA.      -147.6      -83.8      -59.7      -39.2      -23.2      -12.0
   A(I)            96.4       70.6       63.6       57.6       55.9
   V(I)            1.15       1.57       1.74       1.92       1.98

 X STA.       -12.0       -5.9       -1.6        2.2        6.0        9.5
   A(I)            45.8       40.2       37.4       37.6       35.9
   V(I)            2.41       2.75       2.96       2.94       3.08

 X STA.         9.5       13.1       16.5       19.9       23.4       26.9
   A(I)            36.6       35.9       35.8       36.6       37.1
   V(I)            3.02       3.08       3.08       3.02       2.98

 X STA.        26.9       30.6       34.6       39.1       45.9       80.6
   A(I)            37.4       39.6       41.9       51.3       88.1
   V(I)            2.95       2.79       2.64       2.15       1.25
```

WSPRO OUTPUT FILE (continued)

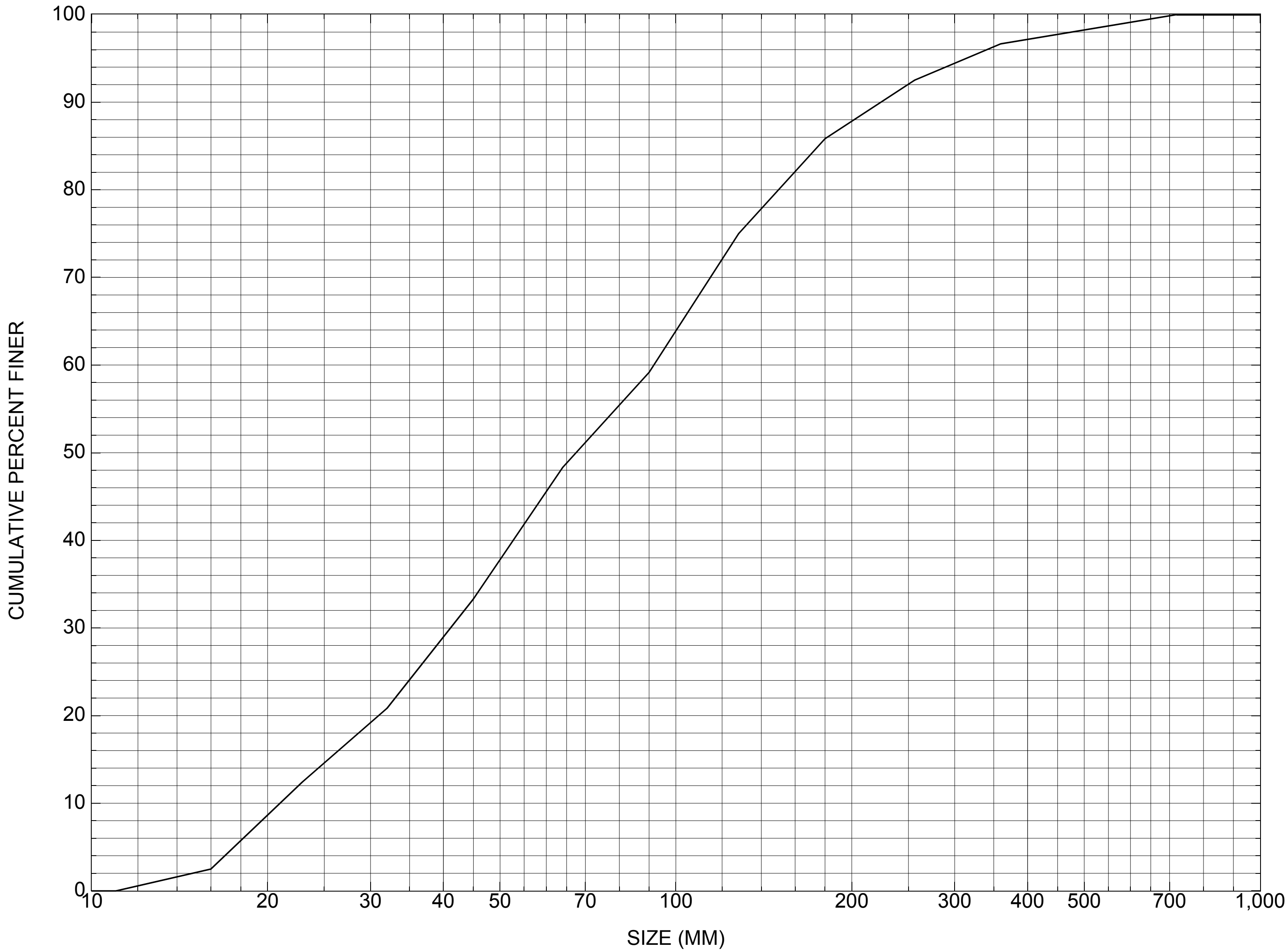
```
        U.S. Geological Survey WSPRO Input File weel023.wsp
        Hydraulic analysis for structure WEELTH00210023   Date: 09-SEP-97
        Bridge #23 on Town Highway 21 over Miller Run in Wheelock, Vt. RHF

