LEVEL II SCOUR ANALYSIS FOR BRIDGE 10 (BENNUS00070010) on U.S. ROUTE 7, crossing the WALLOOMSAC RIVER, BENNINGTON, VERMONT

U.S. Geological Survey
Open-File Report 97-580

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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By SCOTT A. OLSON and RONDA L. BURNS

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1997

U.S. DEPARTMENT OF THE INTERIOR
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CONTENTS

FIGURES

TABLES

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 10 (BENNUS00070010) ON U.S. ROUTE 7, CROSSING THE WALLOOMSAC RIVER, BENNINGTON VERMONT

By **Scott A. Olson and Ronda L. Burns**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BENNUS00070010 on U.S. Route 7, also known as North Street, crossing of the Walloomsac River, Bennington, 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 southwestern Vermont. The 30.1-mi^2 drainage area is a predominantly rural and forested basin. The bridge site is located within an urban setting in the Town of Bennington with buildings, parking lots, lawns, and a playground on the overbank areas.

In the study area, the Walloomsac River has a straight channel with constructed channel banks through much of the reach. The channel is located on a delta and has a slope of approximately 0.02 ft/ft, an average channel top width of 37 ft and an average bank height of 5 ft. The predominant channel bed material is cobble with a median grain size (D_{50}) of 96.0 mm (0.315 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 5, 1996, indicated that the constructed reach was stable.

The U.S. Route 7 crossing of the Walloomsac River is a 53-ft-long, two-lane bridge consisting of one 50-foot steel span (Vermont Agency of Transportation, written communication, September 27, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The wingwalls are angled in toward the channel because the widths of the upstream and downstream constructed channel banks are narrower than the bridge opening. The channel is skewed approximately 5 degrees to the opening and the opening-skew-to-roadway is 10 degrees.

Scour countermeasures at the site include masonry and stone walls on both the upstream and downstream banks. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and 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 computed for all modelled flows ranged from 0.0 to 0.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Computed left abutment scour ranged from 5.9 to 6.8 ft. with the worst-case scour occurring at the 500-year discharge. Computed right abutment scour for all modelled flows was 6.8 ft. Total scour depths for all modelled flows did not exceed the depth of the abutment footings. 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.

Bennington, VT. Quadrangle, 1:24,000, 1954
Pownal, VT. Quadrangle, 1:24,000, 1954

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 BENNUS00070010 ***Stream*** Walloomsac River

County Bennington ***Road*** U.S. 7 ***District*** 1

Description of Bridge

Bridge length 53 ***ft*** ***Bridge width*** 50.0 ***ft*** ***Max span length*** 50 ***ft***

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

Abutment type Vertical, concrete ***Embankment type*** None

Stone fill on abutment? No ***Date of inspection*** 8/5/96

Description of stone fill There was no stone fill present. Scour countermeasures included stone and masonry walls extending from the ends of each wingwall.

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

Is bridge skewed to flood flow according to N ***survey?*** Y ***Angle*** 5

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

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	8/5/96	0	0
Level II	8/5/96	0	0

Potential for debris Moderate. The bridge is in an urban setting.

Describe any features near or at the bridge that may affect flow (include observation date) August 5, 1996. The low chord is below the tops of banks, increasing the potential for the bridge to capture debris. In addition, the bridge railing is solid steel and would block flow above the roadway elevation.

Description of the Geomorphic Setting

General topography The channel is located on a delta and thus the channel has wide flood plains with no valley.

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

Date of inspection 8/5/96

DS left: Constructed channel bank to a wide flood plain.

DS right: Constructed channel bank to a wide flood plain.

US left: Constructed channel bank to a wide flood plain.

US right: Constructed channel bank to a wide flood plain.

Description of the Channel

Average top width 37 ft ***Average depth*** 5 ft

Predominant bed material Cobbles ***Bank material*** Walls

Straight, relatively stable and in an alluvial setting with constructed channel boundaries.

8/5/96

Vegetative co Grass, trees, and buildings on the overbank.

DS left: Grass, trees, parking lot and buildings on the overbank.

DS right: Grass, trees, and buildings on the overbank.

US left: A school playground and buildings with a few trees on the overbank.

US right: Y

Do banks appear stable? August 5, 1996. ***If not, describe location and type of instability and date of observation.***

August 5, 1996. None.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 30.1 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: The drainage is rural, but the bridge itself is located in an urban setting.

Is there a USGS gage on the stream of interest? Yes

USGS gage description Walloomsac River nr N. Bennington, VT

USGS gage number 01334000

Gage drainage area 111 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 4,900 ***ft³/s*** ***Q500*** 7,570 ***ft³/s***

The 100- and 500-year discharges were interpolated between flood frequency estimates for the Walloomsac River in the Flood Insurance Study for the Town of Bennington (Federal Emergency Management Agency, 1986). These discharges were within a range defined by flood frequency curves determined from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). The 100-year discharge was within eight percent of the discharge found in the VTAOT database (written communication, May 1994).

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 Subtract 405.9 ft from the USGS survey datum to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the left abutment (elev. 507.70 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the upstream left wingwall (elev. 505.25 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
APDEP	-381	1	Approach section to Depot Street bridge
XSEC2	-214	1	Surveyed section
EXITX	-87	1	Exit section of U.S. Route 7 bridge
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	23	1	Road Grade section
APPRO	86	2	Modelled approach section to U.S. Route 7 bridge (templated from APTEM)
APTEM	105	1	Surveyed approach section to U.S. Route 7 bridge (used as template only)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.050, and overbank "n" values ranged from 0.035 to 0.060.

The starting water-surface applied to section APDEP was taken from the hydraulic model developed for the Depot Street bridge downstream (Olson, 1997). APDEP was the approach section to the Depot Street bridge.

There are several concerns with both the 100- and 500-year models. First, the bridge site is located on a delta. When the banks are overtopped, flood waters have the potential to inundate a very large area. Flow would likely be diverted down various streets away from the Walloomsac River. In the models, it was necessary to decide where to end the cross sections since the overbanks were flat. Points were chosen to terminate the left and right ends of the sections, generally where the section intersected a building. Secondly, not only will flow spread throughout the large floodplain, the Flood Insurance Study for the Town of Bennington (Federal Emergency Management Agency, 1986) indicates there is a naturally occurring diversion down Main Street between the Main Street bridge, 3000 ft upstream and the Depot Street bridge, 380 ft downstream (Figure 1).

The final concern with the 100- and 500-year discharges is that WSPRO computes flow through the bridge using a submerged orifice equation. This equation incorporates the head on the downstream side of the bridge into the computation. Although the downstream low chord is submerged, the downstream water surface is at or below critical depth which indicates that downstream conditions are not affecting flow through the bridge. Thus, the submerged orifice equation is not entirely appropriate.

Bridge Hydraulics Summary

Average bridge embankment elevation 507.8 ***ft***
Average low steel elevation 506.3 ***ft***

100-year discharge 4,900 ***ft^3/s***
Water-surface elevation in bridge opening 506.3 ***ft***
Road overtopping? Y ***Discharge over road*** 2,710 ***ft^3/s***
Area of flow in bridge opening 259 ***ft^2***
Average velocity in bridge opening 8.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.1 ***ft/s***

Water-surface elevation at Approach section with bridge 510.0
Water-surface elevation at Approach section without bridge 509.4
Amount of backwater caused by bridge 0.6 ***ft***

500-year discharge 7,570 ***ft^3/s***
Water-surface elevation in bridge opening 506.3 ***ft***
Road overtopping? Y ***Discharge over road*** 5,160 ***ft^3/s***
Area of flow in bridge opening 259 ***ft^2***
Average velocity in bridge opening 9.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.3 ***ft/s***

Water-surface elevation at Approach section with bridge 511.5
Water-surface elevation at Approach section without bridge 510.6
Amount of backwater caused by bridge 0.9

Incipient overtopping discharge 1,760 ***ft^3/s***
Water-surface elevation in bridge opening 506.3 ***ft***
Area of flow in bridge opening 258 ***ft^2***
Average velocity in bridge opening 6.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 8.3 ***ft/s***

Water-surface elevation at Approach section with bridge 507.2
Water-surface elevation at Approach section without bridge 506.3
Amount of backwater caused by bridge 0.9 ***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.

All modelled 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 was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Results of this analysis are presented in figure 8 and tables 1 and 2.

Additional estimates of contraction scour were also computed by use of Laursen's clear-water scour equation (Richardson and others, 1995, p. 32, equation 20) and the results are presented in Appendix F. Furthermore, the incipient roadway-overtopping discharge resulted in unsubmerged orifice flow. For this discharge contraction scour was also computed by substituting estimates for the depth of flow in the bridge at the downstream face in the Chang equation and Laursen's clear-water equation. Contraction scour results with respect to these substitutions are provided in Appendix F.

Abutment scour for 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. Variables for the HIRE equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and depth of flow approaching the abutment.

Since the right abutment was not blocking flow (see Figure 3), scour at this abutment was assumed to be equal to the depth of flow approaching the abutment toe, which is the factor of safety in the Froehlich abutment scour equation (Richardson and others, 1995, p. 48, equation 28). This depth at the right abutment was estimated as the roadway elevation minus the elevation of the abutment toe, 6.8 ft.

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	0.1	0.0
Depth to armoring	1.3	2.3	4.2
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	6.3	6.8	5.9
Right abutment	6.8	6.8	6.8
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	1.5	1.9	1.9
Right abutment	1.5	1.9	1.9
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

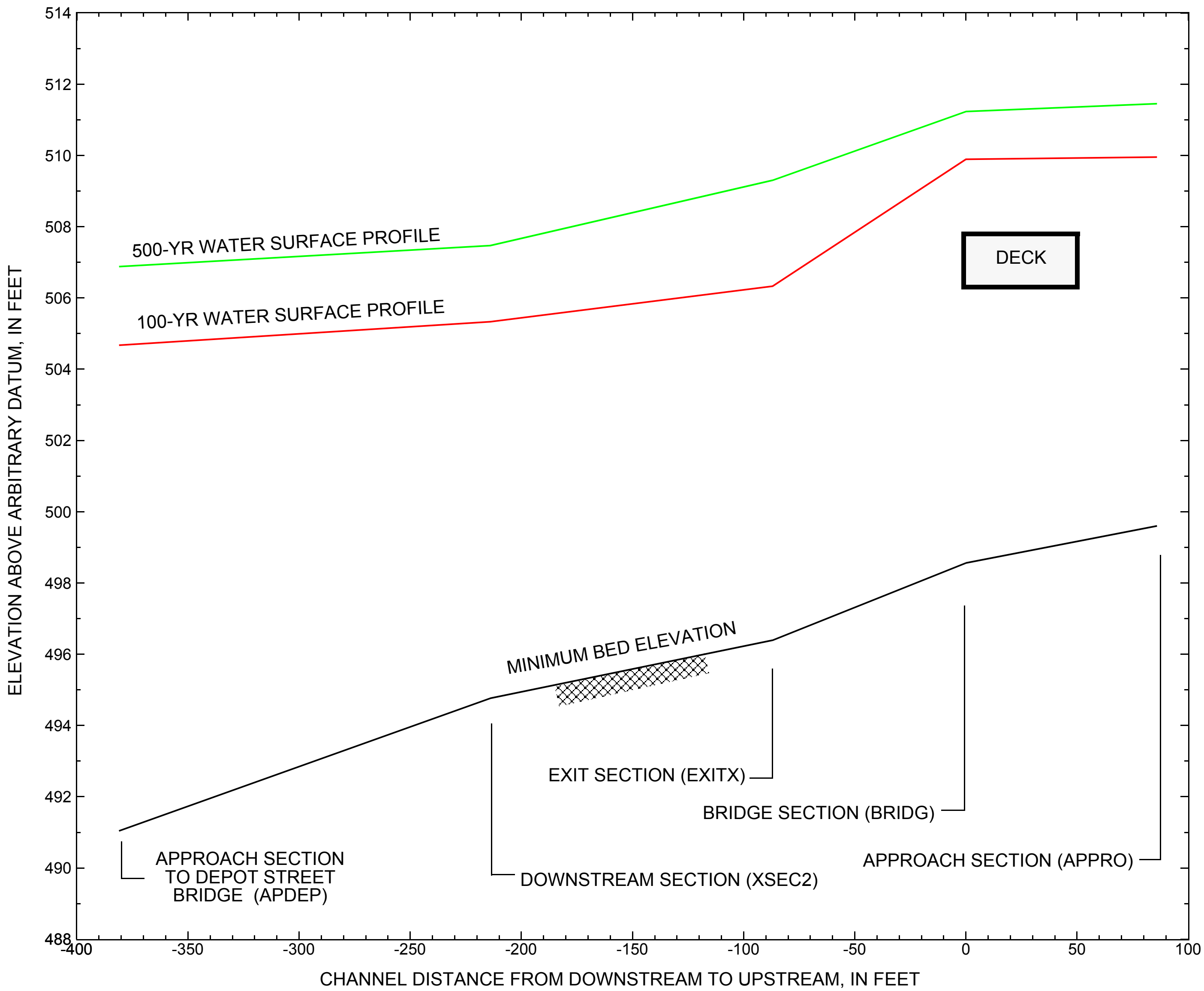

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BENNUS00070010 on U.S. Route 7, crossing the Walloomsac River, Bennington, Vermont.

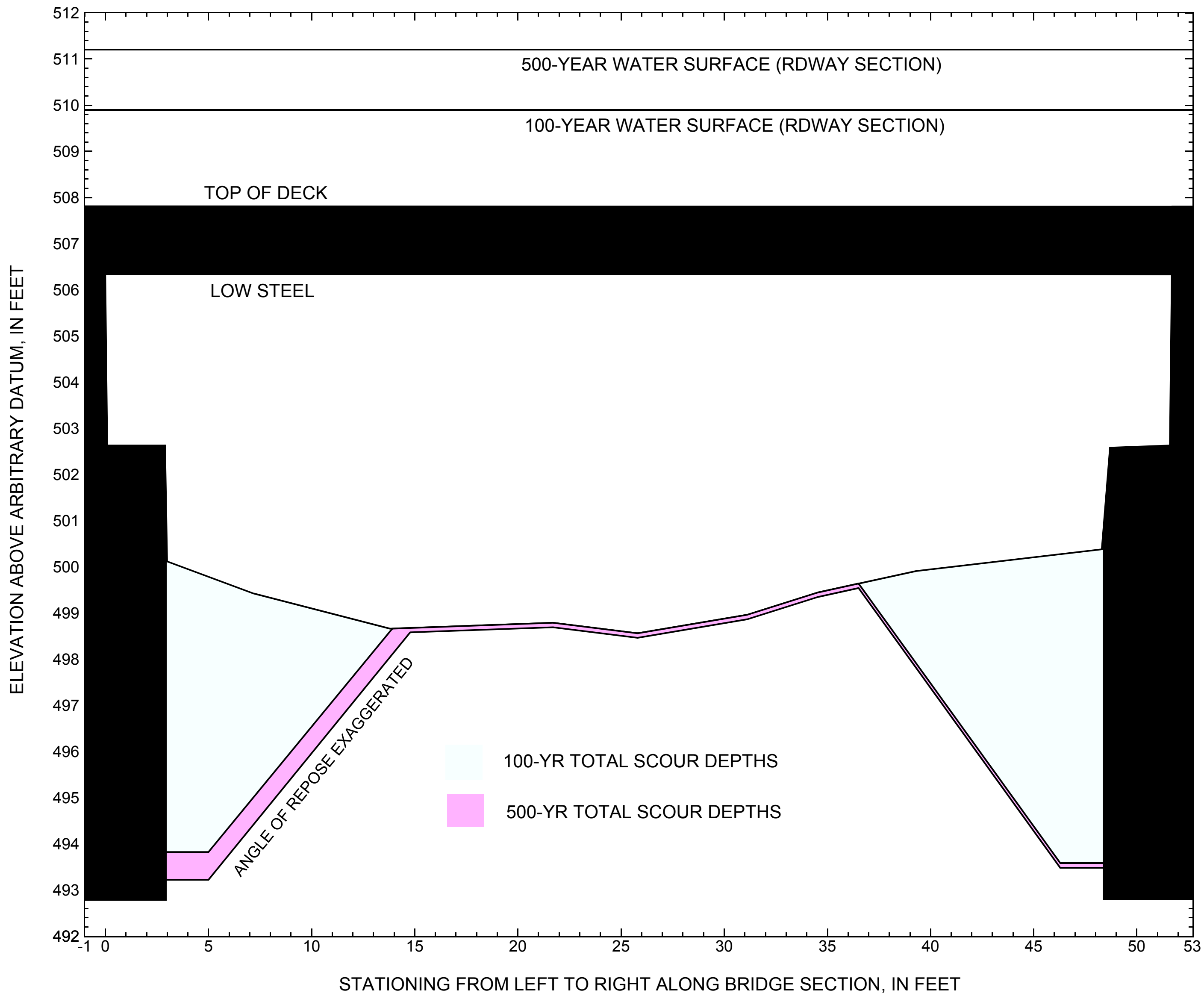

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BENNUS00070010 on U.S. Route 7, crossing the Walloomsac River, Bennington, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BENNUS00070010 on U.S. Route 7, crossing the Walloomsac River, Bennington, Vermont.
[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT bridge seat 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 4,900 cubic-feet per second											
Left abutment	0.0	96.9	506.3	492.8	500.1	0.0	6.3	--	6.3	493.8	1.0
Right abutment	51.7	96.8	506.3	492.8	500.4	0.0	6.8	--	6.8	493.6	0.8

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 BENNUS00070010 on U.S. Route 7, crossing the Walloomsac River, Bennington, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT bridge seat 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 7,570 cubic-feet per second											
Left abutment	0.0	96.9	506.3	492.8	500.1	0.1	6.8	--	6.9	493.2	0.4
Right abutment	51.7	96.8	506.3	492.8	500.4	0.1	6.8	--	6.9	493.5	0.7

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, 1954, Pownal, 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

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T1        U.S. Geological Survey WSPRO Input File benn010.wsp
T2        Hydraulic analysis for structure BENNUS00070010   Date: 16-OCT-96
T3        Bridge # 10 over the Walloomsac River in Bennington, VT  by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           4900 7570 1760
WS          504.67 506.88 497.75
*
XS   APDEP    -381
GR          -31.2, 510.00    -31.2, 501.40    -13.8, 501.40      0.0, 494.29
GR            6.6, 492.96     12.0, 491.59     16.2, 491.11     20.3, 491.04
GR           23.9, 491.39     25.5, 493.12     35.1, 499.90     60.1, 501.80
GR           60.1, 510.00
N           0.045        0.050        0.035
SA                 -13.8         35.1
*
XS   XSEC2    -214
GR          -13.8, 515.00    -13.8, 501.40     -5.0, 497.92      0.0, 496.29
GR            5.6, 495.56     18.8, 494.93     24.9, 494.76     28.2, 495.48
GR           31.5, 495.96     32.3, 500.39     60.1, 501.80     60.1, 515.00
N           0.045        0.050        0.035
SA                 -13.8         32.3
*
XS   EXITX    -87
GR            0.0, 515.00      0.0, 502.28      0.7, 498.82      4.0, 497.89
GR            5.8, 497.08     12.7, 496.46     16.8, 496.39     26.4, 496.98
GR           26.7, 497.87     31.6, 498.76     33.3, 503.03     42.8, 503.95
GR          143.4, 504.00    358.3, 515.00
N               0.045              0.035
SA                      33.3
*
XS   FULLV     0 * * * 0.025
*
BR   BRIDG     0 506.3
GR            8.0, 506.33      8.0, 499.33     13.8, 498.66     21.7, 498.79
GR           25.8, 498.56     31.1, 498.96     34.5, 499.44     39.3, 499.91
GR           43.8, 500.15     43.8, 506.33      8.0, 506.33
N            0.045
CD           1 50
*
*            The following is the actual surveyed bridge section (skew=10)
*            The ends of the section were truncated because the bridge
*            was wider than the main channel of both the approach and
*            the exit.
*
*             0.0, 506.33      0.0, 502.63      3.0, 500.12      7.2, 499.42
*            13.8, 498.66     21.7, 498.79     25.8, 498.56     31.1, 498.96
*            34.5, 499.44     39.3, 499.91     48.3, 500.38     48.7, 502.58
*            51.6, 502.63     51.7, 506.33      0.0, 506.33
*
XR   RDWAY     26 50
GR          -76.0, 520.00    -76.0, 507.07    -40.4, 507.07      0.0, 507.83
GR            1.4, 508.16      2.9, 511.79     27.3, 511.96     50.6, 511.72
GR           52.0, 507.75     52.4, 508.04     74.9, 507.05    143.4, 508.09
GR          143.4, 520.00
*
*
XT   APTEM    105
GR          -76.0, 520.00    -76.0, 506.06     -4.2, 506.02
GR            0.0, 505.45     10.2, 501.50     12.3, 500.93     17.5, 500.63
GR           22.1, 500.32     29.1, 499.83     35.7, 499.92     35.8, 507.14
GR          143.4, 508.09    143.4, 520.00
*
AS   APPRO     86 * * * 0.012
GT
N              0.060        0.045            0.050
SA                   0.0              35.8
*
HP 1 BRIDG    506.33 1 506.33
HP 2 BRIDG    506.33 * * 2271
HP 2 RDWAY    509.89 * * 2712
HP 1 APPRO    509.95 1 509.95
HP 2 APPRO    509.95 * * 4900
*
HP 1 BRIDG    506.33 1 506.33
HP 2 BRIDG    506.33 * * 2547
HP 2 RDWAY    511.23 * * 5158
HP 1 APPRO    511.45 1 511.45
HP 2 APPRO    511.45 * * 7570
*
HP 1 BRIDG    506.30 1 506.30
HP 2 BRIDG    506.30 * * 1760
HP 1 BRIDG    503.99 1 503.99
HP 1 APPRO    507.23 1 507.23
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File benn010.wsp
        Hydraulic analysis for structure BENNUS00070010   Date: 16-OCT-96
        Bridge # 10 over the Walloomsac River in Bennington, VT  by MAI

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     259.   17999.     0.    85.                          0.
   506.33          259.   17999.     0.    85.  1.00     8.    44.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       506.33     8.0    43.8   258.7  17999.    2271.   8.78
 X STA.         8.0        10.8        12.7        14.3        15.9        17.4
   A(I)             20.4        13.5        12.4        12.1        11.6
   V(I)             5.56        8.40        9.13        9.38        9.77

 X STA.        17.4        18.9        20.4        22.0        23.5        25.0
   A(I)             11.7        11.4        11.7        11.3        11.4
   V(I)             9.74        9.97        9.70       10.09        9.98

 X STA.        25.0        26.4        27.9        29.5        31.0        32.7
   A(I)             11.4        11.3        11.7        11.9        11.8
   V(I)             9.93       10.04        9.72        9.58        9.60

 X STA.        32.7        34.5        36.3        38.4        40.6        43.8
   A(I)             12.5        12.7        13.5        14.1        20.3
   V(I)             9.08        8.95        8.41        8.06        5.59

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = RDWAY;  SRD =      26.
         WSEL     LEW     REW    AREA        K        Q    VEL
       509.89   -76.0   143.4   415.5  27714.    2712.   6.53
 X STA.       -76.0       -67.0       -59.5       -52.1       -44.6       -36.9
   A(I)             25.5        20.9        21.1        21.1        21.4
   V(I)             5.32        6.48        6.42        6.42        6.33

 X STA.       -36.9       -28.8       -19.8        -9.4        54.9        64.1
   A(I)             21.7        22.8        24.1        30.0        19.9
   V(I)             6.26        5.93        5.63        4.52        6.82

 X STA.        64.1        71.3        77.3        83.4        89.9        96.8
   A(I)             18.1        16.6        17.1        17.1        17.6
   V(I)             7.48        8.18        7.95        7.91        7.69

 X STA.        96.8       104.3       112.2       121.1       131.0       143.4
   A(I)             18.5        18.4        19.6        20.5        23.5
   V(I)             7.34        7.37        6.91        6.62        5.78

    CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = APPRO;  SRD =      86.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     316.   19560.    76.    80.                       3652.
             2     320.   39929.    36.    44.                       5431.
             3     276.   15195.   108.   110.                       2505.
   509.95          912.   74683.   219.   234.  1.48   -76.   143.   8664.

    VELOCITY DISTRIBUTION:  ISEQ =  7;  SECID = APPRO;  SRD =      86.
         WSEL     LEW     REW    AREA        K        Q    VEL
       509.95   -76.0   143.4   911.6  74683.    4900.   5.37

 X STA.       -76.0       -59.5       -45.0       -31.2       -17.0        -2.8
   A(I)             68.1        60.0        57.0        58.9        59.1
   V(I)             3.60        4.08        4.30        4.16        4.14

 X STA.        -2.8         5.1         9.2        12.4        15.2        18.0
   A(I)             41.6        31.3        27.6        26.9        25.7
   V(I)             5.89        7.82        8.87        9.12        9.55

 X STA.        18.0        20.6        23.3        25.8        28.4        31.2
   A(I)             25.6        26.1        26.0        26.3        28.9
   V(I)             9.55        9.38        9.43        9.31        8.47

 X STA.        31.2        34.7        58.0        82.0       109.1       143.4
   A(I)             35.7        76.3        65.7        67.9        76.8
   V(I)             6.87        3.21        3.73        3.61        3.19
```

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        U.S. Geological Survey WSPRO Input File benn010.wsp
        Hydraulic analysis for structure BENNUS00070010   Date: 16-OCT-96
        Bridge # 10 over the Walloomsac River in Bennington, VT  by MAI

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     259.  17999.     0.    85.                            0.
   506.33          259.  17999.     0.    85.  1.00     8.    44.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       506.33     8.0    43.8   258.7   17999.    2547.   9.85
 X STA.         8.0        10.8        12.7        14.3        15.9        17.4
  A(I)             20.4        13.5        12.4        12.1        11.6
  V(I)             6.24        9.42       10.24       10.52       10.96

 X STA.        17.4        18.9        20.4        22.0        23.5        25.0
  A(I)             11.7        11.4        11.7        11.3        11.4
  V(I)            10.93       11.18       10.87       11.32       11.20

 X STA.        25.0        26.4        27.9        29.5        31.0        32.7
  A(I)             11.4        11.3        11.7        11.9        11.8
  V(I)            11.14       11.26       10.91       10.74       10.77

 X STA.        32.7        34.5        36.3        38.4        40.6        43.8
  A(I)             12.5        12.7        13.5        14.1        20.3
  V(I)            10.18       10.04        9.43        9.04        6.27

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = RDWAY;  SRD =      26.
         WSEL     LEW     REW    AREA        K        Q    VEL
       511.23   -76.0   143.4   644.4   56601.    5158.   8.00
 X STA.       -76.0       -66.0       -57.8       -49.8       -41.6       -33.6
  A(I)             41.6        34.3        33.2        33.9        32.8
  V(I)             6.21        7.51        7.77        7.61        7.86

 X STA.       -33.6       -24.9       -15.5        -5.1        58.0        66.1
  A(I)             34.6        35.6        37.2        46.1        29.1
  V(I)             7.45        7.25        6.93        5.59        8.85

 X STA.        66.1        72.9        79.3        85.8        92.6        99.7
  A(I)             26.9        26.6        26.3        27.1        27.4
  V(I)             9.58        9.70        9.81        9.50        9.42

 X STA.        99.7       107.1       114.9       123.2       132.2       143.4
  A(I)             27.6        28.4        29.0        30.6        36.1
  V(I)             9.33        9.07        8.90        8.44        7.15

    CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = APPRO;  SRD =      86.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     430.   32292.    76.    82.                        5799.
             2     374.   51706.    36.    44.                        6854.
             3     437.   32454.   108.   111.                        5000.
   511.45         1241.  116452.   219.   237.  1.32   -76.   143.  14592.

    VELOCITY DISTRIBUTION:  ISEQ =  7;  SECID = APPRO;  SRD =      86.
         WSEL     LEW     REW    AREA        K        Q    VEL
       511.45   -76.0   143.4  1240.7  116452.    7570.   6.10
 X STA.       -76.0       -59.6       -46.4       -33.1       -20.0        -6.9
  A(I)             91.9        74.5        75.1        73.7        74.4
  V(I)             4.12        5.08        5.04        5.13        5.09

 X STA.        -6.9         3.5         8.6        12.5        15.9        19.1
  A(I)             64.2        44.0        39.5        36.7        36.2
  V(I)             5.90        8.60        9.58       10.32       10.46

 X STA.        19.1        22.4        25.6        28.8        32.3        45.0
  A(I)             36.5        37.2        37.1        41.3        82.6
  V(I)            10.36       10.16       10.20        9.17        4.58

 X STA.        45.0        61.6        79.5        98.8       119.1       143.4
  A(I)             72.7        75.9        78.5        79.1        89.7
  V(I)             5.21        4.99        4.82        4.79        4.22
```

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        U.S. Geological Survey WSPRO Input File benn010.wsp
        Hydraulic analysis for structure BENNUS00070010   Date: 16-OCT-96
        Bridge # 10 over the Walloomsac River in Bennington, VT  by MAI

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1     258.   25771.   36.    49.                       3921.
   506.30          258.   25771.   36.    49.  1.00     8.    44.   3921.

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1     175.   14438.   36.    44.                       2194.
   503.99          175.   14438.   36.    44.  1.00     8.    44.   2194.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       506.30     8.0    43.8   257.6   25771.    1760.   6.83
 X STA.        8.0       11.3       13.2       14.9       16.4       17.9
   A(I)            23.4       14.5       12.7       11.5       11.6
   V(I)            3.76       6.07       6.92       7.64       7.60

 X STA.       17.9       19.4       20.8       22.3       23.7       25.1
   A(I)            11.0       11.1       10.7       10.7       10.8
   V(I)            8.01       7.94       8.23       8.26       8.17

 X STA.       25.1       26.4       27.9       29.3       30.8       32.4
   A(I)            10.6       10.8       11.0       10.9       11.4
   V(I)            8.32       8.15       8.01       8.05       7.73

 X STA.       32.4       34.0       35.9       37.8       40.1       43.8
   A(I)            11.8       12.3       13.2       14.7       22.8
   V(I)            7.43       7.13       6.65       5.97       3.85

    CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = APPRO;  SRD =      86.
     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1     109.    3402.   76.    77.                        741.
             2     223.   21814.   36.    44.                       3152.
             3       6.      50.   36.    36.                         13.
   507.23          337.   25266.  148.   157.  1.50   -76.    72.   2362.

    VELOCITY DISTRIBUTION:  ISEQ =  7;  SECID = APPRO;  SRD =      86.
        WSEL     LEW     REW    AREA        K        Q    VEL
       507.23   -76.0    71.8   337.5   25266.    1760.   5.22
 X STA.      -76.0      -46.4      -18.0        2.9        7.1        9.8
   A(I)            41.6       40.5       34.4       16.7       14.0
   V(I)            2.12       2.17       2.56       5.25       6.29

 X STA.        9.8       11.9       13.6       15.3       17.0       18.6
   A(I)            12.7       11.6       11.4       11.1       11.2
   V(I)            6.94       7.60       7.70       7.95       7.84

 X STA.       18.6       20.2       21.7       23.2       24.8       26.3
   A(I)            10.8       10.9       10.8       11.2       11.0
   V(I)            8.18       8.05       8.13       7.88       8.00

 X STA.       26.3       27.8       29.3       30.9       32.8       71.8
   A(I)            11.2       11.7       12.4       13.8       28.4
   V(I)            7.85       7.52       7.07       6.37       3.10
```

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        U.S. Geological Survey WSPRO Input File benn010.wsp
        Hydraulic analysis for structure BENNUS00070010   Date: 16-OCT-96
        Bridge # 10 over the Walloomsac River in Bennington, VT  by MAI

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

 APDEP:XS   ******   -31.     645.  0.97 *****  505.64  502.14   4900.  504.67
      -381. ******    60.   77050.  1.08 ***** *******    0.52    7.60

 XSEC2:XS     167.   -14.     529.  1.35  0.85  506.67 *******   4900.  505.33
      -214.   167.    60.   61534.  1.01  0.19    0.00    0.61    9.26

  ===125 FR# EXCEEDS FNTEST AT SECID "EXITX":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.84    506.38     506.16
  ===110 WSEL NOT FOUND AT SECID "EXITX":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   504.83     515.00    0.50
  ===115 WSEL NOT FOUND AT SECID "EXITX":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   504.83     515.00     506.16

 EXITX:XS     127.     0.     614.  1.21  0.87  507.54  506.16   4900.  506.33
       -87.   127.   189.   56652.  1.22  0.00   -0.01    0.86    7.99

  ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   505.83     517.17    0.50
  ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   505.83     517.17     508.34
  ===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 =   508.34     517.17     508.34

 FULLV:FV      87.     0.     582.  1.36 *****  509.70  508.34   4900.  508.34
         0.    87.   186.   53070.  1.24 ***** *******    0.93    8.41

 APPRO:AS      86.   -76.     787.  0.95  0.64  510.33 *******   4900.  509.38
        86.    86.   143.   61240.  1.57  0.00   -0.01    0.73    6.22
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   508.34     506.30

            <<<<<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      87.     8.     259.  1.20 *****  507.53  504.10   2271.  506.33
         0. ******    44.   17999.  1.00 ***** *******    0.58    8.78

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  506.30 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      26.    36.  0.16  0.67  510.46    0.02   2712.  509.89

               Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1338.    78.   -76.     2.   2.8   2.6   8.1   6.6   3.2   3.1
   RT:   1374.    92.    51.   143.   2.8   2.3   7.8   6.4   2.9   3.0

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

 APPRO:AS      36.   -76.     911.  0.67  0.40  510.61  508.89   4900.  509.95
        86.    43.   143.   74590.  1.48  0.00    0.02    0.57    5.38

                       <<<<<END OF BRIDGE COMPUTATIONS>>>>>
   FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q         K      AREA     VEL   WSEL
   APDEP:XS    -381.   -31.    60.   4900.   77050.      645.    7.60  504.67
   XSEC2:XS    -214.   -14.    60.   4900.   61534.      529.    9.26  505.33
   EXITX:XS     -87.     0.   189.   4900.   56652.      614.    7.99  506.33
   FULLV:FV       0.     0.   186.   4900.   53070.      582.    8.41  508.34
   BRIDG:BR       0.     8.    44.   2271.   17999.      259.    8.78  506.33
   RDWAY:RG      26.******* 1338.   2712.******************    1.00  509.89
   APPRO:AS      86.   -76.   143.   4900.   74590.      911.    5.38  509.95

  SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   APDEP:XS    502.14    0.52  491.04  510.00************  0.97  505.64  504.67
   XSEC2:XS  ********    0.61  494.76  515.00  0.85  0.19  1.35  506.67  505.33
   EXITX:XS    506.16    0.86  496.39  515.00  0.87  0.00  1.21  507.54  506.33
   FULLV:FV    508.34    0.93  498.57  517.17************  1.36  509.70  508.34
   BRIDG:BR    504.10    0.58  498.56  506.33************  1.20  507.53  506.33
   RDWAY:RG  ****************  507.05  520.00  0.16******  0.67  510.46  509.89
   APPRO:AS    508.89    0.57  499.60  519.77  0.40  0.00  0.67  510.61  509.95
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File benn010.wsp
        Hydraulic analysis for structure BENNUS00070010   Date: 16-OCT-96
        Bridge # 10 over the Walloomsac River in Bennington, VT  by MAI

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

 APDEP:XS   ******   -31.     847.  1.32 *****  508.20  503.85   7570.  506.88
      -381. ******    60.  116202.  1.06 ***** *******    0.53    8.94

 XSEC2:XS     167.   -14.     688.  1.89  0.88  509.36 *******   7570.  507.47
      -214.   167.    60.   93730.  1.00  0.28    0.00    0.64   11.00

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "EXITX"     KRATIO =  1.57

 EXITX:XS     127.     0.    1260.  0.58  0.53  509.88 *******   7570.  509.30
       -87.   127.   247.  147475.  1.04  0.00   -0.01    0.48    6.01

  ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.04     509.08     509.33
  ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   508.80     517.17    0.50
  ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   508.80     517.17     509.33
  ===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 =   509.33     517.17     509.33

 FULLV:FV      87.     0.     777.  1.68 *****  511.01  509.33   7570.  509.33
         0.    87.   205.   76767.  1.14 ***** *******    0.94    9.75
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPRO:AS      86.   -76.    1051.  1.13  0.70  511.71 *******   7570.  510.58
        86.    86.   143.   91312.  1.40  0.00    0.00    0.69    7.20
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   509.33     506.30

             <<<<<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      87.     8.     259.  1.51 *****  507.84  504.50   2547.  506.33
         0. ******    44.   17999.  1.00 ***** *******    0.65    9.85

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  506.30 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF    VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      26.    36.  0.15  0.76  512.06    0.02   5158.  511.23

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
    LT:   2482.    79.   -76.     3.   4.2   3.9  10.0   8.1   4.7   3.1
    RT:   2676.    93.    51.   143.   4.2   3.6   9.7   7.9   4.5   3.1

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

 APPRO:AS      36.   -76.    1241.  0.76  0.53  512.21  509.85   7570.  511.45
        86.    45.   143.  116545.  1.32  0.00    0.02    0.52    6.10

                      <<<<<END OF BRIDGE COMPUTATIONS>>>>>
   FIRST USER DEFINED TABLE.
     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
    APDEP:XS    -381.   -31.    60.   7570.  116202.     847.    8.94  506.88
    XSEC2:XS    -214.   -14.    60.   7570.   93730.     688.   11.00  507.47
    EXITX:XS     -87.     0.   247.   7570.  147475.    1260.    6.01  509.30
    FULLV:FV       0.     0.   205.   7570.   76767.     777.    9.75  509.33
    BRIDG:BR       0.     8.    44.   2547.   17999.     259.    9.85  506.33
    RDWAY:RG      26.******* 2482.   5158.******************    1.00  511.23
    APPRO:AS      86.   -76.   143.   7570.  116545.    1241.    6.10  511.45

  SECOND USER DEFINED TABLE.
     XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
    APDEP:XS    503.85    0.53  491.04  510.00************  1.32  508.20  506.88
    XSEC2:XS  ********    0.64  494.76  515.00  0.88  0.28  1.89  509.36  507.47
    EXITX:XS  ********    0.48  496.39  515.00  0.53  0.00  0.58  509.88  509.30
    FULLV:FV    509.33    0.94  498.57  517.17************  1.68  511.01  509.33
    BRIDG:BR    504.50    0.65  498.56  506.33************  1.51  507.84  506.33
    RDWAY:RG  ****************  507.05  520.00  0.15******  0.76  512.06  511.23
    APPRO:AS    509.85    0.52  499.60  519.77  0.53  0.00  0.76  512.21  511.45
```
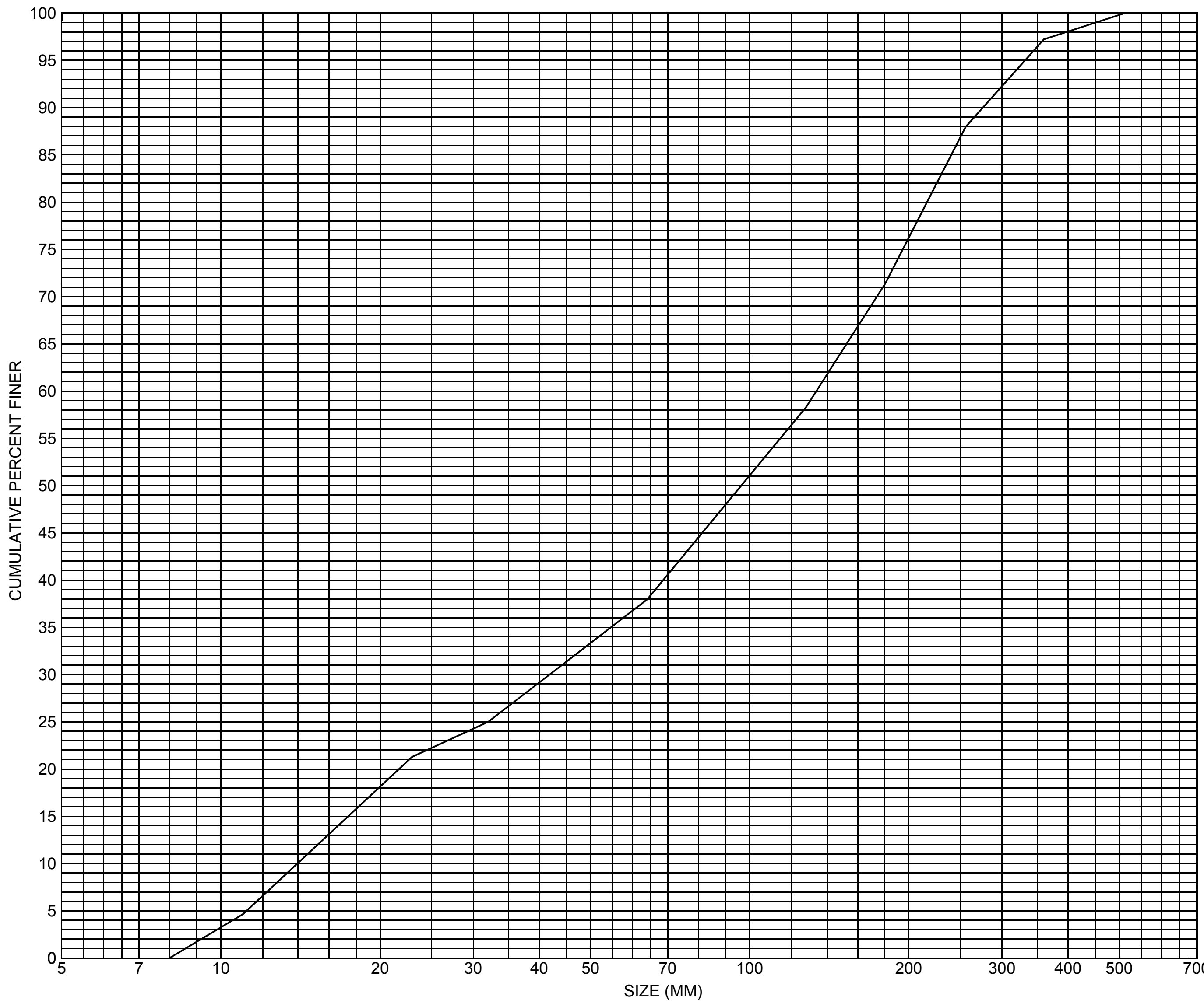

```
        U.S. Geological Survey WSPRO Input File benn010.wsp
        Hydraulic analysis for structure BENNUS00070010   Date: 16-OCT-96
        Bridge # 10 over the Walloomsac River in Bennington, VT  by MAI
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD  FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APDEP:XS   ******    -7.     170.  1.66 *****  499.41  497.30   1760.  497.75
     -381. ******    32.   12848.  1.00 ***** *******    0.87   10.34
XSEC2:XS     167.   -12.     207.  1.14  2.55  501.97 *******   1760.  500.83
     -214.   167.    41.   15817.  1.01  0.00    0.01    0.77    8.50
  ===125 FR# EXCEEDS FNTEST AT SECID "EXITX":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.86     502.29     501.82
  ===110 WSEL NOT FOUND AT SECID "EXITX":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   500.33     515.00    0.50
  ===115 WSEL NOT FOUND AT SECID "EXITX":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =    500.33     515.00     501.82
EXITX:XS     127.     0.     162.  1.83  1.80  504.12  501.82   1760.  502.29
      -87.   127.    33.   13812.  1.00  0.35    0.00    0.86   10.85
  ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.09     503.74     503.99
  ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   501.79     517.17    0.50
  ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =    501.79     517.17     503.99
  ===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 =    503.99     517.17     503.99
FULLV:FV      87.     0.     147.  2.24 *****  506.23  503.99   1760.  503.99
        0.    87.    33.   11890.  1.00 ***** *******    1.00   12.00
  ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.08     506.32     505.23
  ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   503.49     519.77    0.50
  ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =    503.49     519.77     505.23
  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  1.47
APPRO:AS      86.   -76.     229.  1.20  1.28  507.51  505.23   1760.  506.31
       86.    86.    36.   17460.  1.31  0.00    0.00    1.09    7.70
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===230 REJECTED FLOW CLASS 1 SOLUTION.
              WS1,WSSD,WS3 =    505.23        0.00      504.42
                      CRWS =    505.23    ********      503.33
                      YMAX =    519.77    ********      506.33
  ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
  ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                   WS,QBO,QRD =    509.62          0.       1760.
  ===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      87.     8.     258.  0.70 *****  507.00  503.29   1733.  506.30
         0. ******    44.   25771.  1.00 ***** *******    0.44    6.73
      TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   2.  0.376  0.000  506.30 ****** ****** ******
     XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
    RDWAY:RG      26.        <<<<<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      36.   -76.     338.  0.63  0.18  507.87  505.23   1760.  507.23
        86.    37.    72.   25308.  1.50  0.00   -0.02    0.75    5.21
                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

   FIRST USER DEFINED TABLE.
     XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
    APDEP:XS    -381.    -7.    32.   1760.   12848.     170.   10.34  497.75
    XSEC2:XS    -214.   -12.    41.   1760.   15817.     207.    8.50  500.83
    EXITX:XS     -87.     0.    33.   1760.   13812.     162.   10.85  502.29
    FULLV:FV       0.     0.    33.   1760.   11890.     147.   12.00  503.99
    BRIDG:BR       0.     8.    44.   1733.   25771.     258.    6.73  506.30
    RDWAY:RG      26.**************      0.       0.       0.    1.00********
    APPRO:AS      86.   -76.    72.   1760.   25308.     338.    5.21  507.23

  SECOND USER DEFINED TABLE.
     XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
    APDEP:XS    497.30    0.87  491.04  510.00************  1.66  499.41  497.75
    XSEC2:XS  ********    0.77  494.76  515.00  2.55  0.00  1.14  501.97  500.83
    EXITX:XS    501.82    0.86  496.39  515.00  1.80  0.35  1.83  504.12  502.29
    FULLV:FV    503.99    1.00  498.57  517.17************  2.24  506.23  503.99
    BRIDG:BR    503.29    0.44  498.56  506.33************  0.70  507.00  506.30
    RDWAY:RG ***************  507.05  520.00************  0.63  507.69********
    APPRO:AS    505.23    0.75  499.60  519.77  0.18  0.00  0.63  507.87  507.23
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BENNUS00070010, in Bennington, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BENNUS00070010

General Location Descriptive

Data collected by *(First Initial, Full last name)* L. . Medalie

Date *(MM/DD/YY)* 09 / 27 / 95

Highway District Number *(I - 2; nn)* 00

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

Town *(FIPS place code; I - 4; nnnnn)* 04750

Mile marker *(I - 11; nnn.nnn)* 003150

Waterway *(I - 6)* WALLOOMSAC RIVER

Road Name *(I - 7)*: US 00007 RAMP

Route Number -

Vicinity *(I - 9)* 0.2 MI N JCT. VT.9

Topographic Map Bennington

Hydrologic Unit Code: 02020003

Latitude *(I - 16; nnnn.n)* 42529

Longitude *(i - 17; nnnnn.n)* 73118

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20100000100202

Maintenance responsibility *(I - 21; nn)* 04

Maximum span length *(I - 48; nnnn)* 0050

Year built *(I - 27; YYYY)* 1936

Structure length *(I - 49; nnnnnn)* 000053

Average daily traffic, ADT *(I - 29; nnnnnn)* 009980

Deck Width *(I - 52; nn.n)* 500

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

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

Opening skew to Roadway *(I - 34; nn)* 10

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

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

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

Structure type *(I - 43; nnn)* 303

Year Reconstructed *(I - 106)* 0000

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

Clear span *(nnn.n ft)* 46

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

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

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

Waterway of full opening *(nnn.n ft²)* -

Comments:

According to the structural inspection report dated 8/23/93, the structure is a single span side girder bridge. Channel alignment is straight through the structure. The right abutment has leakage at the top, with areas of cracking, staining, and scaling. Upstream and downstream right wingwalls are in fair condition with minor cracking and scaling. The condition of the left abutment similar to the right. The upstream left wingwall meets a concrete retaining wall which continues upstream. Some scour is noted at the junction of this wingwall and retaining wall. There is some spalling at the bottom of the retaining wall. Considerable debris is noted in the channel. According to the report, the structure is in poor condition.

(Continued on page 33)

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -
-

Streambed material: -

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -
-

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

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

Are there other structures nearby? (*Yes, No, Unknown*): - *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:

Notes on the bridge plans show a maximum high water elevation of 100.35 feet. Stream bed material consists of heavy boulders and cobblestones. Velocity of stream flow is swift during high water events. Not very much drift.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **30.1** mi^2

Lake and pond area **0.714** mi^2

Watershed storage *(ST)* **2.37** %

Bridge site elevation **670** ft

Headwater elevation **2900** ft

Main channel length **9.87** mi

10% channel length elevation **740** ft

85% channel length elevation **1400** ft

Main channel slope *(S)* **89.15** 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):* **-** / **1936**

Project Number **WPMH 73-D** Minimum channel bed elevation: **-**

Low superstructure elevation: USLAB **96.85** DSLAB **96.85** USRAB **96.82** DSRAB **96.77**

Benchmark location description:

BM 1 elev. 100', at 48" elm, near US side of road about 250' right of bridge.

BM 2 elev. 100.85 at streamward and road-side of Taylor's garage (DS left bank).

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

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

If 1: Footing Thickness **2** Footing bottom elevation: **86.86**

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

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

Briefly describe material at foundation bottom elevation or around piles:

Note on plans: foundation heavy boulders and cobble stones. It was impossible to bore through or around with auger or wash boring equipment

Comments:

Footing bottom elevation given above for the right abutment. Footing bottom elevation for the left abutment is 86.89 feet. Low superstructure elevations noted above are bridge seat elevations.

Cross-sectional Data

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

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

Comments:

Station	1149	1151	1182	1191	1194	1199	1201	-	-	-	-
Feature	LAB	-	-	-	-	-	RAB	-	-	-	-
Low cord elevation	674.4	674.4	674.4	674.4	674.4	674.4	674.4	-	-	-	-
Bed elevation	-	671.0	669.9	670.1	671.1	672.0	-	-	-	-	-
Low cord to bed length	-	3.4	4.5	4.3	3.3	2.4		-	-	-	-

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

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

Comments: -

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 9/13/96
Computerized by: EW Date: 9/13/96
Reviewd by: SAO Date: 4/4/97

Structure Number BENNUS00070010

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. BURNS Date *(MM/DD/YY)* 08 / 05 / 1996

2. Highway District Number 01 Mile marker 003150

County BENNINGTON (003) Town BENNINGTON (04750)

Waterway *(I - 6)* WALLOOMSAC RIVER Road Name US 007 RAMP

Route Number US 7 Hydrologic Unit Code: 02020003

3. Descriptive comments:
LOCATED 0.2 MILES NORTH OF JUNCTION WITH VT 9. THIS IS A SIDE GIRDER BRIDGE.

B. Bridge Deck Observations

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

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

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

7. Bridge length 53 *(feet)* Span length 50 *(feet)* Bridge width 50 *(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)*

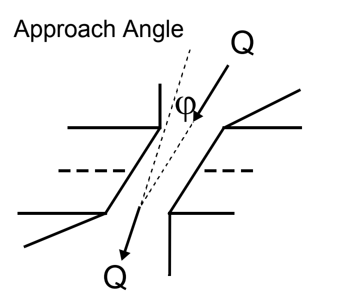
10. Embankment slope (*run / rise in feet / foot*):
US left N/A US right N/A

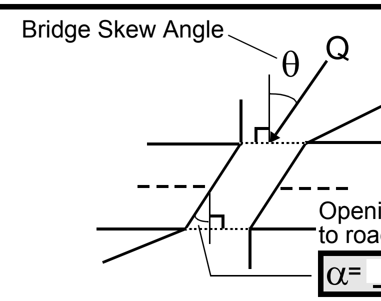
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: 10 16. Bridge skew: 5





Opening skew to roadway α= 10.0

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

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

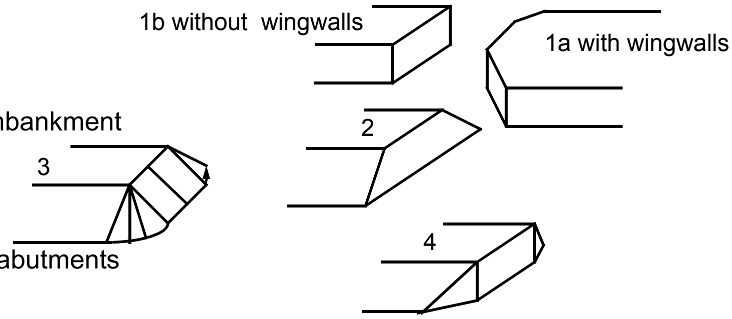
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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.)

#4: There is lawn on the LBUS and LBDS. On the RBUS, there is a playground. The RBDS has a large paved parking lot.

#7: Measured bridge opening = 51.7 feet; bridge length = 55 feet.

#18: There is a gap between the bridge rail and the roadway for the sidewalks on both the upstream and downstream sides. The inside bridge rails are solid steel, while the outside rails are bars.

The wingwalls are angled towards the stream, instead of back toward the road.

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
56.0	4.5			5.5	1	1	7	7	0	0

23. Bank width 15.0 24. Channel width 80.0 25. Thalweg depth 40.0 29. Bed Material 43

30 .Bank protection type: LB 5 RB 5 31. Bank protection condition: LB 1 RB 1

SRD - Section ref. dist. to US face *% Vegetation (Veg) cover:* ***1****- 0 to 25%;* ***2****- 26 to 50%;* ***3****- 51 to 75%;* ***4****- 76 to 100%*

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

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

Bank protection types: ***0****- absent;* ***1****- < 12 inches;* ***2****- < 36 inches;* ***3****- < 48 inches;* ***4****- < 60 inches;* ***5****- wall / artificial levee*

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

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

#27: The right bank has a concrete wall 7 feet tall.The thalweg runs along the wall.

The left bank has a series of wire baskets 2x2x6 feet, interconnected and filled with stone. The 6 ft dimension is parallel to the channel.

A culvert two feet in diameter enters the channel on the right bank 225 feet upstream. Also at this point the retaining wall ends and there is dumped stone.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 20 35. Mid-bar width: 4

36. Point bar extent: 45 feet US (US, UB) to 0 feet US (US, UB, DS) positioned 0 %LB to 15 %RB

37. Material: 42

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

In front of the wire rock cages, there is a sandy point bar that is vegetated with shrubs.

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

There is a large scour hole from 190 feet US to 135 feet US. It is two feet deep along the RB wall and is positioned from 20% LB to 100% RB.

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
25.5		1.5		2	7	7	-

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

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

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

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

453

The bridge is made of steel girders that run almost parallel to flow and are 2.5 feet high. There are six of them and the two on the outside are sitting on the bridge seat.

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

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

2

#66: There are some large logs under the bridge.

#67: Debris potential is considered moderate due to the urban setting.

#68: Capture efficiency and ice blockage potential is moderate because of low clearance and girders under

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	brid	ge.	5	90	1	0	-	90.0
RABUT	-	1	0			90	1	51.0

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

-

-

1

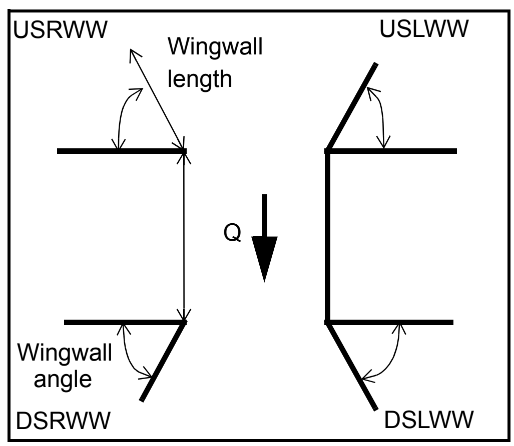
The concrete abutment walls are short. There is only about 2 to 3 feet exposed. The top of the abutment walls are the bridge seat and 3 feet bankward from the edge of the abutment is the back-wall. The back-wall is about 5 feet high to the top of the road.

#73: Toe location assessed as set back because the channel under the bridge is wider than the constructed channel US and DS.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						51.0	1.5
USRWW:			Y		1	51.5	
DSLWW:	0		-		-	51.5	
DSRWW:	Y		1		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	-	1	-	0	0	0	0	0
Condition	-	0	Y	-	-	-	-	-
Extent	Y	-	1	-	-	-	-	-

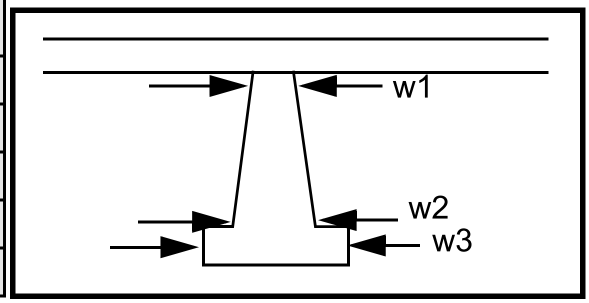
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

84. Are there piers? _-____ *(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	125.0			6.5	155.0	13.5
Pier 2				140.0	13.0	110.0
Pier 3		-	-	10.5	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	Ther	build	WW		*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	e is	-up	act		***1**- Solid pier, **2**- column, **3**- bent*
88. Material	no	of	like		***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	place	stone	pro-	N	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	d	s in	tec-	-	*Y- yes; N- no*
91. Attack ∠ (BF)	wing	front	tion.	-	
92. Pushed	wall	of		-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	pro-	the		-	
95. Cross-members	tec-	DSL		-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	tion,	WW		-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	but	and		-	
98. Exposure depth	the	DSR		-	

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

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	-	-	-	-	-

Bank width (BF) -_____ Channel width (Amb) -_____ Thalweg depth (Amb) -_____ 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):
-
-

NO PIERS

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 **1** *(US, UB, DS)* positioned **1** %LB to **7** %RB

Material: **7**

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

0
0
453
5

Is a cut-bank present? **5** *(Y or if N type ctrl-n cb)* Where? **1** *(LB or RB)* Mid-bank distance: **1**

Cut bank extent: **On** feet **the** *(US, UB, DS)* to **right** feet **ba** *(US, UB, DS)*

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

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

from the end of the wingwall to 40 feet downstream, the wall is stone masonry. From 40 to 60 feet downstream, the wall is concrete block masonry. From 60 feet downstream to the next bridge, the wall is made of laid-up stone.

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

Scour dimensions: Length **left** Width **bank** Depth: **,** Positioned **the** %LB to **re** %RB

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

is a concrete wall from the end of the wingwall to 25 feet downstream. From 25 to 40 ft downstream, a stone dry wall exists. There is a concrete faced laid-up stone wall from 40 feet downstream and continues along the entire length of the Bennington Brush Company building.

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

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

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

Confluence comments (eg. confluence name):

-
NO DROP STRUCTURE

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)*:

There is a strip of concrete, 2 feet wide and 1 foot high, under the bridge 20 feet from the upstream bridge face. This concrete is covering the water main which can be seen because part of the concrete has eroded away.

Y
10
15
25
UB
70
DS
65
100

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: BENNUS00070010 Town: Bennington
Road Number: US7 County: Bennington
Stream: Walloomsac River

Initials SAO Date: 4/4/97 Checked: EB

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	4900	7570	1760
Main Channel Area, ft2	320	374	223
Left overbank area, ft2	316	430	109
Right overbank area, ft2	276	437	6
Top width main channel, ft	36	36	36
Top width L overbank, ft	76	76	76
Top width R overbank, ft	108	108	36
D50 of channel, ft	0.315	0.315	0.315
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.9	10.4	6.2
y1, average depth, LOB, ft	4.2	5.7	1.4
y1, average depth, ROB, ft	2.6	4.0	0.2
Total conveyance, approach	74683	116452	25266
Conveyance, main channel	39929	51706	21814
Conveyance, LOB	19560	32292	3402
Conveyance, ROB	15195	32454	50
Percent discrepancy, conveyance	-0.0013	0.0000	0.0000
Qm, discharge, MC, cfs	2619.8	3361.2	1519.5
Ql, discharge, LOB, cfs	1283.3	2099.2	237.0
Qr, discharge, ROB, cfs	997.0	2109.7	3.5
Vm, mean velocity MC, ft/s	8.2	9.0	6.8
Vl, mean velocity, LOB, ft/s	4.1	4.9	2.2
Vr, mean velocity, ROB, ft/s	3.6	4.8	0.6
Vc-m, crit. velocity, MC, ft/s	11.0	11.3	10.3
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	2271	2547	1760
Main channel area (DS), ft2	259	259	175

Main channel width (normal), ft	35.8	35.8	35.8
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	35.8	35.8	35.8
D90, ft	0.9053	0.9053	0.9053
D95, ft	1.0883	1.0883	1.0883
Dc, critical grain size, ft	0.3696	0.4648	0.5813
Pc, Decimal percent coarser than Dc	0.454	0.378	0.293
Depth to armoring, ft	**1.34**	**2.29**	**4.21**

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	4900	7570	1760
(Q) discharge thru bridge, cfs	2271	2547	1760
Main channel conveyance	17999	17999	25771
Total conveyance	17999	17999	25771
Q2, bridge MC discharge,cfs	2271	2547	1760
Main channel area, ft2	259	259	258
Main channel width (normal), ft	35.8	35.8	35.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	35.8	35.8	35.8
y_bridge (avg. depth at br.), ft	7.23	7.23	7.21
Dm, median (1.25*D50), ft	0.39375	0.39375	0.39375
y2, depth in contraction,ft	5.66	6.25	4.55
ys, scour depth (y2-ybridge), ft	-1.57	-0.99	-2.65

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	4900	7570	1760
Q, thru bridge MC, cfs	2271	2547	1760
Vc, critical velocity, ft/s	10.98	11.27	10.34
Va, velocity MC approach, ft/s	8.19	8.99	6.81
Main channel width (normal), ft	35.8	35.8	35.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	35.8	35.8	35.8
qbr, unit discharge, ft2/s	63.4	71.1	49.2
Area of full opening, ft2	259.0	259.0	258.0
Hb, depth of full opening, ft	7.23	7.23	7.21
Fr, Froude number, bridge MC	0.58	0.65	0.44
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	N/A	N/A	175
**Hb, depth at downstream face, ft	N/A	N/A	4.89
**Fr, Froude number at DS face	ERR	ERR	0.80
**Cf, for downstream face (<=1.0)	N/A	N/A	1.00
Elevation of Low Steel, ft	506.33	506.33	506.33
Elevation of Bed, ft	499.10	499.10	499.12
Elevation of Approach, ft	509.95	511.45	507.23
Friction loss, approach, ft	0.4	0.53	0.18
Elevation of WS immediately US, ft	509.55	510.92	507.05
ya, depth immediately US, ft	10.45	11.82	7.93

Mean elevation of deck, ft	511.8	511.8	511.8
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.90	0.86	0.98
**Cc, for downstream face (<=1.0)	ERR	ERR	0.865288
Ys, scour w/Chang equation, ft	**-0.85**	**0.09**	**-2.34**
Ys, scour w/Umbrell equation, ft	2.42	4.14	-0.41

**=for UNsubmerged orifice flow using an estimate of downstream water surface

**Ys, scour w/Chang equation, ft	N/A	N/A	0.61
**Ys, scour w/Umbrell equation, ft	N/A	N/A	1.91

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

y2, from Laursen's equation, ft	5.66	6.25	4.55
WSEL at downstream face, ft	--	--	503.99
Depth at downstream face, ft	ERR	ERR	4.87
Ys, depth of scour (Laursen), ft	N/A	N/A	-0.31

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	4900	7570	1760	4900	7570	1760
a', abut.length blocking flow, ft	76	76	76	--	--	--
Ae, area of blocked flow ft2	116.3	125	111.7	--	--	--
Qe, discharge blocked abut.,cfs	--	--	251.8	--	--	--
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	4.13	4.96	2.25	--	--	--
ya, depth of f/p flow, ft	1.53	1.64	1.47	6.76	6.76	6.76
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	1	1	1
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	80	80	80	100	100	100
K2	0.98	0.98	0.98	1.01	1.01	1.01
Fr, froude number f/p flow	0.356	0.367	0.328	--	--	--
ys, scour depth, ft	11.30	12.01	10.55	**6.76**	**6.76**	**6.76**

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)	76	76	76	--	--	--
y1 (depth f/p flow, ft)	1.53	1.64	1.47	ERR	ERR	ERR
a'/y1	49.66	46.21	51.71	ERR	ERR	ERR
Skew correction (p. 49, fig. 16)	0.97	0.97	0.97	1.02	1.02	1.02
Froude no. f/p flow	0.36	0.37	0.33	--	--	--
Ys w/ corr. factor K1/0.55:						
vertical	7.65	8.31	7.15	ERR	ERR	ERR
vertical w/ ww's	**6.28**	**6.81**	**5.87**	ERR	ERR	ERR

spill-through	4.21	4.57	3.93	ERR	ERR	ERR

Abutment riprap Sizing

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

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number (DS)	0.58	0.65	0.8	0.58	0.65	0.8
y, depth of flow in bridge (DS), ft	7.23	7.23	4.89	7.23	7.23	4.89
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	**1.50**	**1.89**	**1.93**	**1.50**	**1.89**	**1.93**
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR