LEVEL II SCOUR ANALYSIS FOR BRIDGE 43 (BENNCYDEPO0043) on DEPOT STREET, crossing the WALLOOMSAC RIVER, BENNINGTON, VERMONT

U.S. Geological Survey
Open-File Report 97-346

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

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By SCOTT A. OLSON

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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 43 (BENNCYDEPO0043) ON DEPOT STREET, CROSSING THE WALLOOMSAC RIVER, BENNINGTON VERMONT

By **Scott A. Olson**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BENNCYDEPO0043 on the Depot 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 and parking lots on overbanks.

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 48 ft and an average bank height of 6 ft. The predominant channel bed material is cobble with a median grain size (D_{50}) of 108 mm (0.356 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 5, 1996, indicated that the reach was stable.

The Depot Street crossing of the Walloomsac River is a 46-ft-long, two-lane bridge consisting of one 40-foot concrete span (Vermont Agency of Transportation, written communication, December 13, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 5 degrees to the opening and the opening-skew-to-roadway is 15 degrees.

Scour countermeasures at the site include type-2 stone fill (less than 36 inches diameter) at the upstream end of the upstream right wing wall and type-1 stone fill (less than 12 inches diameter) along the base of the upstream left wing wall. Downstream banks are protected by concrete and stone walls. The upstream right bank is protected by alternating type-2 stone fill and masonry walls. 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 4.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Computed right abutment scour ranged from 2.9 to 13.4 ft. with the worst-case scour occurring at the 500-year discharge. Computed left abutment scour ranged from 5.6 to 16.3 ft. with the worst-case scour also occurring at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and 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 BENNCYDEPO0043 ***Stream*** Walloomsac River

County Bennington ***Road*** Depot St. ***District*** 1

Description of Bridge

Bridge length 46 ***ft*** ***Bridge width*** 44.3 ***ft*** ***Max span length*** 40 ***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 Type-1, along the upstream left wingwall. Type-2 at the upstream end of the upstream right wing wall. The upstream right bank is protected by alternating type-2 stone fill and masonry walls.

Abutments and wingwalls are concrete. The right abutment footing is undermined along its entire length by 0.2 vertical feet. Penetration under the footing is one horizontal foot.

N 5

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

There is a mild change in direction of the channel at the bridge. This bend results in an impact zone at the right abutment.

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 concrete 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 no valley and wide flood plains.

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: Steep channel bank to a wide flood plain.

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

Description of the Channel

Average top width 48 ***ft*** ***Average depth*** 6 ***ft***

Predominant bed material Cobbles ***Bank material*** Stone fill/walls

Straight, relatively stable and in an alluvial setting with channel boundaries of man-placed materials.

8/5/96

Vegetative co Grass, trees, and buildings on overbanks.

DS left: Grass, trees, and buildings on overbanks.

DS right: Grass, trees, and buildings on overbanks.

US left: Grass, trees, and buildings on overbanks.

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) and were within eight percent of discharges 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 None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the upstream left wing wall (elev. 500.24 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the downstream right wingwall (elev. 499.77 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	-37	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	23	1	Road Grade section
APPRO	87	1	Approach section

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

Data and Assumptions Used in WSPRO Model

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

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

Critical depth at the exit section (EXITX) was assumed as the starting water surface for the 100- and 500-year events. Normal depth at the exit section was assumed as the starting water surface of the incipient roadway-overtopping discharge. Normal depth at the exit section for all modelled discharges was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0218 ft/ft, which was the slope of the 100-year water-surface profile downstream of the bridge in the Flood Insurance Study for the Town of Bennington (Federal Emergency Management Agency, 1986). The resulting normal water-surface elevations for the 100- and 500-year discharges were within a foot below critical depth.

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, 3500 ft upstream and the vicinity of this bridge (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 499.9 ***ft***
Average low steel elevation 497.6 ***ft***

100-year discharge 4,900 ***ft^3/s***
Water-surface elevation in bridge opening 497.6 ***ft***
Road overtopping? Y ***Discharge over road*** 1,830 ***ft^3/s***
Area of flow in bridge opening 215 ***ft^2***
Average velocity in bridge opening 14.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 16.6 ***ft/s***

Water-surface elevation at Approach section with bridge 504.7
Water-surface elevation at Approach section without bridge 502.1
Amount of backwater caused by bridge 2.6 ***ft***

500-year discharge 7,570 ***ft^3/s***
Water-surface elevation in bridge opening 497.6 ***ft***
Road overtopping? Y ***Discharge over road*** 4,010 ***ft^3/s***
Area of flow in bridge opening 215 ***ft^2***
Average velocity in bridge opening 16.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 19.3 ***/s***

Water-surface elevation at Approach section with bridge 506.9
Water-surface elevation at Approach section without bridge 503.9
Amount of backwater caused by bridge 3.0

Incipient overtopping discharge 2,090 ***ft^3/s***
Water-surface elevation in bridge opening 497.6 ***ft***
Area of flow in bridge opening 215 ***ft^2***
Average velocity in bridge opening 9.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.3 ***ft/s***

Water-surface elevation at Approach section with bridge 500.3
Water-surface elevation at Approach section without bridge 499.1
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 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. The results of Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) were also computed and can be found in Appendix F.

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. Contration scour results with respect to these substitutions also are provided in Appendix F.

Abutment scour 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 depth of flow approaching the abutment. Since the abutments were nearly even with the channel banks, the depth of flow for the 100- and 500-year events was estimated as the roadway elevation minus the elevation of the abutment toe. This depth results in a factor of safety which adds 6.6 ft to the left abutment scour result and 8.7 feet to the right abutment scour.

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	3.0	4.1	0.0
Depth to armoring	N/A	N/A	5.7
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	12.8	13.4	2.9
Right abutment	16.2	16.3	5.6
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	2.3	2.3	2.0
Right abutment	2.3	2.3	2.0
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

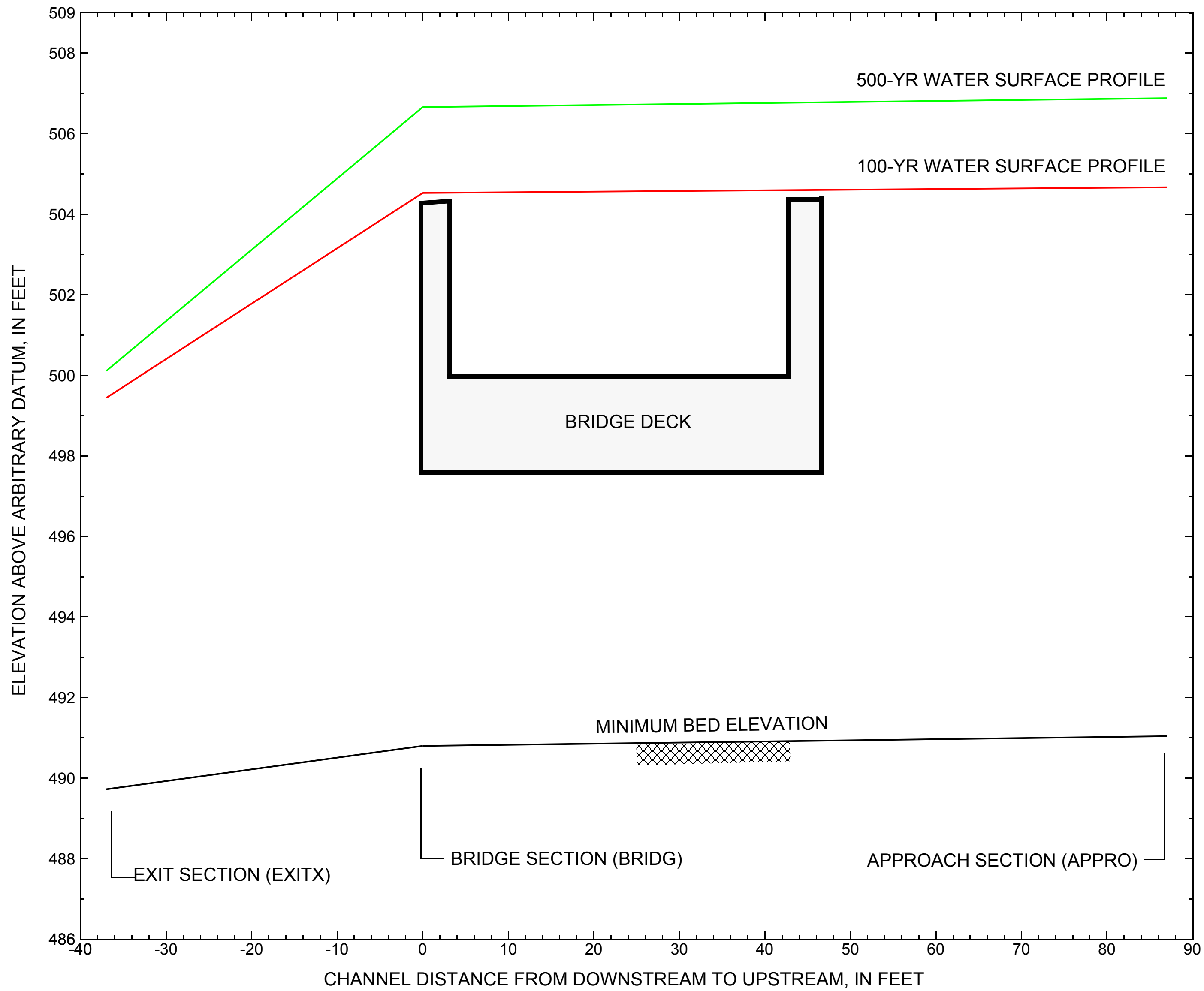

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BENNCYDEPO0043 on Depot Street, crossing the Walloomsac River, Bennington, Vermont.

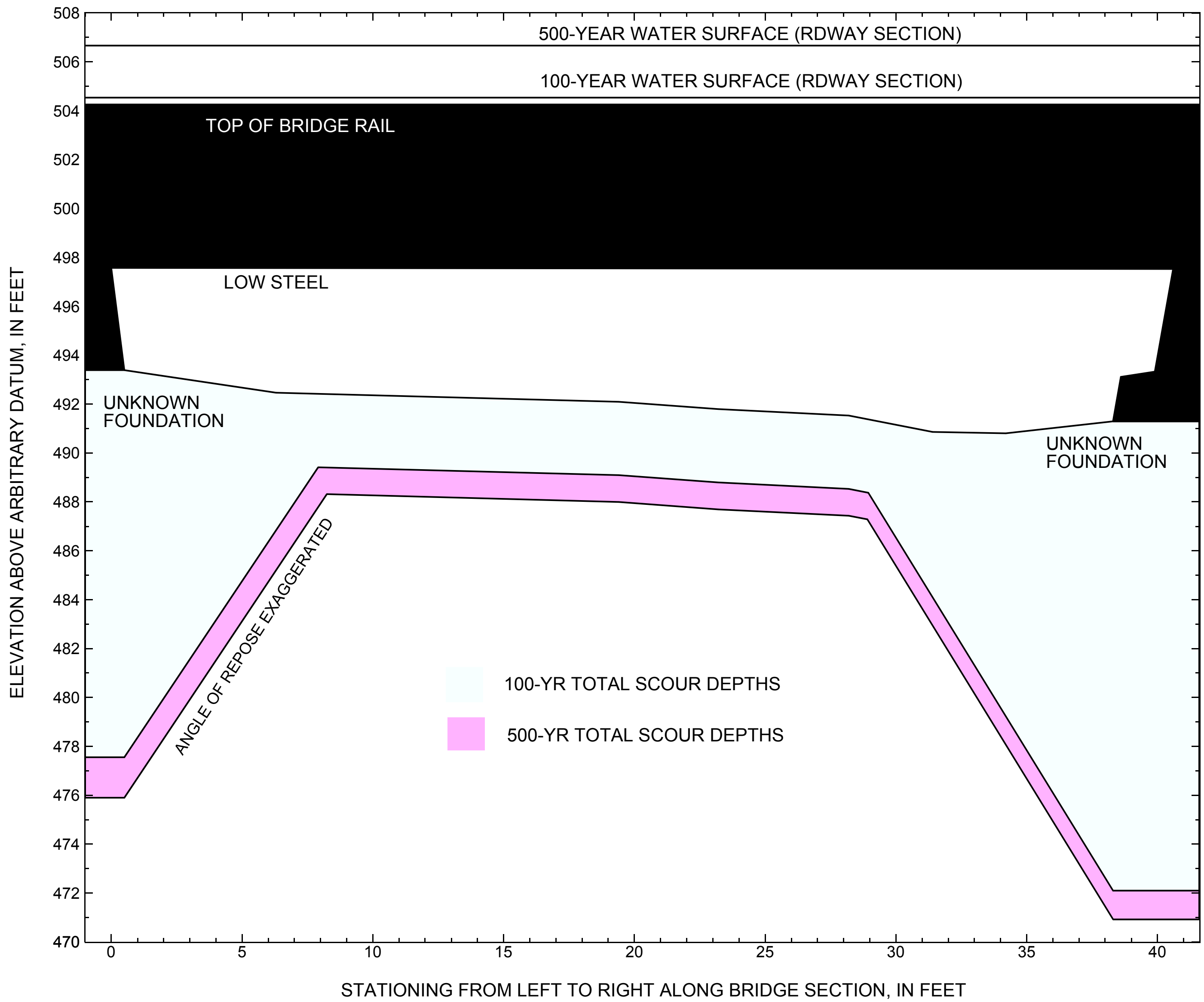

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BENNCYDEPO0043 on Depot Street, crossing the Walloomsac River, Bennington, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BENNCYDEPO0043 on Depot Street, crossing the Walloomsac River, Bennington, Vermont.

[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 4,900 cubic-feet per second											
Left abutment	0.0	--	497.6	--	493.4	3.0	12.8	--	15.8	477.6	--
Right abutment	40.6	--	497.5	--	491.3	3.0	16.2	--	19.2	472.1	--

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 BENNCYDEPO0043 on Depot Street, crossing the Walloomsac River, Bennington, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 7,570 cubic-feet per second											
Left abutment	0.0	--	497.6	--	493.4	4.1	13.4	--	17.5	475.9	--
Right abutment	40.6	--	497.5	--	491.3	4.1	16.3	--	20.4	470.9	--

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

```
T1        U.S. Geological Survey WSPRO Input File benn043.wsp
T2        Hydraulic analysis for structure BENNCYDEPO0043   Date: 27-DEC-96
T3        BENNINGTON BRIDGE #43 OVER WALLOOMSAC RIVER (SOUTH STREAM)   SAO
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           4900 7570 2090
SK          0.0218 0.0218 0.0218
*
XS   EXITX    -37
GR          -31.2, 506.00    -31.2, 497.40    -11.2, 497.32      0.0, 491.78
GR            6.7, 491.22     14.3, 490.62     17.9, 489.72     22.7, 490.58
GR           26.2, 490.47     35.8, 498.01    287.1, 497.88    287.1, 506.00
N           0.045        0.050        0.040
SA                 -11.2         35.8
*
XS   FULLV     0 * * * 0.0218
*
BR   BRIDG     0 497.55 15
GR            0.0, 497.57      0.5, 493.39      6.3, 492.46     19.4, 492.09
GR           23.2, 491.79     28.2, 491.53     31.4, 490.86     34.2, 490.80
GR           38.3, 491.29     38.6, 493.11     39.9, 493.32     40.6, 497.52
GR            0.0, 497.57
N           0.035
CD           1 56 * * 90 0
*
XR   RDWAY     23 44
GR          -31.2, 510.00    -31.2, 499.99     -1.6, 499.99
GR           -1.6, 504.31     43.9, 504.19     43.9, 499.89     60.1, 501.80
GR           60.1, 510.00
*
AS   APPRO     87
GR          -31.2, 510.00    -31.2, 501.40    -13.8, 501.40
GR            0.0, 494.29      6.6, 492.96     12.0, 491.59     16.2, 491.11
GR           20.3, 491.04     23.9, 491.39     25.5, 493.12     35.1, 499.90
GR           60.1, 501.80     60.1, 510.00
N           0.045        0.050        0.035
SA                 -13.8         35.1
*
HP 1 BRIDG   497.57 1 497.57
HP 2 BRIDG   497.57 * * 3075
HP 2 RDWAY   504.53 * * 1832
HP 1 APPRO   504.67 1 504.67
HP 2 APPRO   504.67 * * 4900
*
HP 1 BRIDG   497.57 1 497.57
HP 2 BRIDG   497.57 * * 3578
HP 2 RDWAY   506.66 * * 4014
HP 1 APPRO   506.88 1 506.88
HP 2 APPRO   506.88 * * 7570
*
HP 1 BRIDG   497.57 1 497.57
HP 2 BRIDG   497.57 * * 2090
HP 1 BRIDG   497.13 1 497.13
HP 2 BRIDG   497.13 * * 2090
HP 1 APPRO   500.27 1 500.27
HP 2 APPRO   500.27 * * 2090
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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       U.S. Geological Survey WSPRO Input File benn043.wsp
       Hydraulic analysis for structure BENNCYDEPO0043   Date: 27-DEC-96
       BENNINGTON BRIDGE #43 OVER WALLOOMSAC RIVER (SOUTH STREAM)   SAO
          *** RUN DATE & TIME: 03-20-97  14:36
   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW     REW     QCR
            1     215.  16602.     0.    88.                             0.
  497.57          215.  16602.     0.    88.  1.00     0.    41.       0.

   VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      497.57     0.0    40.6   214.5   16602.    3075.  14.33
X STA.         0.0         4.0         6.4         8.6        10.8        12.9
  A(I)             15.9        11.8        10.9        10.9        10.5
  V(I)             9.66       13.08       14.06       14.09       14.68

X STA.        12.9        14.9        16.9        18.8        20.7        22.6
  A(I)             10.5        10.2        10.2        10.0        10.0
  V(I)            14.69       15.07       15.08       15.35       15.44

X STA.        22.6        24.3        26.0        27.7        29.3        30.8
  A(I)              9.7         9.8         9.4         9.6         9.4
  V(I)            15.88       15.63       16.34       15.99       16.38

X STA.        30.8        32.3        33.8        35.3        37.0        40.6
  A(I)              9.3         9.6         9.6        11.0        16.3
  V(I)            16.58       15.95       16.01       14.01        9.46

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      23.
        WSEL     LEW     REW    AREA        K        Q    VEL
      504.53   -31.2    60.1   206.8   12507.    1832.   8.86
X STA.       -31.2       -28.3       -26.3       -24.6       -22.9       -21.3
  A(I)             13.2         8.9         7.7         7.7         7.4
  V(I)             6.95       10.27       11.84       11.90       12.45

X STA.       -21.3       -19.7       -18.2       -16.6       -15.1       -13.5
  A(I)              7.2         7.1         7.1         7.0         7.0
  V(I)            12.72       12.97       12.87       13.02       13.02

X STA.       -13.5       -12.0       -10.0        -7.5        -4.6        47.7
  A(I)              7.0         8.7        11.5        13.3        43.0
  V(I)            13.11       10.52        8.00        6.91        2.13

X STA.        47.7        49.5        51.5        53.6        56.2        60.1
  A(I)              7.5         7.6         7.8         8.6        11.5
  V(I)            12.14       12.05       11.70       10.60        7.98

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      87.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW     REW     QCR
            1      57.    3700.    17.    21.                          584.
            2     492.   64125.    49.    54.                         8865.
            3      96.    9225.    25.    28.                         1059.
  504.67          645.   77050.    91.   102.  1.08    -31.    60.    9351.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      87.
        WSEL     LEW     REW    AREA        K        Q    VEL
      504.67   -31.2    60.1   644.7   77050.    4900.   7.60
X STA.       -31.2       -13.2        -5.0        -1.0         1.9         4.6
  A(I)             59.0        46.2        35.8        30.5        29.2
  V(I)             4.15        5.30        6.84        8.04        8.40

X STA.         4.6         6.9         9.1        11.2        13.1        14.9
  A(I)             27.1        26.5        25.8        25.4        24.3
  V(I)             9.04        9.26        9.49        9.63       10.06

X STA.        14.9        16.7        18.5        20.3        22.2        24.2
  A(I)             24.2        24.3        24.7        24.8        27.0
  V(I)            10.13       10.08        9.94        9.86        9.08

X STA.        24.2        26.9        30.8        38.0        46.7        60.1
  A(I)             31.5        35.8        40.6        36.6        45.3
  V(I)             7.77        6.83        6.04        6.69        5.41
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        U.S. Geological Survey WSPRO Input File benn043.wsp
        Hydraulic analysis for structure BENNCYDEPO0043   Date: 27-DEC-96
        BENNINGTON BRIDGE #43 OVER WALLOOMSAC RIVER (SOUTH STREAM)   SAO
           *** RUN DATE & TIME: 03-20-97  14:36
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     215.   16602.     0.    88.                          0.
   497.57          215.   16602.     0.    88.  1.00     0.    41.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       497.57     0.0    40.6   214.5   16602.    3578.  16.68
X STA.         0.0        4.0        6.4        8.6       10.8       12.9
  A(I)            15.9       11.8       10.9       10.9       10.5
  V(I)           11.24      15.22      16.36      16.39      17.08

X STA.        12.9       14.9       16.9       18.8       20.7       22.6
  A(I)            10.5       10.2       10.2       10.0       10.0
  V(I)           17.09      17.54      17.55      17.86      17.96

X STA.        22.6       24.3       26.0       27.7       29.3       30.8
  A(I)             9.7        9.8        9.4        9.6        9.4
  V(I)           18.48      18.19      19.02      18.61      19.05

X STA.        30.8       32.3       33.8       35.3       37.0       40.6
  A(I)             9.3        9.6        9.6       11.0       16.3
  V(I)           19.29      18.56      18.63      16.30      11.00

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      23.
         WSEL     LEW     REW    AREA        K        Q    VEL
       506.66   -31.2    60.1   401.3   32053.    4014.  10.00
X STA.       -31.2      -27.1      -24.5      -22.1      -19.9      -17.7
  A(I)            27.3       17.4       15.7       14.9       14.6
  V(I)            7.35      11.53      12.78      13.45      13.74

X STA.       -17.7      -15.6      -13.4      -11.3       -8.9       -6.2
  A(I)            14.4       14.1       14.3       16.4       17.4
  V(I)           13.98      14.24      14.05      12.25      11.50

X STA.        -6.2       -3.5       10.4       23.4       35.8       45.6
  A(I)            18.2       41.1       31.1       30.4       30.9
  V(I)           11.02       4.88       6.46       6.61       6.50

X STA.        45.6       47.8       50.1       52.7       55.6       60.1
  A(I)            14.3       14.6       14.9       16.1       23.3
  V(I)           14.06      13.73      13.47      12.45       8.63

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      87.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      95.    8176.    17.    23.                       1267.
             2     600.   89261.    49.    54.                      11938.
             3     151.   18765.    25.    30.                       2101.
   506.88          847.  116202.    91.   107.  1.06   -31.    60.  14198.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      87.
         WSEL     LEW     REW    AREA        K        Q    VEL
       506.88   -31.2    60.1   846.5  116202.    7570.   8.94
X STA.       -31.2      -18.2       -8.5       -3.4        0.3        3.2
  A(I)            71.4       59.9       49.3       42.6       38.4
  V(I)            5.30       6.32       7.67       8.89       9.86

X STA.         3.2        5.9        8.4       10.8       13.0       15.1
  A(I)            36.5       35.5       34.6       34.1       32.7
  V(I)           10.37      10.67      10.94      11.09      11.58

X STA.        15.1       17.2       19.3       21.4       23.6       26.5
  A(I)            32.7       32.9       33.3       34.0       41.1
  V(I)           11.56      11.51      11.38      11.13       9.20

X STA.        26.5       30.2       36.4       42.6       49.6       60.1
  A(I)            44.3       51.1       41.3       43.0       57.7
  V(I)            8.54       7.40       9.16       8.81       6.55
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        U.S. Geological Survey WSPRO Input File benn043.wsp
        Hydraulic analysis for structure BENNCYDEPO0043   Date: 27-DEC-96
        BENNINGTON BRIDGE #43 OVER WALLOOMSAC RIVER (SOUTH STREAM)   SAO
           *** RUN DATE & TIME: 03-20-97  14:36
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     215.   16602.     0.    88.                           0.
  497.57           215.   16602.     0.    88.  1.00     0.    41.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       497.57     0.0    40.6   214.5   16602.    2090.   9.74
X STA.         0.0        4.0        6.4        8.6       10.8       12.9
  A(I)            15.9       11.8       10.9       10.9       10.5
  V(I)            6.56       8.89       9.56       9.57       9.98

X STA.        12.9       14.9       16.9       18.8       20.7       22.6
  A(I)            10.5       10.2       10.2       10.0       10.0
  V(I)            9.98      10.25      10.25      10.43      10.49

X STA.        22.6       24.3       26.0       27.7       29.3       30.8
  A(I)             9.7        9.8        9.4        9.6        9.4
  V(I)           10.79      10.62      11.11      10.87      11.13

X STA.        30.8       32.3       33.8       35.3       37.0       40.6
  A(I)             9.3        9.6        9.6       11.0       16.3
  V(I)           11.27      10.84      10.88       9.52       6.43

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     198.   21894.    39.    47.                        2533.
  497.13           198.   21894.    39.    47.  1.00     0.    41.   2533.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       497.13     0.1    40.5   198.3   21894.    2090.  10.54
X STA.         0.1        4.4        6.9        9.1       11.2       13.2
  A(I)            15.9       11.3       10.0        9.7        9.5
  V(I)            6.57       9.29      10.43      10.79      10.98

X STA.        13.2       15.2       17.1       19.0       20.8       22.5
  A(I)             9.3        9.0        9.0        9.0        8.7
  V(I)           11.27      11.56      11.56      11.56      11.97

X STA.        22.5       24.2       25.9       27.5       29.0       30.5
  A(I)             8.7        8.5        8.6        8.6        8.6
  V(I)           12.06      12.24      12.15      12.21      12.18

X STA.        30.5       31.9       33.4       34.9       36.7       40.5
  A(I)             8.4        8.7        9.4       10.5       16.9
  V(I)           12.51      11.96      11.11       9.98       6.20

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      87.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     278.   25585.    47.    51.                        3857.
             3       1.      12.     5.     5.                           2.
  500.27           279.   25597.    52.    56.  1.01   -12.    40.   3679.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      87.
         WSEL     LEW     REW    AREA        K        Q    VEL
       500.27   -11.6    40.0   279.3   25597.    2090.   7.48
X STA.       -11.6       -1.6        1.4        3.7        5.8        7.5
  A(I)            25.8       17.6       15.0       14.0       13.1
  V(I)            4.05       5.93       6.98       7.44       7.99

X STA.         7.5        9.1       10.6       12.0       13.3       14.5
  A(I)            12.3       12.0       11.7       11.3       11.2
  V(I)            8.51       8.68       8.90       9.22       9.36

X STA.        14.5       15.7       16.9       18.1       19.3       20.6
  A(I)            10.8       11.0       11.1       11.1       11.3
  V(I)            9.64       9.52       9.38       9.43       9.23

X STA.        20.6       21.9       23.2       24.9       27.4       40.0
  A(I)            11.8       12.2       14.6       16.9       24.4
  V(I)            8.87       8.54       7.16       6.19       4.28
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        U.S. Geological Survey WSPRO Input File benn043.wsp
        Hydraulic analysis for structure BENNCYDEPO0043   Date: 27-DEC-96
        BENNINGTON BRIDGE #43 OVER WALLOOMSAC RIVER (SOUTH STREAM)   SAO
           *** RUN DATE & TIME: 03-20-97  14:36

 ===015 WSI IN WRONG FLOW REGIME AT SECID “EXITX”:  USED WSI = CRWS.
                             WSI,CRWS =   498.59     499.44

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

EXITX:XS   ******   -31.     749.  0.95 *****  500.39  499.44   4900.  499.44
      -37. ******   287.   54698.  1.43 ***** *******    0.90    6.54

 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   498.94     506.81    0.50

 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   498.94     506.81     500.25

 ===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 =   500.25     506.81     500.25

FULLV:FV      37.   -31.     749.  0.95 *****  501.20  500.25   4900.  500.25
        0.    37.   287.   54698.  1.43 ***** *******    0.90    6.54
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   499.75     510.00    0.50

 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   499.75     510.00     502.14

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID “APPRO”
                  WSBEG,WSEND,CRWS =   502.14     510.00     502.14

APPRO:AS      87.   -31.     414.  2.40 *****  504.54  502.14   4900.  502.14
       87.    87.    60.   41511.  1.10 ***** *******    1.03   11.85
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   500.25     497.55

            <<<<<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      37.     0.     215.  3.20 *****  500.77  497.52   3075.  497.57
        0. ******    41.   16602.  1.00 ***** *******    1.10   14.34

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.55 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      23.    43.  0.17  0.97  505.46    0.00   1832.  504.53

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1251.    54.   -31.    23.   4.5   2.6   9.8   8.9   3.5   3.5
   RT:    581.    38.    23.    60.   4.6   1.8   8.6   8.7   2.7   3.5

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

APPRO:AS      31.   -31.     644.  0.97  0.41  505.64  502.14   4900.  504.67
       87.    33.    60.   76979.  1.08  0.00    0.00    0.52    7.60

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS     -37.   -31.   287.   4900.   54698.     749.    6.54  499.44
   FULLV:FV       0.   -31.   287.   4900.   54698.     749.    6.54  500.25
   BRIDG:BR       0.     0.    41.   3075.   16602.     215.   14.34  497.57
   RDWAY:RG      23.******* 1251.   1832.******************    1.00  504.53
   APPRO:AS      87.   -31.    60.   4900.   76979.     644.    7.60  504.67

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    499.44    0.90  489.72  506.00************  0.95  500.39  499.44
   FULLV:FV    500.25    0.90  490.53  506.81************  0.95  501.20  500.25
   BRIDG:BR    497.52    1.10  490.80  497.57************  3.20  500.77  497.57
   RDWAY:RG  ***************  499.89  510.00  0.17******  0.97  505.46  504.53
   APPRO:AS    502.14    0.52  491.04  510.00  0.41  0.00  0.97  505.64  504.67
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        U.S. Geological Survey WSPRO Input File benn043.wsp
        Hydraulic analysis for structure BENNCYDEPO0043   Date: 27-DEC-96
        BENNINGTON BRIDGE #43 OVER WALLOOMSAC RIVER (SOUTH STREAM)   SAO
           *** RUN DATE & TIME: 03-20-97  14:36

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                          WSI,CRWS =   499.32     500.11

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

EXITX:XS   ******   -31.     964.  1.22 *****  501.33  500.11   7570.  500.11
      -37. ******   287.   77174.  1.27 ***** *******    0.90    7.85

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                WSLIM1,WSLIM2,DELTAY =   499.61     506.81    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                WSLIM1,WSLIM2,CRWS =   499.61     506.81     500.92

 ===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 =   500.92     506.81     500.92

FULLV:FV      37.   -31.     964.  1.22 *****  502.14  500.92   7570.  500.92
        0.    37.   287.   77174.  1.27 ***** *******    0.90    7.85
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                WSLIM1,WSLIM2,DELTAY =   500.42     510.00    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                WSLIM1,WSLIM2,CRWS =   500.42     510.00     503.85

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
           ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                WSBEG,WSEND,CRWS =   503.85     510.00     503.85

APPRO:AS      87.   -31.     570.  3.00 *****  506.85  503.85   7570.  503.85
       87.    87.    60.   64243.  1.09 ***** *******    0.98   13.29
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                     WS3N,LSEL =   500.92     497.55

            <<<<<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      37.     0.     215.  4.33 *****  501.90  497.54   3578.  497.57
        0. ******    41.   16602.  1.00 ***** *******    1.28   16.68

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.55 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      23.    43.  0.18  1.32  508.02    0.00   4014.  506.66

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   2586.    54.   -31.    23.   6.7   4.7  11.8  10.1   6.1   3.2
   RT:   1428.    38.    23.    60.   6.8   3.9  10.9   9.8   5.3   3.2

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

APPRO:AS      31.   -31.     846.  1.32  0.53  508.20  503.85   7570.  506.88
       87.    33.    60.  116186.  1.06  0.00    0.00    0.53    8.94

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -37.   -31.   287.   7570.   77174.     964.    7.85  500.11
   FULLV:FV       0.   -31.   287.   7570.   77174.     964.    7.85  500.92
   BRIDG:BR       0.     0.    41.   3578.   16602.     215.   16.68  497.57
   RDWAY:RG      23.******* 2586.   4014.******************    1.00  506.66
   APPRO:AS      87.   -31.    60.   7570.  116186.     846.    8.94  506.88

    SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    500.11    0.90  489.72  506.00************  1.22  501.33  500.11
   FULLV:FV    500.92    0.90  490.53  506.81************  1.22  502.14  500.92
   BRIDG:BR    497.54    1.28  490.80  497.57************  4.33  501.90  497.57
   RDWAY:RG  ****************  499.89  510.00  0.18******  1.32  508.02  506.66
   APPRO:AS    503.85    0.53  491.04  510.00  0.53  0.00  1.32  508.20  506.88
```

```
        U.S. Geological Survey WSPRO Input File benn043.wsp
        Hydraulic analysis for structure BENNCYDEPO0043   Date: 27-DEC-96
        BENNINGTON BRIDGE #43 OVER WALLOOMSAC RIVER (SOUTH STREAM)   SAO
           *** RUN DATE & TIME: 03-20-97  14:36

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

EXITX:XS   ******    -9.     187.  1.95 *****  498.24  496.11   2090.  496.29
      -37. ******    34.   14146.  1.00 ***** *******    0.94   11.20

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     0.93     497.14     496.91

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   495.79     506.81    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   495.79     506.81     496.91

FULLV:FV      37.    -9.     188.  1.92  0.80  499.05  496.91   2090.  497.13
        0.    37.    34.   14308.  1.00  0.00    0.01    0.93   11.11
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      87.    -9.     225.  1.34  1.40  500.43 *******   2090.  499.10
       87.    87.    34.   18985.  1.00  0.00   -0.01    0.72    9.27
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   497.53     497.58     498.28     497.55

 ===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      37.     0.     215.  1.42 *****  498.99  496.47   2050.  497.57
        0. ******    41.   16602.  1.00 ***** *******    0.73    9.56

     TYPE PPCD FLOW       C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.492  0.000  497.55 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL      ERR       Q    WSEL
   RDWAY:RG      23.        <<<<<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.   -12.     279.  0.87  0.38  501.15  497.86   2090.  500.27
       87.    37.    40.   25619.  1.01  0.41   -0.02    0.57    7.48

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   499.99

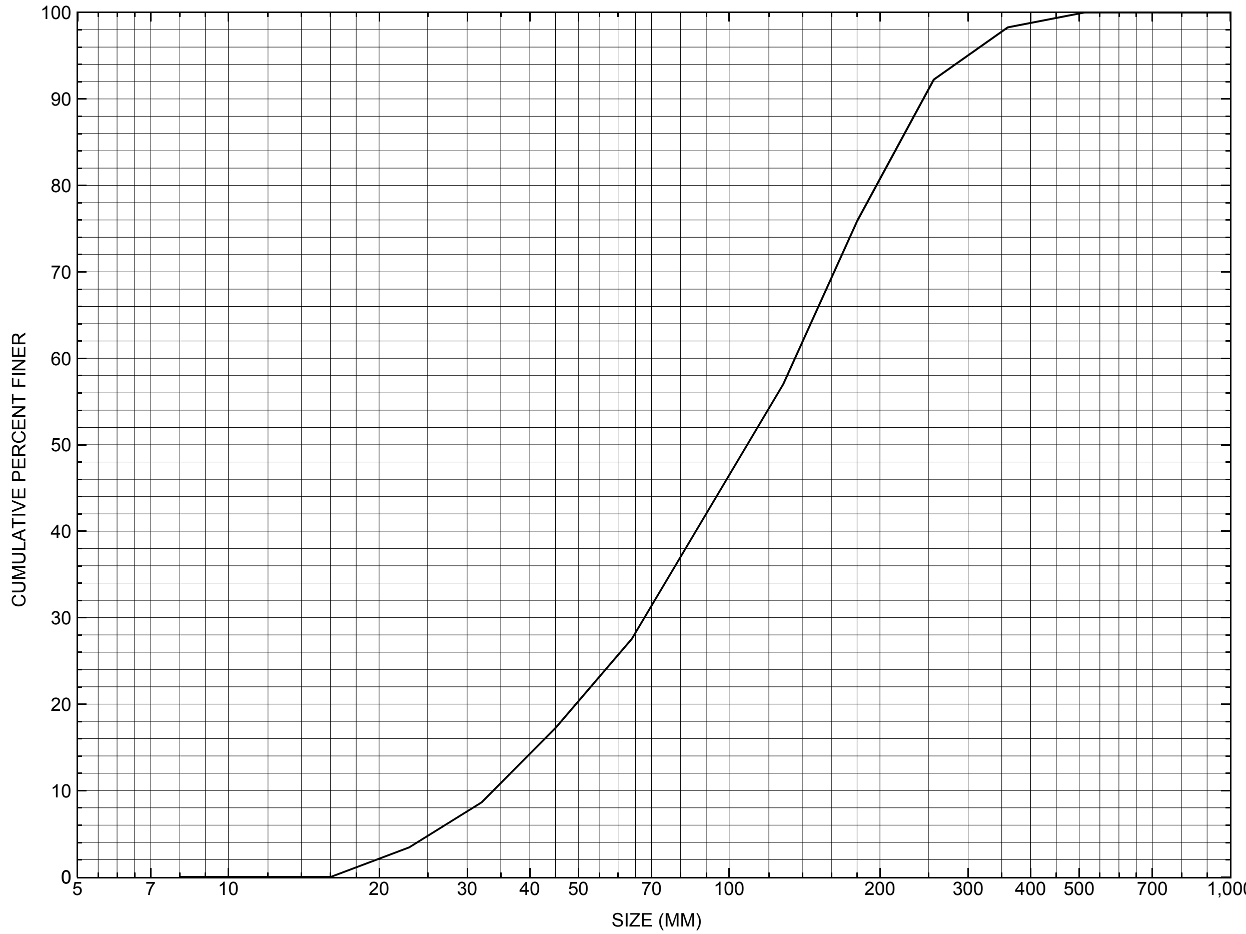
                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>

 FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -37.    -9.    34.   2090.   14146.     187.   11.20  496.29
   FULLV:FV       0.    -9.    34.   2090.   14308.     188.   11.11  497.13
   BRIDG:BR       0.     0.    41.   2050.   16602.     215.    9.56  497.57
   RDWAY:RG      23.**************      0.        0.       0.    1.00********
   APPRO:AS      87.   -12.    40.   2090.   25619.     279.    7.48  500.27

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    496.11    0.94  489.72  506.00************  1.95  498.24  496.29
   FULLV:FV    496.91    0.93  490.53  506.81  0.80  0.00  1.92  499.05  497.13
   BRIDG:BR    496.47    0.73  490.80  497.57************  1.42  498.99  497.57
   RDWAY:RG  ****************  499.89  510.00************  0.87  500.86********
   APPRO:AS    497.86    0.57  491.04  510.00  0.38  0.41  0.87  501.15  500.27
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BENNCYDEPO0043, in Bennington, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BENNCYDEPO0043

General Location Descriptive

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

Date *(MM/DD/YY)* 12 / 13 / 95

Highway District Number *(I - 2; nn)* 01

County *(FIPS county code; I - 3; nnn)* 003

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

Mile marker *(I - 11; nnn.nnn)* 000110

Waterway *(I - 6)* WALLOOMSAC RIVER

Road Name *(I - 7)*: DEPOT STREET

Route Number -

Vicinity *(I - 9)* -

Topographic Map Bennington

Hydrologic Unit Code: 2020003

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

Longitude *(i - 17; nnnnn.n)* 73119

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20101800430202

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

Maximum span length *(I - 48; nnnn)* 0040

Year built *(I - 27; YYYY)* 1926

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 008690

Deck Width *(I - 52; nn.n)* 443

Year of ADT *(I - 30; YY)* 90

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

Opening skew to Roadway *(I - 34; nn)* 15

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)* 0000

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*) -

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

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

Comments:

According to the structural inspection report dated 7/20/94, the structure is a single span "jack arch" bridge. The stem of the LAB has areas of staining, minor cracking, and scaling. The stem of the RAB has some full height vertical and some horizontal cracking. There is heavy scaling near the footing of the RAB, which is exposed. There is moderate to heavy scaling on most of the footing. All wingwalls have areas of cracking and scaling. There is a large spalled area at the bottom of the left wingwall at the RAB, where the wingwall matches into an old concrete railroad abutment. The channel is straight entering and takes a slight turn out of the structure. Debris in the channel is **(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*): U 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:

composed of shopping carts, pallets, and some metal. Flow in the channel is currently against right abutment. There is some scour, though no undermining at this time. There is a sand, stone and gravel buildup on the left abutment side of the channel.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **30.14** mi^2 Lake and pond area **0.714** mi^2

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

Bridge site elevation **665** ft Headwater elevation **2900** ft

Main channel length **9.96** mi

10% channel length elevation **720** ft 85% channel length elevation **1300** ft

Main channel slope *(S)* **77.63** 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 BENCKMARK 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 DRILL BORING INFORMATION

Comments:

--

Cross-sectional Data

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

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

Comments: **Datum is sea level.**

Station	**1460**	**1475**	**1489**	**1498**	**1500**	-	-	-	-	-	-
Feature	**LAB**	-	-	-	**RAB**	-	-	-	-	-	-
Low cord elevation	**668.6**	-	-	-	**668.6**	-	-	-	-	-	-
Bed elevation	**664.7**	**662.7**	**661.6**	**661.9**	**662.7**	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

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: 9/19/96

Computerized by: EW Date: 9/20/96

Reviewd by: SAO Date: 3/28/97

Structure Number BENNCYDEPO0043

A. General Location Descriptive

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

2. Highway District Number 1 Mile marker -

County BENNINGTON (003) Town BENNINGTON (04750)

Waterway *(I - 6)* WALLOOMSAC RIVER Road Name DEPOT STREET

Route Number - Hydrologic Unit Code: 2020003

3. Descriptive comments:

LOCATED 0.1 MILES FROM INTERSECTION OF ROUTE 9 AND DEPOT STREET.

B. Bridge Deck Observations

4. Surface cover... LBUS 1 RBUS 1 LBDS 1 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 1 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 46 *(feet)* Span length 40 *(feet)* Bridge width 44.3 *(feet)*

Road approach to bridge:

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

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

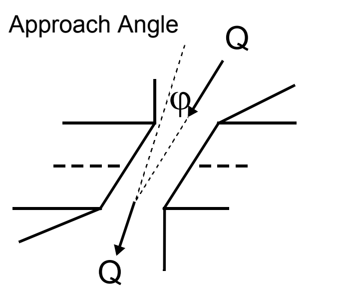
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

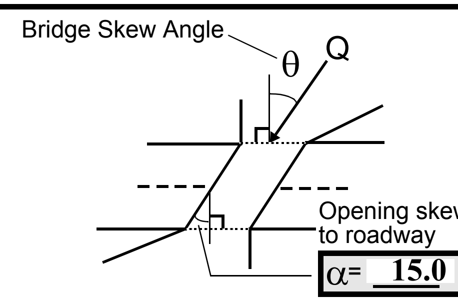
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	2	1	0	-
RBDS	5	1	0	-
LBDS	5	1	0	-

*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: 20 16. Bridge skew: 5





α= 15.0

17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 10 feet US *(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**

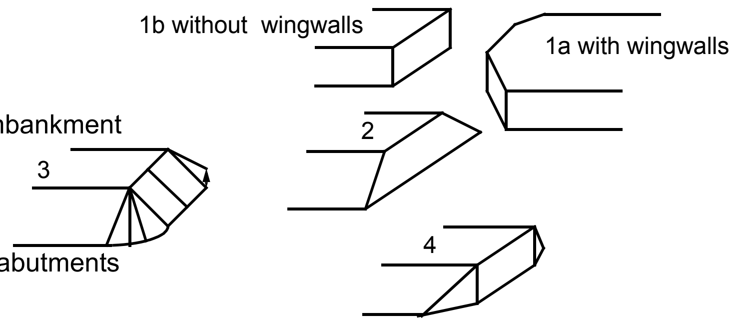
1a- Vertical abutments with wingwalls

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.)

The site surroundings are urban.

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
43.0	**7.0**			**7.0**	**3**	**0**	**4**	**7**	**0**	**2**

23. Bank width **25.0** 24. Channel width **35.0** 25. Thalweg depth **49.0** 29. Bed Material **453**

30 .Bank protection type: LB **0** RB **2** 31. Bank protection condition: LB **-** RB **1**

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

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

#27: The right bank material consists of stone fill and a stone masonry wall, which extends from the upstream bridge face to the US7 bridge upstream (approximately 450 feet upstream).

#28: Right bank erosion is moderate and concentrated along the toes of stone fill from upstream end of right wingwall to about 80 feet upstream. The bed seems to be subjected to erosion along the stone fill. Stone fill at toe is very loose and easily moved. This stone fill does not support other stone fill on slope. Stone fill is beginning to slope especially along the toe of the bank. There is a small nick point (waterfall) just upstream of approach section. Upstream of the nick point, the channel has a steep, steady gradient

33. Point/Side bar present? **Y** *(Y or N. if N type ctrl-n pb)* 34. Mid-bar distance: **26UB** 35. Mid-bar width: **22**

36. Point bar extent: **35** feet **US** *(US, UB)* to **25** feet **DS** *(US, UB, DS)* positioned **0** %LB to **60** %RB

37. Material: **453**

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

Point bar is unvegetated along LABUT.

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? **Y** *(Y or if N type ctrl-n cs)* 46. Mid-scour distance: **40**

47. Scour dimensions: Length **80** Width **5** Depth : **1** Position **85** %LB to **95** %RB

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

Scour is at thalweg along toe of stone fill slope on USRB.

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		2.0		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

Some urban debris is on point bar under the bridge (bikes, iron bars, trash, etc.). Channel gradient is flatter from downstream of nick point in upstream reach to about the downstream bridge face where the gradient steepens again. But not as steep as upstream of approach.

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 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

The low chord of the bridge is low--lower than the top of banks. Thus, debris and ice may tend to accumulate during bank full flows.

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		-	90	0	0	-	-	90.0
RABUT	1	15	90			2	3	39.0

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

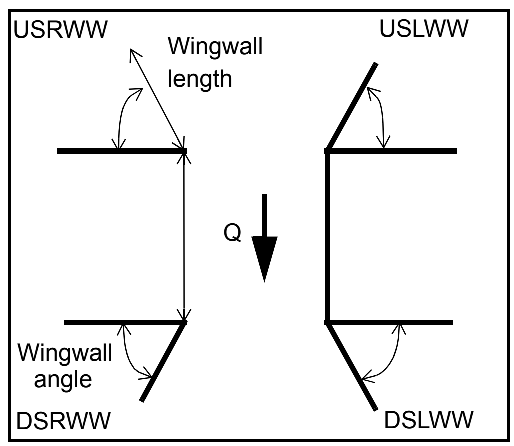
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

1.0
2.0
1

Right abutment is located at a minor to moderate bend in the channel and flow impacts abutment. Thalweg runs along the right abutment side under the bridge. Footing is undermined for its entire length by 0.2 feet and penetrating up to one foot. Point bar under left half of bridge is composed mainly of cobbles and gravel.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						39.0	
USRWW:	Y		1		0	1.0	
DSLWW:	-		-		Y	46.5	
DSRWW:	1		2		1	46.5	



*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	2.0	0	Y	-	1	1	-	-
Condition	Y	-	1	-	1	2	-	-
Extent	1	-	4	1	2	0	0	-

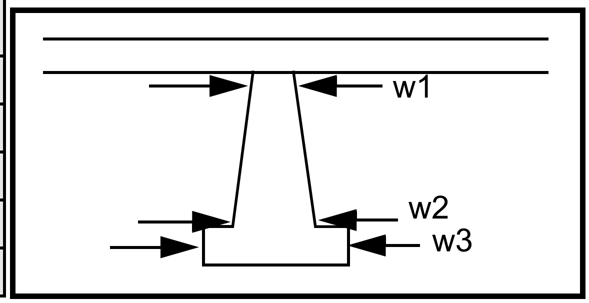
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		9.0	9.0	105.0	75.0	80.0
Pier 2				10.5	110.0	26.5
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e	dle	WW	half	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	USR	of	foot-	of	**1**- Solid pier, **2**- column, **3**- bent
88. Material	WW	the	ing is	the	**1**- Wood; **2**- concrete; **3**- metal; **4**- stone
89. Shape	is	foot-	no	wall	**1**- Round; **2**- Square; **3**- Pointed
90. Inclined?	unde	ing	lon-	brok	Y- yes; N- no
91. Attack ∠ (BF)	rmin	lengt	ger	e off	
92. Pushed	ed	h of	in	and	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	sligh	the	place	left	
95. Cross-members	tly	wing	.	the	**0**- none; **1**- laterals; **2**- diagonals; **3**- both
96. Scour Condition	near	wall.	The	top	**0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed
97. Scour depth	the	The	bot-	half	
98. Exposure depth	mid-	DSR	tom	sus-	

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

pended. Blocks of stone have been put in place of the wall and footing to prevent erosion behind the wall. Road approach protection is also wingwall protection.

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 (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):

-
-
-
-
-
-

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

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

Material: -

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

-
-
-
-

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

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

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

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

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

Scour dimensions: Length 1 Width 7 Depth: 7 Positioned 0 %LB to 0 %RB

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

453
5
5
1

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

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

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

Confluence comments (eg. confluence name):

protecting both banks downstream. Beyond the bend at bridge, the downstream channel is straight for at least 300 feet.

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: BENNCYDEPO　　Town: Bennington
Road Number: Depot Street　　County: Bennington
Stream: Walloomsac River

Initials SAO　　Date: 3/24/97　　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	2090
Main Channel Area, ft2	492	600	278
Left overbank area, ft2	57	95	0
Right overbank area, ft2	96	151	1
Top width main channel, ft	49	49	47
Top width L overbank, ft	17	17	0
Top width R overbank, ft	25	25	5
D50 of channel, ft	0.356	0.356	0.356
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	10.0	12.2	5.9
y1, average depth, LOB, ft	3.4	5.6	ERR
y1, average depth, ROB, ft	3.8	6.0	0.2
Total conveyance, approach	77050	116202	25597
Conveyance, main channel	64125	89261	25585
Conveyance, LOB	3700	8176	0
Conveyance, ROB	9225	18765	12
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	4078.0	5814.9	2089.0
Ql, discharge, LOB, cfs	235.3	532.6	0.0
Qr, discharge, ROB, cfs	586.7	1222.4	1.0
Vm, mean velocity MC, ft/s	8.3	9.7	7.5
Vl, mean velocity, LOB, ft/s	4.1	5.6	ERR
Vr, mean velocity, ROB, ft/s	6.1	8.1	1.0
Vc-m, crit. velocity, MC, ft/s	11.7	12.1	10.7
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

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	2090
(Q) discharge thru bridge, cfs	3075	3578	2090
Main channel conveyance	16602	16602	16602
Total conveyance	16602	16602	16602
Q2, bridge MC discharge,cfs	3075	3578	2090
Main channel area, ft2	215	215	215
Main channel width (normal), ft	39.2	39.2	39.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	39.2	39.2	39.2
y_bridge (avg. depth at br.), ft	5.48	5.48	5.48
Dm, median (1.25*D50), ft	0.445	0.445	0.445
y2, depth in contraction,ft	6.56	7.47	4.71
ys, scour depth (y2-ybridge), ft	1.08	1.99	-0.77

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	2090
Q, thru bridge MC, cfs	3075	3578	2090
Vc, critical velocity, ft/s	11.67	12.06	10.68
Va, velocity MC approach, ft/s	8.29	9.69	7.51
Main channel width (normal), ft	39.2	39.2	39.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	39.2	39.2	39.2
qbr, unit discharge, ft2/s	78.4	91.3	53.3
Area of full opening, ft2	215.0	215.0	215.0
Hb, depth of full opening, ft	5.48	5.48	5.48
Fr, Froude number, bridge MC	1	1	0.73
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	N/A	N/A	198
**Hb, depth at downstream face, ft	N/A	N/A	5.05
**Fr, Froude number at DS face	ERR	ERR	0.83
**Cf, for downstream face (<=1.0)	N/A	N/A	1.00
Elevation of Low Steel, ft	497.55	497.55	497.55
Elevation of Bed, ft	492.07	492.07	492.07
Elevation of Approach, ft	504.67	506.88	500.27
Friction loss, approach, ft	0.41	0.53	0.38
Elevation of WS immediately US, ft	504.26	506.35	499.89
ya, depth immediately US, ft	12.19	14.28	7.82

Mean elevation of deck, ft	504.25	504.25	504.25
w, depth of overflow, ft (>=0)	0.01	2.10	0.00
Cc, vert contrac correction (<=1.0)	0.79	0.79	0.91
**Cc, for downstream face (<=1.0)	ERR	ERR	0.882479
Ys, scour w/Chang equation, ft	3.02	4.09	0.01
Ys, scour w/Umbrell equation, ft	5.44	7.05	1.49

**=for UNsubmerged orifice flow only.

**Ys, scour w/Chang equation, ft	N/A	N/A	0.60
**Ys, scour w/Umbrell equation, ft	N/A	N/A	1.92

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

y2, from Laursen's equation, ft	6.56	7.47	4.71
WSEL at downstream face, ft	--	--	497.13
Depth at downstream face, ft	ERR	ERR	5.06
Ys, depth of scour (Laursen), ft	N/A	N/A	-0.35

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	3075	3578	2090
Main channel area (DS), ft2	215	215	198
Main channel width (normal), ft	39.2	39.2	39.2
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	39.2	39.2	39.2
D90, ft	0.8004	0.8004	0.8004
D95, ft	0.9815	0.9815	0.9815
Dc, critical grain size, ft	1.0527	1.4252	0.5953
Pc, Decimal percent coarser than Dc	0.038	0.008	0.238
Depth to armoring, ft	N/A	N/A	5.73

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	2090	4900	7570	2090
a', abut.length blocking flow, ft	4.9	4.9	2.7	4.8	4.8	9.7
Ae, area of blocked flow ft2	--	--	1.9	--	--	12.3
Qe, discharge blocked abut.,cfs	--	--	7.7	--	--	52.7
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	--	--	4.05	--	--	4.28
ya, depth of f/p flow, ft	6.60	6.60	0.70	8.70	8.70	1.27

--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	105	105	105	75	75	75
K2	1.02	1.02	1.02	0.98	0.98	0.98
Fr, froude number f/p flow	0.393	0.448	0.851	0.448	0.454	0.671
ys, scour depth, ft	12.84	13.36	2.86	16.20	16.27	5.60

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)	1	1	0.83	1	1	0.83
y, depth of flow in bridge (DS), ft	5.48	5.48	5.05	5.48	5.48	5.05

Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	2.29	2.29	2.00	2.29	2.29	2.00