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

EXITX:XS   ******    -81      924  0.41 *****  504.04  498.59    4500  503.63
       -42 ******     82    86525  1.12 ***** *******    0.38    4.87

FULLV:FV       43    -83      947  0.39  0.11  504.16 *******    4500  503.77
         0     43     83    89376  1.12  0.00    0.01    0.37    4.75
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  1.53

APPRO:AS       53   -183     1436  0.18  0.09  504.25 *******    4500  504.07
        53     53     86   136938  1.16  0.00    0.00    0.26    3.13
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =    503.77      499.43

            <<<<<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       43      0      288  0.89 *****  500.43  496.49    2173  499.54
         0 ******     42    21009  1.00 ***** *******    0.51    7.56

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  499.43 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q   WSEL
   RDWAY:RG       7.    39.  0.03  0.12  505.24    0.00   2332.  504.73

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1560.   156.  -134.    22.   2.5   1.7   6.8   5.9   2.2   3.1
   RT:    772.    68.    22.    90.   2.5   1.9   7.1   6.0   2.4   3.1

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

APPRO:AS       31   -205     1741  0.12  0.12  505.27  498.70    4500  505.15
        53     39     90   176724  1.14  0.00    0.00    0.20    2.58

       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     -43.   -82.    82.   4500.   86525.     924.    4.87  503.63
   FULLV:FV       0.   -84.    83.   4500.   89376.     947.    4.75  503.77
   BRIDG:BR       0.     0.    42.   2173.   21009.     288.    7.56  499.54
   RDWAY:RG       7.******* 1560.    2332.******************    2.00  504.73
   APPRO:AS      53.  -206.    90.   4500.  176724.    1741.    2.58  505.15

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF     HO   VHD     EGL    WSEL
   EXITX:XS    498.59    0.38  491.00  511.95************  0.41  504.04  503.63
   FULLV:FV  ********    0.37  491.00  511.95  0.11  0.00  0.39  504.16  503.77
   BRIDG:BR    496.49    0.51  490.72  499.54************  0.89  500.43  499.54
   RDWAY:RG  ****************  502.19  516.66  0.03******  0.12  505.24  504.73
   APPRO:AS    498.70    0.20  491.68  511.43  0.12  0.00  0.12  505.27  505.15
```

```
       U.S. Geological Survey WSPRO Input File weel023.wsp
       Hydraulic analysis for structure WEELTH00210023   Date: 09-SEP-97
       Bridge #23 on Town Highway 21 over Miller Run in Wheelock, Vt. RHF

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

EXITX:XS   ******   -130     1224  0.49 *****  505.72  500.27    6250  505.23
       -42 ******     89   120241  1.21 ***** *******    0.42    5.10

FULLV:FV       43   -135     1257  0.47  0.11  505.84 *******    6250  505.38
         0     43     89   123796  1.22  0.00    0.01    0.41    4.97
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  1.62

APPRO:AS       53   -216     1920  0.19  0.08  505.93 *******    6250  505.74
        53     53     93   201140  1.13  0.00    0.00    0.25    3.26
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                      WS3N,LSEL =    505.38     499.43

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                 QRD,QRDMAX,RATIO =     4482.      3974.    1.13

            <<<<<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       43      0      288  0.59 *****  500.13  495.89    1771  499.54
         0 ******     42    21009  1.00 ***** *******    0.42    6.16

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  499.43 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR      Q    WSEL
   RDWAY:RG       7.    39.  0.03  0.16  506.41    0.00   4482.  505.70

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   3058.   191.  -169.    22.   3.5   2.3   8.1   7.1   3.0   3.1
   RT:   1424.    74.    22.    96.   3.5   2.7   8.6   7.2   3.4   3.1

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

APPRO:AS       31   -227     2091  0.16  0.14  506.44  500.58    6250  506.28
        53     41     95   225314  1.13  0.00    0.00    0.22    2.99

       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     -43.  -131.    89.   6250.  120241.    1224.    5.10  505.23
   FULLV:FV       0.  -136.    89.   6250.  123796.    1257.    4.97  505.38
   BRIDG:BR       0.     0.    42.   1771.   21009.     288.    6.16  499.54
   RDWAY:RG       7.******* 3058.   4482.******************    2.00  505.70
   APPRO:AS      53.  -228.    95.   6250.  225314.    2091.    2.99  506.28

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    500.27    0.42  491.00  511.95************  0.49  505.72  505.23
   FULLV:FV  ********    0.41  491.00  511.95  0.11  0.00  0.47  505.84  505.38
   BRIDG:BR    495.89    0.42  490.72  499.54************  0.59  500.13  499.54
   RDWAY:RG  ****************  502.19  516.66  0.03******  0.16  506.41  505.70
   APPRO:AS    500.58    0.22  491.68  511.43  0.14  0.00  0.16  506.44  506.28
```

```
        U.S. Geological Survey WSPRO Input File weel023.wsp
        Hydraulic analysis for structure WEELTH00210023   Date: 09-SEP-97
        Bridge #23 on Town Highway 21 over Miller Run in Wheelock, Vt. RHF

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

 EXITX:XS   ******    -51      518  0.30 *****  500.97  496.20    2210  500.67
        -42 ******     64    42510  1.07 ***** *******    0.37    4.27

 FULLV:FV       43    -52      534  0.29  0.11  501.09 *******    2210  500.80
          0     43     65    43986  1.08  0.00    0.01    0.36    4.14
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPRO:AS       53   -126      715  0.18  0.10  501.19 *******    2210  501.01
         53     53     77    56123  1.22  0.00    0.00    0.32    3.09
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   500.80     499.43

             <<<<<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       43      0      288  0.92 *****  500.46  496.54    2206  499.54
          0 ******     42    21009  1.00 ***** *******    0.52    7.67

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   3.  0.800  0.000  499.43 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG       7.        <<<<<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       31   -147      980  0.09  0.10  502.33  496.33    2210  502.24
         53     35     81    83214  1.19  0.00    0.00    0.21    2.25

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      ****** ****** ******** ****** ******   502.21

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


   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
    EXITX:XS     -43.   -52.    64.   2210.   42510.     518.    4.27  500.67
    FULLV:FV       0.   -53.    65.   2210.   43986.     534.    4.14  500.80
    BRIDG:BR       0.     0.    42.   2206.   21009.     288.    7.67  499.54
    RDWAY:RG       7.**************      0.        0.       0.    2.00********
    APPRO:AS      53.  -148.    81.   2210.   83214.     980.    2.25  502.24

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

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    EXITX:XS    496.20    0.37  491.00  511.95************  0.30  500.97  500.67
    FULLV:FV  ********    0.36  491.00  511.95  0.11  0.00  0.29  501.09  500.80
    BRIDG:BR    496.54    0.52  490.72  499.54************  0.92  500.46  499.54
    RDWAY:RG  ****************  502.19  516.66************  0.09  502.30********
    APPRO:AS    496.33    0.21  491.68  511.43  0.10  0.00  0.09  502.33  502.24
   ER

1  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WEELTH00210023, in Wheelock, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WEELTH00210023

General Location Descriptive

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

Date *(MM/DD/YY)* 04 / 05 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 83500

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

Waterway *(I - 6)* Miller Run

Road Name *(I - 7):* -

Route Number TH021

Vicinity *(I - 9)* 0.1 MI JCT TH 21 + VT122

Topographic Map Lyndonville

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44353

Longitude *(i - 17; nnnnn.n)* 72052

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10031700230317

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

Maximum span length *(I - 48; nnnn)* 0043

Year built *(I - 27; YYYY)* 1928

Structure length *(I - 49; nnnnnn)* 000046

Average daily traffic, ADT *(I - 29; nnnnnn)* 000005

Deck Width *(I - 52; nn.n)* 144

Year of ADT *(I - 30; YY)* 93

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

Opening skew to Roadway *(I - 34; nn)* 23

Waterway adequacy *(I - 71; n)* 6

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

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

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

Year Reconstructed *(I - 106)* 1974

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

Clear span (*nnn.n ft*)

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

Vertical clearance from streambed (*nnn.n ft*) 8.6

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

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

Comments:

The structural inspection report of 05/21/93 indicates that the structure is a steel stringer type bridge with a creosote treated wooden deck. The abutments, wingwalls and backwalls are concrete. The right abutment has a few fine cracks and small leaks reported overall, with cracks, leaks and spalls in both wingwalls. A few boulders are present in front of the wingwalls on each abutment, with random boulders along the up- and downstream channel banks.

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:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **28.28** mi^2

Lake/pond/swamp area **0.16** mi^2

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

Bridge site elevation **758** ft

Headwater elevation **2720** ft

Main channel length **9.11** mi

10% channel length elevation **827** ft

85% channel length elevation **1545** ft

Main channel slope *(S)* **105.11** ft / mi

Watershed Precipitation Data

Average site precipitation - in

Average headwater precipitation - in

Maximum 2yr-24hr precipitation event *(I24,2)* - in

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

Are plans available? N *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY):* - / -

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

NO BENCHMARK INFORMATION

Reference Point (*MSL, Arbitrary, Other*): -

Datum (*NAD27, NAD83, Other*): -

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

If 1: Footing Thickness _______ Footing bottom elevation: ______

If 2: Pile Type: ____ (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: _______

If 3: Footing bottom elevation: ______

Is boring information available? N *If no, type ctrl-n bi* Number of borings taken: -

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **3/21/96**
Computerized by: **RB** Date: **3/25/96**
Reviewd by: **RHF** Date: **9/25/97**

Structure Number **WEELTH00210023**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E. BOEHMLER** Date *(MM/DD/YY)* **08** / **02** / 19**95**

2. Highway District Number **07** Mile marker **0000**

County **Caledonia** Town **Wheelock (83500)**

Waterway *(I - 6)* **Miller Run** Road Name **-**

Route Number **TH021** Hydrologic Unit Code: **01080102**

3. Descriptive comments:

Located about 0.1 miles from the intersection of TH 21 with VT 122.

B. Bridge Deck Observations

4. Surface cover... LBUS **4** RBUS **6** LBDS **2** 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 **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 **46** *(feet)* Span length **43** *(feet)* Bridge width **14.4** *(feet)*

Road approach to bridge:

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

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

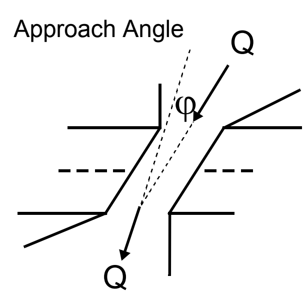
10. Embankment slope (*run / rise in feet / foot*):
US left **-** US right **-**

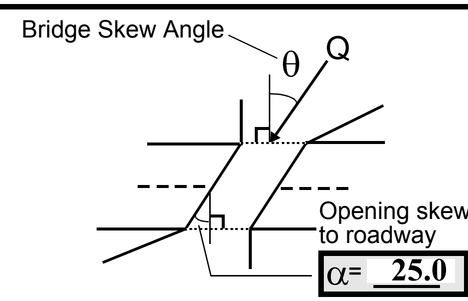
	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	3	1	0	0
RBUS	0	-	2	1
RBDS	2	2	3	2
LBDS	0	-	0	0

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

Channel approach to bridge (BF):

15. Angle of approach: **0** 16. Bridge skew: **20**





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: **1a**

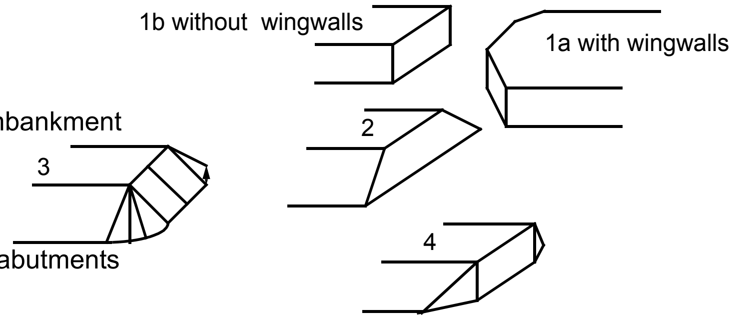
1a- Vertical abutments with wingwalls

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. Surface cover is as shown except for the left bank US which has backyard lawns for homes along VT 122 and some small trees, shrubs and brush mainly on the immediate left bank. On the right bank DS, TH 21 bisects the over bank area which is mainly forest on the immediate bank and high right bank side of the roadway.
7. Values are from the VT AOT files. Measured bridge length is 46 feet, span length is 44 feet and the bridge width is 14.4 feet.
11. The protection on the DS right road embankment is limited to immediately behind the end of the DS right wingwall. The protection is a stack of boulders which has slumped. Just DS of these boulders is a cavity eroded into the bank material from road wash and channel erosion.
13. There is some gully erosion due to road wash draining down the embankment just around the end of the DS right wingwall. The road wash around the US right wingwall is not as severe as there is a tree and stone fill on top of the wingwall and backfill behind the wingwall. The tree is growing at the very immediate end of the US right wingwall and protects and prevents erosion there.

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
67.0	4.5			5.0	1	4	324	423	1	1

23. Bank width **20.0** 24. Channel width **25.0** 25. Thalweg depth **79.5** 29. Bed Material **435**

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

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

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

There are bedrock outcrops on the right bank at approximately 130 feet US. Some bedrock forms the bed material along the right bank side of the channel in this area. The channel reach is very straight. The bank material is intermittently pitted and scalloped in places, especially on the left bank but, there is no distinctive bank cutting.

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

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

37. Material: -

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

NO POINT BARS

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

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

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

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

NO CUT BANKS

45. Is channel scour present? **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

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
44.0		**1.0**		**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.):

435

-

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? 1___ *(Y or N)* Ice Blockage Potential N____ *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

1

There are many trees on the banks of this straight stream, but little erosion, so the debris potential is low. Debris and ice are not likely to get hung up on or near the bridge due to the steep gradient and straight reach.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	90	2	0	0	0	90.0
RABUT	1	-	90			2	0	38.0

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

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

0

0

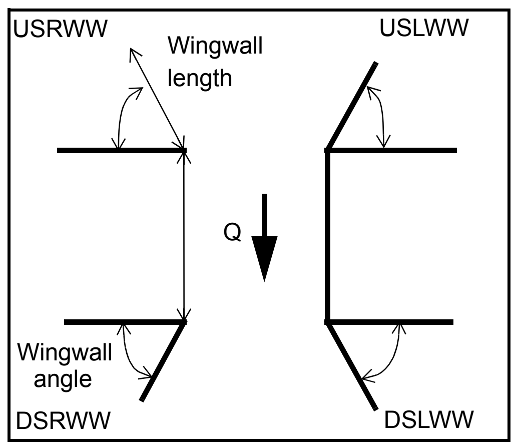
1

82. The left abutment protection consists of 2 large rounded boulders, some smaller rounded boulders, 2 to 4 blocks of old concrete and some smaller channel fill material randomly scattered along the base of the wall (mainly to the US end).

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						38.0	
USRWW:	Y		1		0	1.5	
DSLWW:	0		0		Y	16.0	
DSRWW:	1		0		0	13.5	

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



82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	0	0	Y	0	1	1	1	-
Condition	Y	0	1	0	2	1	4	-
Extent	1	0	0	3	2	3	0	-

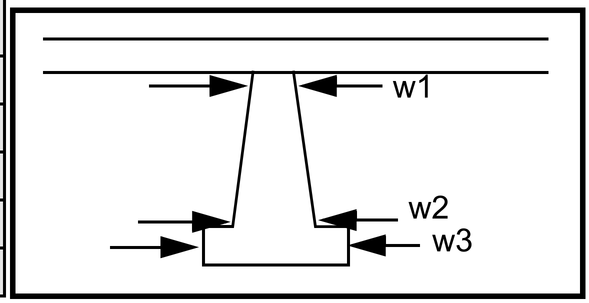
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
4
1
1
2
2
1

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		**7.5**		**35.0**	**80.0**	**10.0**
Pier 2		**4.5**	**6.0**	**60.0**	**40.0**	**-**
Pier 3	**-**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e pro-**	**n. The**	**at the**	**Thus,**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**tec-**	**DS**	**sur-**	**it**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**tion**	**right**	**face**	**pro-**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**on**	**wing**	**and**	**vides**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**the**	**wall**	**has**	**min-**	*Y- yes; N- no*
91. Attack ∠ (BF)	**US**	**pro-**	**slum**	**imal**	
92. Pushed	**wing**	**tec-**	**ped**	**pro-**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**walls**	**tion**	**away**	**tec-**	
95. Cross-members	**is in**	**is**	**from**	**tion.**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**good**	**barel**	**the**	**Roa**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**con-**	**y vis-**	**wing**	**d**	
98. Exposure depth	**ditio**	**ible**	**wall.**	**wash**	

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

and channel erosion have both contributed to the voided area of the bank just DS of the wingwall and behind it. The DS left wingwall is protected by one large slab of concrete which covers all of its lower half.

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: 2

Scour dimensions: Length 4 Width 435 Depth: 435 Positioned 1 %LB to 1 %RB

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

345
2
0
1

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

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

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

Confluence comments (eg. confluence name):

extends from the DS end of the DS left wingwall to about 90 feet DS. There is no protection on the right bank. The reach is straight for about 200 feet before bending slightly to the right.

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: WEELTH00210023 Town: Wheelock
Road Number: TH021 County: Caledonia
Stream: Miller Run
Initials RHF Date: 9/23/97 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	4500	6250	2210
Main Channel Area, ft2	820	900	612
Left overbank area, ft2	781	1007	317
Right overbank area, ft2	141	184	52
Top width main channel, ft	71	71	71
Top width L overbank, ft	189	212	131
Top width R overbank, ft	35	40	26
D50 of channel, ft	0.2213	0.2213	0.2213
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	11.5	12.7	8.6
y1, average depth, LOB, ft	4.1	4.8	2.4
y1, average depth, ROB, ft	4.0	4.6	2.0
Total conveyance, approach	176714	225310	83311
Conveyance, main channel	101477	118666	62338
Conveyance, LOB	66602	94324	18908
Conveyance, ROB	8636	12319	2065
Percent discrepancy, conveyance	-0.0006	0.0004	0.0000
Qm, discharge, MC, cfs	2584.1	3291.7	1653.6
Ql, discharge, LOB, cfs	1696.0	2616.5	501.6
Qr, discharge, ROB, cfs	219.9	341.7	54.8
Vm, mean velocity MC, ft/s	3.2	3.7	2.7
Vl, mean velocity, LOB, ft/s	2.2	2.6	1.6
Vr, mean velocity, ROB, ft/s	1.6	1.9	1.1
Vc-m, crit. velocity, MC, ft/s	10.2	10.4	9.7
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

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

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	2173	1771	2210
Main channel area (DS), ft2	287.5	287.5	287.5
Main channel width (normal), ft	38.2	38.2	38.2

Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	38.2	38.2	38.2
D90, ft	0.7360	0.7360	0.7360
D95, ft	1.0305	1.0305	1.0305
Dc, critical grain size, ft	0.2472	0.1642	0.2556
Pc, Decimal percent coarser than Dc	0.465	0.621	0.454
Depth to armoring, ft	**0.85**	**0.30**	**0.92**

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	4500	6250	2210
(Q) discharge thru bridge, cfs	2173	1771	2210
Main channel conveyance	21009	21009	21009
Total conveyance	21009	21009	21009
Q2, bridge MC discharge,cfs	2173	1771	2210
Main channel area, ft2	288	288	288
Main channel width (normal), ft	38.2	38.2	38.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	38.15	38.15	38.15
y_bridge (avg. depth at br.), ft	7.54	7.54	7.54
Dm, median (1.25*D50), ft	0.276625	0.276625	0.276625
y2, depth in contraction,ft	5.71	4.79	5.80
ys, scour depth (y2-ybridge), ft	-1.82	-2.74	-1.74

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	4500	6250	2210
Q, thru bridge MC, cfs	2173	1771	2210
Vc, critical velocity, ft/s	10.19	10.35	9.71
Va, velocity MC approach, ft/s	3.15	3.66	2.70
Main channel width (normal), ft	38.2	38.2	38.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	38.2	38.2	38.2
qbr, unit discharge, ft2/s	57.0	46.4	57.9
Area of full opening, ft2	287.5	287.5	287.5
Hb, depth of full opening, ft	7.54	7.54	7.54
Fr, Froude number, bridge MC	0.51	0.42	0.52
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**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	499.43	499.43	499.43

Elevation of Bed, ft	491.89	491.89	491.89
Elevation of Approach, ft	505.15	506.28	502.24
Friction loss, approach, ft	0.12	0.14	0.1
Elevation of WS immediately US, ft	505.03	506.14	502.14
ya, depth immediately US, ft	13.14	14.25	10.25
Mean elevation of deck, ft	502.25	502.25	502.25
w, depth of overflow, ft (>=0)	2.78	3.89	0.00
Cc, vert contrac correction (<=1.0)	0.92	0.92	0.92
**Cc, for downstream face (<=1.0)	ERR	ERR	ERR
Ys, scour w/Chang equation, ft	**-1.46**	**-2.66**	**-1.07**
Ys, scour w/Umbrell equation, ft	-1.36	-0.62	-2.31

Abutment Scour

Froehlich's Abutment Scour

Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1

(Richardson and others, 1995, p. 48, eq. 28)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	4500	6250	2210	4500	6250	2210
a', abut.length blocking flow, ft	207.6	230.3	149.6	49.87	54.87	40.47
Ae, area of blocked flow ft2	770.75	869.11	465.53	179.36	189.87	131.63
Qe, discharge blocked abut.,cfs	-	-	878.18	-	-	204.26
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.34	2.76	1.89	1.97	2.32	1.55
ya, depth of f/p flow, ft	3.71	3.77	3.11	3.60	3.46	3.25
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	65	65	65	115	115	115
K2	0.96	0.96	0.96	1.03	1.03	1.03
Fr, froude number f/p flow	0.190	0.210	0.188	0.152	0.169	0.152
ys, scour depth, ft	17.28	19.00	13.72	**10.38**	**10.84**	**9.10**

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)	207.6	230.3	149.6	49.87	54.87	40.47
y1 (depth f/p flow, ft)	3.71	3.77	3.11	3.60	3.46	3.25
a'/y1	55.92	61.03	48.07	13.87	15.86	12.44
Skew correction (p. 49, fig. 16)	0.92	0.92	0.92	1.06	1.06	1.06
Froude no. f/p flow	0.19	0.21	0.19	0.15	0.17	0.15
Ys w/ corr. factor K1/0.55:						
vertical	14.31	15.04	11.96	ERR	ERR	ERR
vertical w/ ww's	**11.74**	**12.33**	**9.81**	ERR	ERR	ERR
spill-through	7.87	8.27	6.58	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	0.51	0.42	0.52	0.51	0.42	0.52
y, depth of flow in bridge, ft	7.53	7.53	7.53	7.53	7.53	7.53
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	**1.21**	**0.82**	**1.26**	**1.21**	**0.82**	**1.26**
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR