LEVEL II SCOUR ANALYSIS FOR BRIDGE 42 (BENNCYSCHL0042) on SCHOOL STREET, crossing the WALLOOMSAC RIVER, BENNINGTON, VERMONT

U.S. Geological Survey
Open-File Report 97-208

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

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By SCOTT A. OLSON and JAMES R. DEGNAN

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Pembroke, New Hampshire

1997

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

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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 42 (BENNCYSCHL0042) ON SCHOOL STREET, CROSSING THE WALLOOMSAC RIVER, BENNINGTON VERMONT

By **Scott A. Olson and James R. Degnan**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure BENNCYSCHL0042 on the School 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 residences on all overbanks.

In the study area, the Walloomsac River has a straight channel with constructed channel banks downstream of the bridge. 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 6 ft. The predominant channel bed material is cobble with a median grain size (D_{50}) of 132 mm (0.435 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 6, 1996, indicated that the reach was stable.

The School Street crossing of the Walloomsac River is a 36-ft-long, two-lane bridge consisting of one 33-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 zero degrees to the opening and the opening-skew-to-roadway is also zero degrees.

Scour countermeasures at the site include type-2 stone fill (less than 36 inches diameter) along both upstream banks and upstream wingwalls. Downstream banks are protected by stone walls extending from the downstream wingwalls to more than 100 feet downstream. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and 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 was 0.0 ft. Computed left abutment scour ranged from 9.4 to 10.2 ft. with the worst-case scour occurring at the 500-year discharge. Computed right abutment scour ranged from 2.7 to 5.7 ft. with the worst-case scour occurring at the incipient roadway-overtopping discharge. Additional information on scour depths and depths to armoring are included in the section titled "Scour Results". Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives "excessively conservative estimates of scour depths" (Richardson and others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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 BENNCYSCHL0042 ***Stream*** Walloomsac River

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

Description of Bridge

Bridge length 36 ***ft*** ***Bridge width*** 44.5 ***ft*** ***Max span length*** 33 ***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*** 8/6/96

Description of stone fill Type-2, along the upstream banks and upstream wingwalls. Downstream banks are protected by stone walls.

Abutments and wingwalls are concrete. Footings are exposed on both abutments. It is assumed that the abutments were constructed with footings exposed.

Is bridge skewed to flood flow according to N ***survey?*** ***Angle*** N 0

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	8/6/96	0	0
Level II	8/6/96	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 6, 1996. The low chord is below the tops of banks, increasing the potential for the bridge to capture debris.

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 8/6/96

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 37 ***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.

8/6/96

Vegetative co[ver] Grass, trees, and buildings.

DS left: Grass, trees, and buildings.

DS right: Grass, trees, and buildings.

US left: Grass, trees, and buildings.

US right:

Do banks appear stable? Y ***If not, describe location and type of instability and date of observation.*** August 6, 1996. The top of the downstream left wall is eroded from 66 to 88 feet downstream of the bridge.

August 6, 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 at N. Bennington, VT

USGS gage number 01334000

Gage drainage area 111 ***mi²***

Is there a lake/p [illegible] 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 Add 191.0 feet to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum.

RM1 is a chiseled X on top of the upstream end of the right abutment (elev. 499.84 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the downstream left wingwall (elev. 499.93 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	24	1	Road Grade section
APPRO	79	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 0.045 to 0.050, and overbank "n" values ranged from 0.045 to 0.150.

Critical depth at the exit section (EXITX) was assumed as the starting water surface. Normal depth at the exit section was also determined. Normal depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0195 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 are 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, 2500 ft upstream, and Depot Street, 1000 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 499.3 ***ft***
Average low steel elevation 496.9 ***ft***

100-year discharge 4,900 ***ft³/s***
Water-surface elevation in bridge opening 497.0 ***ft***
Road overtopping? Y ***Discharge over road*** 3,720 ***ft³/s***
Area of flow in bridge opening 177 ***ft²***
Average velocity in bridge opening 6.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 7.5 ***ft/s***

Water-surface elevation at Approach section with bridge 501.5
Water-surface elevation at Approach section without bridge 502.4
Amount of backwater caused by bridge N/A ***t***

500-year discharge 7,570 ***ft³/s***
Water-surface elevation in bridge opening 497.0 ***ft***
Road overtopping? Y ***Discharge over road*** 6,320 ***ft³/s***
Area of flow in bridge opening 177 ***ft²***
Average velocity in bridge opening 6.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 7.5 ***/s***

Water-surface elevation at Approach section with bridge 502.6
Water-surface elevation at Approach section without bridge 503.7
Amount of backwater caused by bridge N /A

Incipient overtopping discharge 1,620 ***ft³/s***
Water-surface elevation in bridge opening 496.9 ***ft***
Area of flow in bridge opening 177 ***ft²***
Average velocity in bridge opening 9.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.4 ***ft/s***

Water-surface elevation at Approach section with bridge 499.0
Water-surface elevation at Approach section without bridge 498.4
Amount of backwater caused by bridge 0.6 ***t***

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). 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. There is no computed contraction scour for all modelled flows.

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 the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	0.0
Depth to armoring	0.2	0.3	1.5
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	10.1	10.2	9.4
Right abutment	2.7	3.7	5.7
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	0.8	0.8	1.6
Right abutment	0.8	0.8	1.6
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

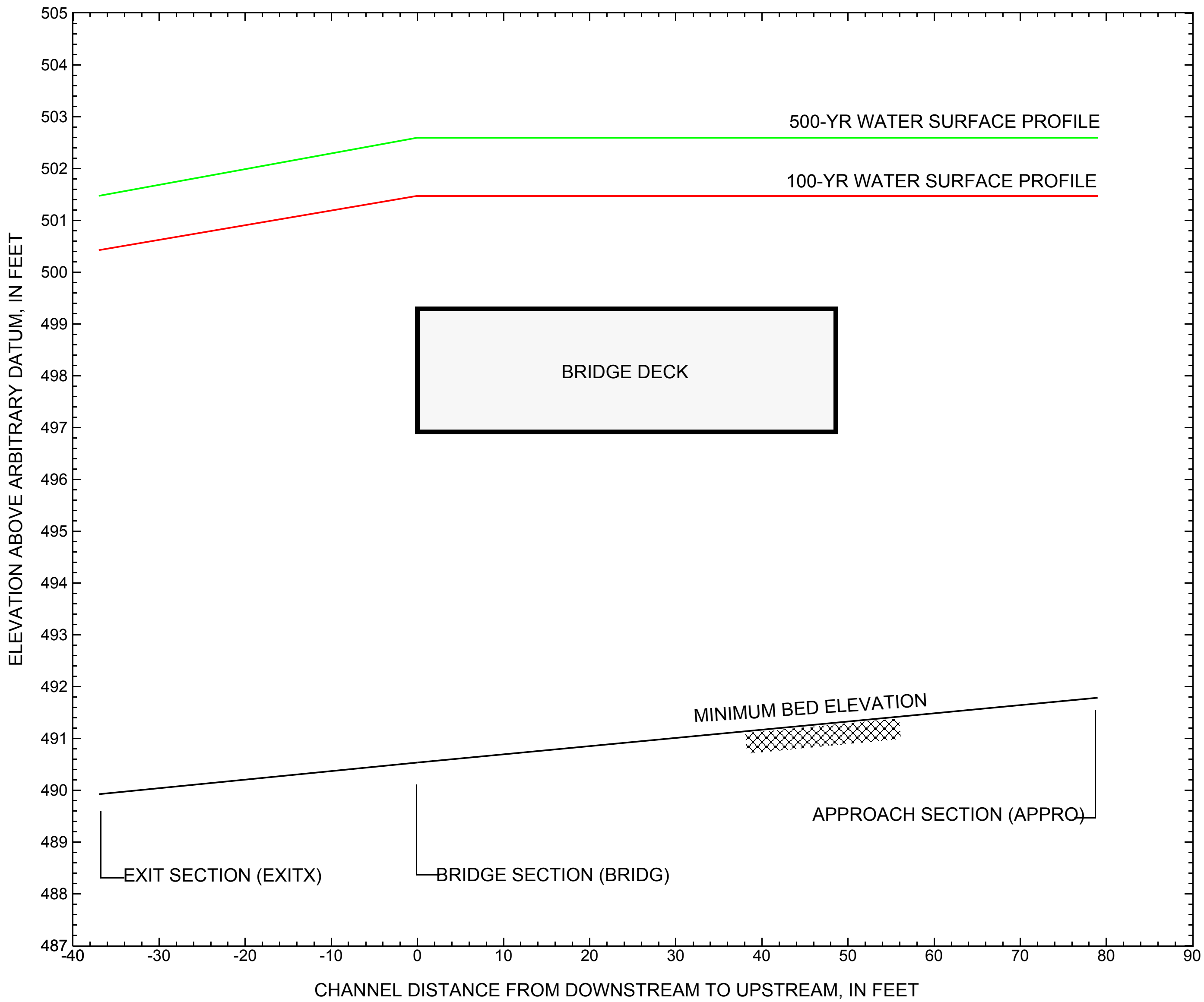

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BENNCYSCHL0042 on School Street, crossing the Walloomsac River, Bennington, Vermont.

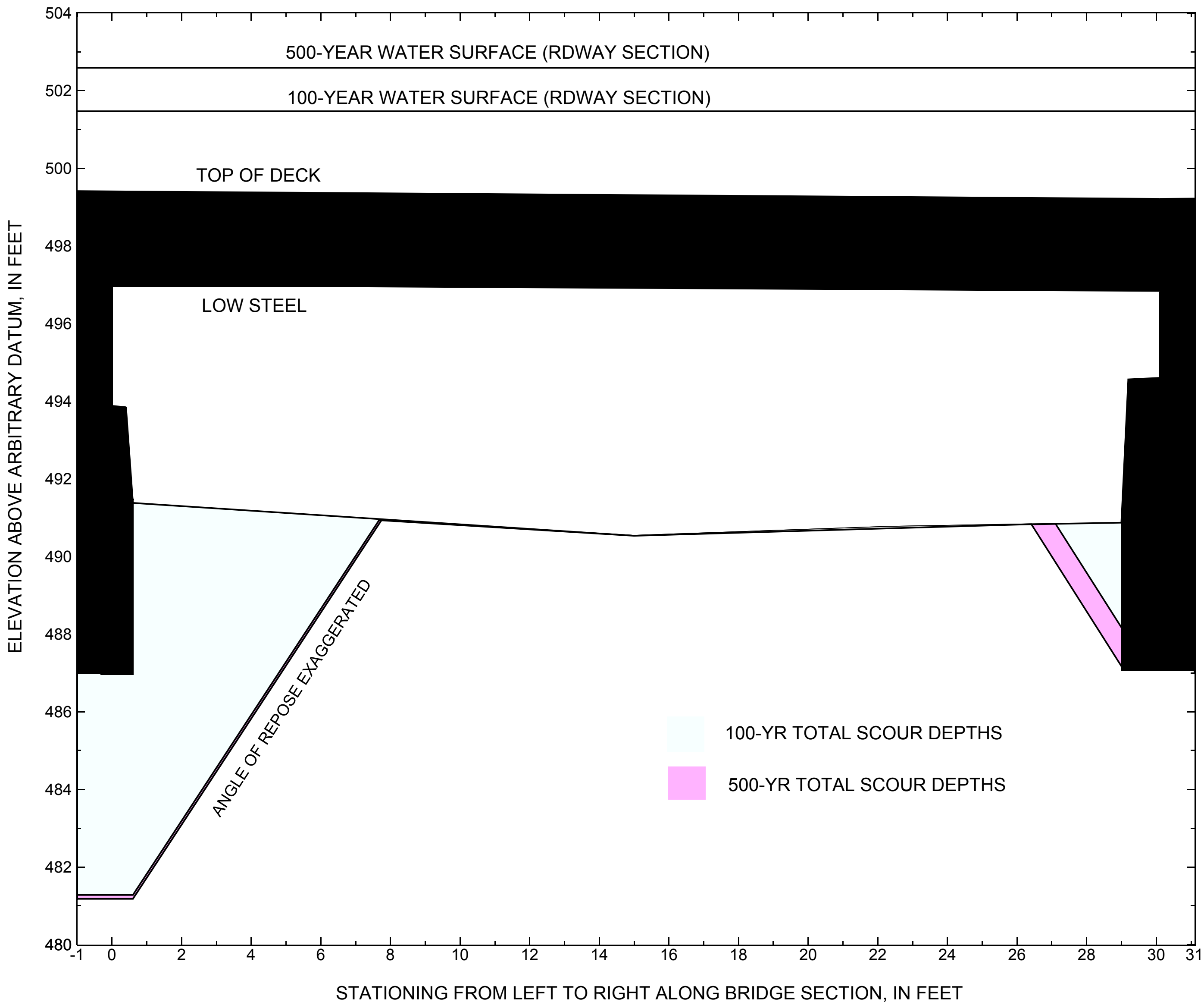

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BENNCYSCHL0042 on School Street, crossing the Walloomsac River, Bennington, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BENNCYSCHL0042 on School 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	--	497.0	487	491.4	0.0	10.1	--	10.1	481.3	-6
Right abutment	30.1	--	496.8	487	490.9	0.0	2.7	--	2.7	488.2	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 BENNCYSCHL0042 on School 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	--	497.0	487	491.4	0.0	10.2	--	10.2	481.2	-6
Right abutment	30.1	--	496.8	487	490.9	0.0	3.7	--	3.7	487.2	0

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 benn042.wsp
T2        Hydraulic analysis for structure BENNCYSCHL0042   Date: 22-JAN-97
T3        Hydraulic analysis of the School Street Bridge over Walloomsac River
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           4900 7570 1620
SK          0.0195 0.0195 0.0195
*
*           Exit section notes:
*           Left vertical wall (-88.6) set at approximate location of
*           the side of the building. Right vertical wall set at approximate
*           end of effective flow. The large right overbank n-value is used
*           to compensate for the homes on the overbank.
*
XS   EXITX    -37
GR          -88.6, 510.00    -88.6, 498.45    -46.4, 499.09    -15.8, 497.97
GR            0.0, 496.79      1.6, 491.31      1.6, 490.69      6.8, 490.27
GR           14.8, 490.14     20.4, 489.92     23.1, 490.08     27.1, 490.72
GR           27.1, 491.36     28.3, 497.19     56.5, 498.62     90.0, 498.07
GR          122.4, 497.24    207.0, 497.14    242.9, 498.10    242.9, 510.00
N           0.070        0.045        0.150
SA                   0.0          28.3
*
XS   FULLV      0  * * *   0.017
*
BR   BRIDG     0 496.90
GR            0.0, 496.97      0.0, 493.88      0.4, 493.84      0.6, 491.38
GR            6.2, 491.01     15.0, 490.53     22.3, 490.76     29.0, 490.87
GR           29.2, 494.56     30.1, 494.60     30.1, 496.82      0.0, 496.97
N            0.045
CD           1 62.3 * * 60 8
*
*            Roadway section notes:
*            left (-32.4) and right (199.0) vertical walls are assumed
*            cutoff location of effective flow.
*
XR   RDWAY     24 45
GR          -32.4, 510.00    -32.4, 499.26      0.0, 499.40     30.6, 499.21
GR          199.0, 499.14    199.0, 510.00
*
*            Approach section notes:
*            left vertical wall (-18.2) set at location of edge home.
*            right vertical wall (209.2) set at location of school.
*            incipient roadway overflow limited to 498.99, the right
*            subarea break. Right of this point water will overtop road.
*
AS   APPRO     79
GR          -18.2, 510.00    -18.2, 499.13    -12.2, 498.86      0.0, 492.95
GR            2.7, 492.05      9.6, 491.86     13.3, 491.78     17.3, 492.12
GR           22.9, 492.25     23.6, 493.06     33.6, 498.99     95.4, 499.49
GR          209.2, 499.70    209.2, 510.00
N           0.065        0.050        0.045
SA                 -12.2          33.6
*
HP 1 BRIDG   496.97 1 496.97
HP 2 BRIDG   496.97 * * 1144
```

```
*
HP 1 BRIDG   496.90 1 496.90
HP 2 BRIDG   496.90 * * 1620
HP 1 APPRO   498.95 1 498.95
HP 2 APPRO   498.95 * * 1620
*
EX
ER
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File benn042.wsp
        Hydraulic analysis for structure BENNCYSCHL0042   Date: 22-JAN-97
        Hydraulic analysis of the School Street Bridge over Walloomsac River

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1     177.   10762.    0.    71.                           0.
   496.97          177.   10762.    0.    71.  1.00     0.    30.       0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       496.97     0.0    30.1   177.2   10762.    1144.   6.46
X STA.        0.0          2.7         4.3         5.8         7.2         8.6
  A(I)             13.9         9.4         8.8         8.5         8.3
  V(I)             4.11        6.09        6.52        6.73        6.86

X STA.        8.6          9.9        11.2        12.5        13.7        15.0
  A(I)              8.0         8.0         8.0         7.7         7.7
  V(I)             7.18        7.19        7.19        7.46        7.39

X STA.       15.0         16.2        17.4        18.7        20.0        21.3
  A(I)              7.8         7.8         7.8         8.0         8.0
  V(I)             7.31        7.37        7.33        7.14        7.11

X STA.       21.3         22.6        24.0        25.4        27.0        30.1
  A(I)              8.2         8.4         8.6         9.6        14.6
  V(I)             6.95        6.84        6.61        5.94        3.91

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      24.
         WSEL     LEW     REW    AREA        K        Q    VEL
       501.47   -32.4   199.0   522.1   12429.    3720.   7.13
X STA.      -32.4        -23.2       -15.2        -6.6         1.2         6.8
  A(I)             20.1        17.3        18.1        16.3        11.7
  V(I)             9.25       10.75       10.26       11.42       15.85

X STA.        6.8         12.0        17.2        22.3        27.3        41.0
  A(I)             11.1        11.3        11.2        11.0        31.0
  V(I)            16.75       16.51       16.58       16.84        6.00

X STA.       41.0         56.9        72.7        88.8       104.7       120.1
  A(I)             35.9        36.0        36.6        36.4        35.4
  V(I)             5.17        5.16        5.08        5.11        5.25

X STA.      120.1        135.7       151.2       166.9       182.3       199.0
  A(I)             35.7        35.7        36.4        35.9        38.8
  V(I)             5.21        5.21        5.11        5.19        4.80

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      79.
     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1      15.     500.    6.     8.                         133.
             2     344.   37454.   46.    49.                        5354.
             3     351.   18335.  176.   177.                        2818.
   501.47          710.   56289.  227.   235.  1.40   -18.   209.   6025.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      79.
         WSEL     LEW     REW    AREA        K        Q    VEL
       501.47   -18.2   209.2   710.2   56289.    4900.   6.90
X STA.      -18.2         -5.0        -0.8         2.1         4.6         7.0
  A(I)             46.1        30.0        24.9        23.5        22.7
  V(I)             5.32        8.16        9.83       10.41       10.78

X STA.        7.0          9.2        11.6        13.8        16.1        18.5
  A(I)             22.0        22.2        21.4        22.1        22.4
  V(I)            11.16       11.04       11.43       11.08       10.95

X STA.       18.5         20.9        23.7        28.0        43.8        64.8
  A(I)             22.7        25.2        30.6        48.3        48.6
  V(I)            10.81        9.73        8.02        5.08        5.04

X STA.       64.8         89.1       116.8       145.6       176.4       209.2
  A(I)             51.7        54.5        55.1        57.3        59.0
  V(I)             4.74        4.50        4.45        4.27        4.15
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     U.S. Geological Survey WSPRO Input File benn042.wsp
     Hydraulic analysis for structure BENNCYSCHL0042   Date: 22-JAN-97
     Hydraulic analysis of the School Street Bridge over Walloomsac River

 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1     177.   10762.     0.    71.                            0.
 496.97         177.   10762.     0.    71.  1.00     0.    30.       0.

 VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
      WSEL     LEW     REW    AREA        K        Q    VEL
    496.97     0.0    30.1   177.2   10762.    1146.   6.47
X STA.        0.0        2.7        4.3        5.8        7.2        8.6
  A(I)            13.9        9.4        8.8        8.5        8.3
  V(I)            4.12       6.10       6.53       6.74       6.87

X STA.        8.6        9.9       11.2       12.5       13.7       15.0
  A(I)             8.0        8.0        8.0        7.7        7.7
  V(I)            7.19       7.20       7.20       7.47       7.40

X STA.       15.0       16.2       17.4       18.7       20.0       21.3
  A(I)             7.8        7.8        7.8        8.0        8.0
  V(I)            7.33       7.38       7.34       7.16       7.12

X STA.       21.3       22.6       24.0       25.4       27.0       30.1
  A(I)             8.2        8.4        8.6        9.6       14.6
  V(I)            6.97       6.85       6.62       5.95       3.91

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      24.
      WSEL     LEW     REW    AREA        K        Q    VEL
    502.59   -32.4   199.0   781.2   24362.    6315.   8.08
X STA.      -32.4      -23.0      -14.8       -6.7        1.1        6.4
  A(I)            31.2       26.7       26.3       24.9       16.9
  V(I)           10.12      11.81      12.00      12.68      18.66

X STA.        6.4       11.5       16.6       21.6       26.5       38.6
  A(I)            16.7       16.6       16.5       16.4       40.8
  V(I)           18.87      19.01      19.18      19.26       7.74

X STA.       38.6       54.5       70.5       86.6      102.6      118.2
  A(I)            54.0       54.1       54.9       54.6       53.1
  V(I)            5.84       5.83       5.75       5.79       5.95

X STA.      118.2      134.3      149.9      165.8      181.5      199.0
  A(I)            55.0       53.7       54.6       53.8       60.5
  V(I)            5.74       5.88       5.78       5.87       5.22

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      79.
  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1      22.     856.     6.     9.                          232.
          2     395.   47212.    46.    49.                         6594.
          3     548.   38313.   176.   178.                         5491.
 502.59         965.   86381.   227.   237.  1.24   -18.   209.  10110.

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      79.
      WSEL     LEW     REW    AREA        K        Q    VEL
    502.59   -18.2   209.2   964.9   86381.    7570.   7.85
X STA.      -18.2       -4.9       -0.2        3.2        6.2        9.2
  A(I)            62.0       39.6       34.2       31.7       32.0
  V(I)            6.10       9.56      11.08      11.94      11.81

X STA.        9.2       12.1       14.9       17.9       21.0       24.5
  A(I)            30.8       30.3       31.7       32.3       35.1
  V(I)           12.28      12.49      11.95      11.73      10.79

X STA.       24.5       31.0       47.5       64.3       82.5      101.8
  A(I)            45.9       60.9       57.5       59.4       60.5
  V(I)            8.25       6.22       6.58       6.37       6.25

X STA.      101.8      122.4      142.8      164.0      185.4      209.2
  A(I)            63.4       61.6       63.6       63.1       69.3
  V(I)            5.97       6.14       5.95       6.00       5.46
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        U.S. Geological Survey WSPRO Input File benn042.wsp
        Hydraulic analysis for structure BENNCYSCHL0042   Date: 22-JAN-97
        Hydraulic analysis of the School Street Bridge over Walloomsac River

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     177.   12409.    14.    57.                        3555.
   496.90          177.   12409.    14.    57.  1.00     0.    30.   3555.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       496.90     0.0    30.1   176.7   12409.    1620.   9.17
X STA.        0.0        2.6        4.1        5.3        6.5        7.6
  A(I)            13.4        8.3        7.2        6.8        6.6
  V(I)            6.03       9.78      11.20      11.87      12.28

X STA.        7.6        8.7        9.8       10.8       11.9       13.0
  A(I)             6.5        6.6        6.5        6.5        6.6
  V(I)           12.42      12.34      12.39      12.41      12.30

X STA.       13.0       14.0       15.5       17.0       18.5       20.0
  A(I)             6.7        9.3        9.3        9.4        9.6
  V(I)           12.06       8.72       8.73       8.59       8.46

X STA.       20.0       21.6       23.2       24.9       26.8       30.1
  A(I)             9.8        9.7       10.5       11.0       16.3
  V(I)            8.31       8.31       7.73       7.34       4.98

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      79.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       0.       0.     2.     2.                           0.
             2     229.   18979.    46.    49.                        2903.
   498.95          229.   18980.    48.    51.  1.00   -14.    34.   2842.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      79.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.95   -14.2    33.5   228.8   18980.    1620.   7.08
X STA.      -14.2       -3.1       -0.4        1.5        3.1        4.6
  A(I)            20.9       14.0       11.9       10.6       10.3
  V(I)            3.88       5.80       6.80       7.62       7.88

X STA.        4.6        6.0        7.4        8.7       10.0       11.3
  A(I)            10.0        9.5        9.4        9.4        9.4
  V(I)            8.14       8.52       8.58       8.64       8.60

X STA.       11.3       12.6       13.9       15.3       16.7       18.1
  A(I)             9.3        9.3        9.3        9.8        9.7
  V(I)            8.74       8.72       8.74       8.25       8.32

X STA.       18.1       19.6       21.1       22.8       25.3       33.5
  A(I)            10.3       10.3       11.5       13.9       20.1
  V(I)            7.86       7.83       7.06       5.82       4.03
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       U.S. Geological Survey WSPRO Input File benn042.wsp
       Hydraulic analysis for structure BENNCYSCHL0042   Date: 22-JAN-97
       Hydraulic analysis of the School Street Bridge over Walloomsac River

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                          WSI,CRWS =   499.34     500.42

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

EXITX:XS   ******   -89.    1056.  1.43 *****  501.84  500.42   4900.  500.42
      -37. ******   243.   51879.  4.26 ***** *******    0.95    4.64

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.39     500.34     501.05

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   499.92     510.63    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   499.92     510.63     501.05

 ===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 =   501.05     510.63     501.05

FULLV:FV      37.   -89.    1056.  1.43 *****  502.47  501.05   4900.  501.05
        0.    37.   243.   51879.  4.26 ***** *******    0.95    4.64
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "APPRO"     KRATIO =  1.54

APPRO:AS      79.   -18.     913.  0.57  0.46  502.93 *******   4900.  502.36
       79.    79.   209.   79698.  1.27  0.00    0.00    0.53    5.37
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   501.05     496.90

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                  QRD,QRDMAX,RATIO =    3720.      3139.    1.18

            <<<<<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.     177.  0.65 *****  497.62  494.53   1144.  496.97
        0. ******    30.   10762.  1.00 ***** *******    0.47    6.46

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  496.90 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       24.    34.  0.26  1.04  502.25   -0.01   3720.  501.47

            Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    715.    47.   -32.    15.   2.2   2.1   7.8   7.1   2.9   3.0
   RT:   3005.   184.    15.   199.   2.3   2.3   8.0   7.1   3.1   3.0

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

APPRO:AS      17.   -18.     709.  1.04  0.45  502.50  501.24   4900.  501.47
       79.    29.   209.   56192.  1.40  0.00   -0.01    0.82    6.91

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -37.   -89.   243.   4900.   51879.    1056.    4.64  500.42
   FULLV:FV       0.   -89.   243.   4900.   51879.    1056.    4.64  501.05
   BRIDG:BR       0.     0.    30.   1144.   10762.     177.    6.46  496.97
   RDWAY:RG      24.*******   715.   3720.******************    1.00  501.47
   APPRO:AS      79.   -18.   209.   4900.   56192.     709.    6.91  501.47

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    500.42    0.95  489.92  510.00************  1.43  501.84  500.42
   FULLV:FV    501.05    0.95  490.55  510.63************  1.43  502.47  501.05
   BRIDG:BR    494.53    0.47  490.53  496.97************  0.65  497.62  496.97
   RDWAY:RG  ****************  499.14  510.00  0.26******  1.04  502.25  501.47
   APPRO:AS    501.24    0.82  491.78  510.00  0.45  0.00  1.04  502.50  501.47
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       U.S. Geological Survey WSPRO Input File benn042.wsp
       Hydraulic analysis for structure BENNCYSCHL0042   Date: 22-JAN-97
       Hydraulic analysis of the School Street Bridge over Walloomsac River

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                           WSI,CRWS =   500.55     501.47

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

EXITX:XS   ******   -89.    1405.  1.75 *****  503.22  501.47   7570.  501.47
      -37. ******   243.   72383.  3.87 ***** *******    0.91    5.39

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.10     501.66     502.10

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   500.97     510.63    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   500.97     510.63     502.10

 ===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 =   502.10     510.63     502.10

FULLV:FV      37.   -89.    1405.  1.75 *****  503.85  502.10   7570.  502.10
        0.    37.   243.   72383.  3.87 ***** *******    0.91    5.39
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

APPRO:AS      79.   -18.    1207.  0.71  0.52  504.36 *******   7570.  503.65
       79.    79.   209.  120727.  1.16  0.00    0.00    0.52    6.27
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   502.10     496.90

 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                  QRD,QRDMAX,RATIO =    6315.      5803.    1.09

            <<<<<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.     177.  0.65 *****  497.62  494.53   1146.  496.97
        0. ******    30.   10762.  1.00 ***** *******    0.47    6.47

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  496.90 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      24.    34.  0.26  1.19  503.52   -0.01   6315.  502.59

            Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1237.    47.   -32.    15.   3.3   3.3   9.4   8.0   4.2   3.1
   RT:   5078.   184.    15.   199.   3.5   3.4   9.5   8.1   4.3   3.1

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

APPRO:AS      17.   -18.     966.  1.19  0.67  503.78  502.11   7570.  502.59
       79.    32.   209.   86499.  1.24  0.00   -0.01    0.75    7.84

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -37.   -89.   243.   7570.   72383.    1405.    5.39  501.47
   FULLV:FV       0.   -89.   243.   7570.   72383.    1405.    5.39  502.10
   BRIDG:BR       0.     0.    30.   1146.   10762.     177.    6.47  496.97
   RDWAY:RG      24.******* 1237.   6315.******************    1.00  502.59
   APPRO:AS      79.   -18.   209.   7570.   86499.     966.    7.84  502.59

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    501.47    0.91  489.92  510.00************  1.75  503.22  501.47
   FULLV:FV    502.10    0.91  490.55  510.63************  1.75  503.85  502.10
   BRIDG:BR    494.53    0.47  490.53  496.97************  0.65  497.62  496.97
   RDWAY:RG  ***************  499.14  510.00  0.26******  1.19  503.52  502.59
   APPRO:AS    502.11    0.75  491.78  510.00  0.67  0.00  1.19  503.78  502.59
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        U.S. Geological Survey WSPRO Input File benn042.wsp
        Hydraulic analysis for structure BENNCYSCHL0042   Date: 22-JAN-97
        Hydraulic analysis of the School Street Bridge over Walloomsac River

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

EXITX:XS   ******     0.     140.  2.08 *****  497.63  495.21   1620.  495.56
      -37. ******    28.   11594.  1.00 ***** *******    0.90   11.55

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.85     496.41     495.84

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   495.06     510.63    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   495.06     510.63     495.84

FULLV:FV      37.     0.     146.  1.91  0.68  498.31  495.84   1620.  496.40
        0.    37.    28.   12304.  1.00  0.00    0.00    0.85   11.09
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      79.   -11.     202.  1.00  1.06  499.35 *******   1620.  498.35
       79.    79.    33.   15937.  1.00  0.00   -0.01    0.66    8.02
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===230 REJECTED FLOW CLASS 1 SOLUTION.
             WS1,WSSD,WS3 =   499.18       0.00     496.97
                     CRWS =   497.01   ********     495.49
                     YMAX =   510.00   ********     496.97

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   500.81         0.      1620.

 ===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      37.     0.     177.  1.27 *****  498.17  495.45   1595.  496.90
        0. ******    30.   12409.  1.00 ***** *******    0.66    9.03

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.477  0.000  496.90 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      24.        <<<<<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      17.   -14.     229.  0.78  0.20  499.73  497.01   1620.  498.95
       79.    18.    34.   18961.  1.00  0.00   -0.02    0.57    7.08

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   498.70

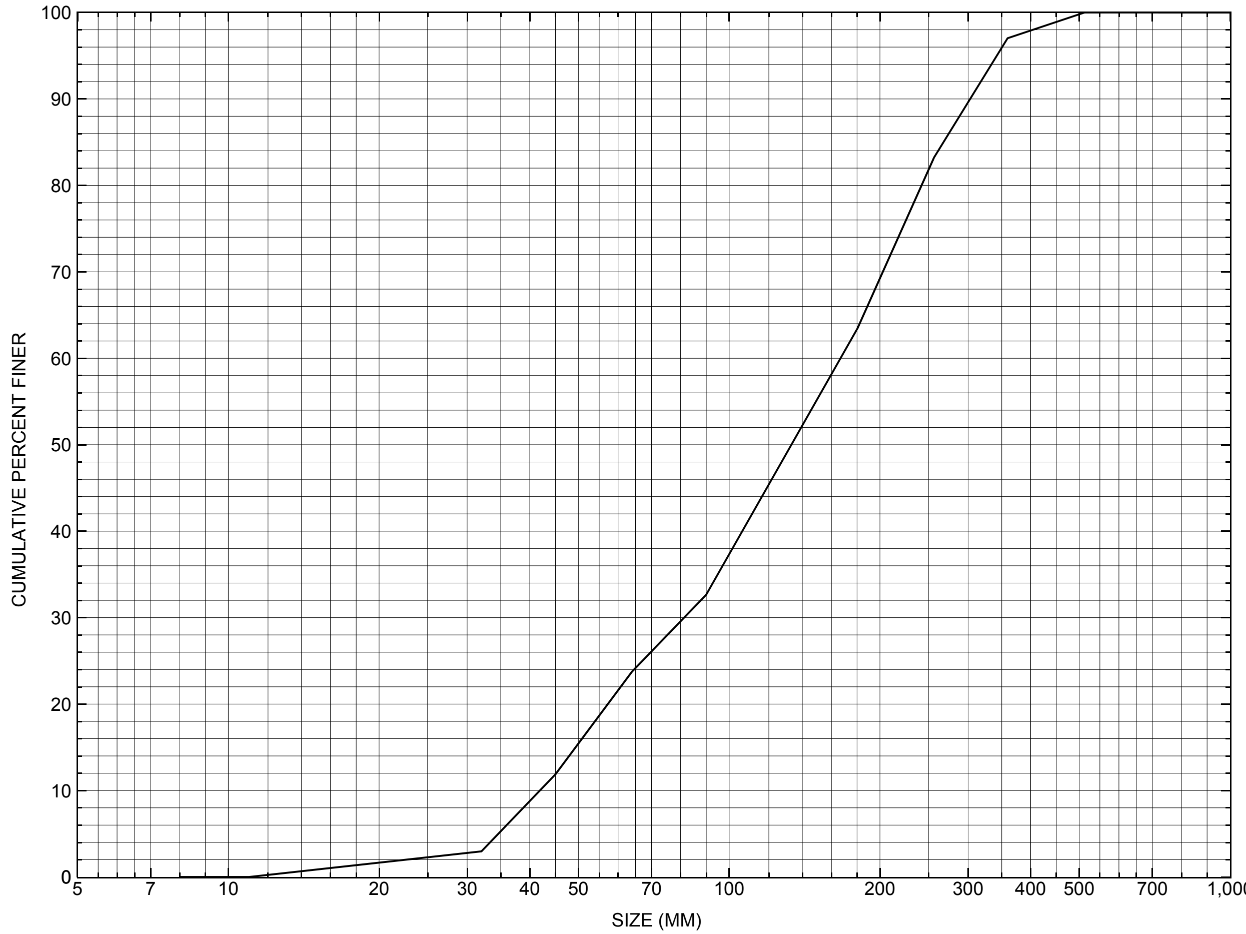
                  <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -37.     0.    28.   1620.   11594.     140.   11.55  495.56
   FULLV:FV       0.     0.    28.   1620.   12304.     146.   11.09  496.40
   BRIDG:BR       0.     0.    30.   1595.   12409.     177.    9.03  496.90
   RDWAY:RG      24.**************      0.       0.       0.    1.00********
   APPRO:AS      79.   -14.    34.   1620.   18961.     229.    7.08  498.95

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    495.21    0.90  489.92  510.00************  2.08  497.63  495.56
   FULLV:FV    495.84    0.85  490.55  510.63  0.68  0.00  1.91  498.31  496.40
   BRIDG:BR    495.45    0.66  490.53  496.97************  1.27  498.17  496.90
   RDWAY:RG  ****************  499.14  510.00************  0.66  499.82********
   APPRO:AS    497.01    0.57  491.78  510.00  0.20  0.00  0.78  499.73  498.95
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BENNCYSCHL0042, in Bennington, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number **BENNCYSCHL0042**

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)* **000140**

Waterway *(I - 6)* **WALLOOMSAC RIVER**

Road Name *(I - 7):* **School Street**

Route Number **-**

Vicinity *(I - 9)* **-**

Topographic Map **Bennington**

Hydrologic Unit Code: **2020003**

Latitude *(I - 16; nnnn.n)* **42528**

Longitude *(i - 17; nnnnn.n)* **73116**

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* **20104600420202**

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

Maximum span length *(I - 48; nnnn)* **0033**

Year built *(I - 27; YYYY)* **1985**

Structure length *(I - 49; nnnnnn)* **000036**

Average daily traffic, ADT *(I - 29; nnnnnn)* **002660**

Deck Width *(I - 52; nn.n)* **445**

Year of ADT *(I - 30; YY)* **89**

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

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

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

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

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

Structure type *(I - 43; nnn)* **101**

Year Reconstructed *(I - 106)* **0000**

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

Clear span (*nnn.n ft*) **28.5**

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

Vertical clearance from streambed (*nnn.n ft*) **7**

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

Waterway of full opening (*nnn.n ft*^{2}) **200**

Comments:

According to the structural inspection report dated 7-20-94, structure is a single span concrete slab bridge. Both concrete abutments and wingwalls are in good condition. The channel is straight through the structure. There is some minor debris in the channel. There are laid up stone retaining walls downstream of the structure for a considerable distance.

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area (*mi²*): **29.6**

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data (*cfs*): $Q_{2.33}$ - Q_{10} **2950** Q_{25} **3850**

Q_{50} **4500** Q_{100} **5200** 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*)	-	**687.9**	**688.9**	**689.2**	**689.6**
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} (*ft³/ sec*): -

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

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

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

Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (*ft²*): -

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

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

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

Comments:

According to the hydraulic report dated 1/15/82, tailwater depth @Q25=7.4'; velocity @Q25 = 22.0 fps. Overflow begins @ Q 25+-.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **30.10** mi^2 Lake and pond area **0.714** mi^2

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

Bridge site elevation **680** ft   Headwater elevation **2900** ft

Main channel length **9.75** mi

10% channel length elevation **740** ft   85% channel length elevation **1440** ft

Main channel slope *(S)* **95.72** 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)*: - / -

Project Number BRM 1000(6)S Minimum channel bed elevation: ________

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

Benchmark location description:
NO BENCHMARK INFORMATION.

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 - Footing bottom elevation: 678.0

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:
The average low steel elevation is 687.51 feet.

Cross-sectional Data

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

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

Comments:

Station	**1083**	**1097**	**1112**		-	-	-	-	-	-	-
Feature	**LAB**	-	**RAB**	-	-	-	-	-	-	-	-
Low cord elevation	**687.2**	-	**687.5**	-	-	-	-	-	-	-	-
Bed elevation	**682.3**	**682.0**	**682.5**	-	-	-	-	-	-	-	-
Low cord to bed length	**4.9**	-	**5.0**	-	-	-	-	-	-	-	-

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: 9/16/96
Computerized by: EW Date: 9/16/96
Reviewd by: SAO Date: 2/26/96

Structure Number BENNCYSCHL0042

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* J. DEGNAN Date *(MM/DD/YY)* 08 / 06 / 1996

2. Highway District Number 01 Mile marker 000140

County BENNINGTON (003) Town BENNINGTON (04750)

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

Route Number ________ Hydrologic Unit Code: 2020003

3. Descriptive comments:

Concrete abutments, wingwalls and road surface exist at this site. A brass plate on the streamward face of the US end of the left abutment is in the shape of Vermont and displays the bridge number BRM 1000(6) S, 1984.

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 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 36 *(feet)* Span length 33 *(feet)* Bridge width 44.5 *(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)*

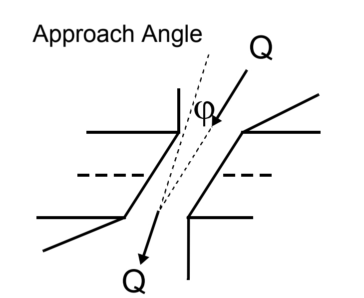
10. Embankment slope (*run / rise in feet / foot*):
US left 0.0:1 US right 0.0:1

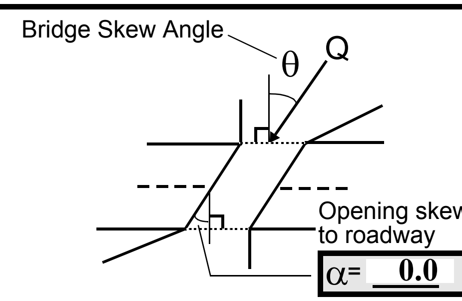
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

*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: 15 16. Bridge skew: 0





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 0
Range? 0 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**

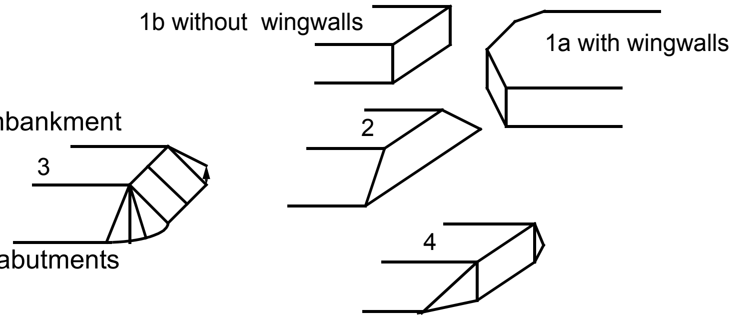
1a- Vertical abutments with wingwalls

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.)

There is a walkway along the DSLB and grass, otherwise urban classification prevails.

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
34.0	**6.0**			**6.0**	**2**	**2**	**7**	**7**	**2**	**2**

23. Bank width **25.0** 24. Channel width **25.0** 25. Thalweg depth **46.5** 29. Bed Material **453**

30 .Bank protection type: LB **2** RB **2** 31. Bank protection condition: LB **3** RB **3**

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.):

The bank protection on both banks has been eroded.
Left bank protection: From bridge to 30 ft upstream protection is type-2 stone-fill. From 30 to 130 ft upstream the left channel bank is a stone wall. From 130 to 320 ft upstream the protection is stone-fill again.
Right bank protection: From bridge to 30 ft upstream protection is type-2 stone-fill. From 30 to 280 ft upstream the channel bank is a 4 ft stone wall with some areas resembling stone-fill due to erosion.

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

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

37. Material: -

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

NO POINT BARS

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

41. Mid-bank distance: 300 42. Cut bank extent: 320 feet US (US, UB) to 280 feet US (US, UB, DS)

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

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

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
23.5		1.0		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

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 **Y**___ *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

2

The low cord elevation is a few feet lower than the tops of banks, constricting the channel. Ice scaring is evident on the trees along the banks. The debris potential is moderate due to the existence of large trees on banks upstream and the urban setting.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		**0**	**90**	**2**	**2**	**0**	**2.5**	**90.0**
RABUT	**1**	**0**	**90**			**2**	**2**	**30.0**

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

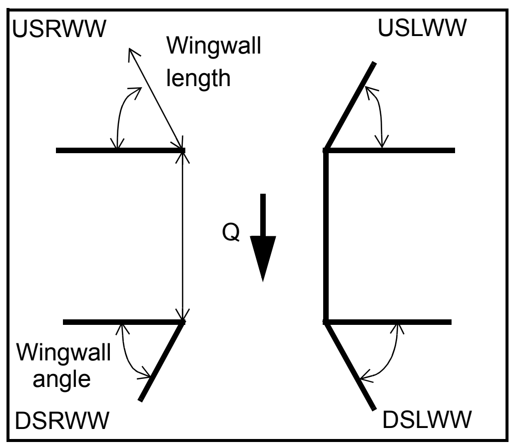
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0
2.5
1

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**30.0**	
USRWW:	**Y**		**1**		**0**	**1.5**	
DSLWW:	**-**		**-**		**Y**	**48.5**	
DSRWW:	**1**		**0**		**-**	**48.5**	

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	**-**	**3**	**Y**	**-**	**1**	**1**	**-**	**-**
Condition	**Y**	**-**	**1**	**-**	**1**	**1**	**-**	**-**
Extent	**1**	**-**	**0**	**2**	**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

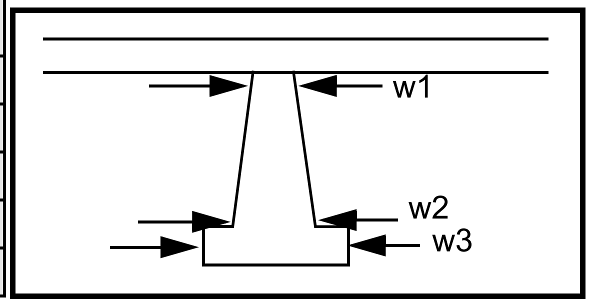
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
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				**60.0**	**16.0**	**60.0**
Pier 2			**4.5**	**16.0**	**90.0**	**90.0**
Pier 3	**6.0**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e**	**also**	**ing it**		*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**DSL**	**a**	**was**		***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**WW**	**smal**	**pour**		***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**has**	**l gap**	**ed**	**N**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**expe**	**betw**	**upon**	**-**	*Y- yes; N- no*
91. Attack ∠ (BF)	**rienc**	**een**	**.**	**-**	
92. Pushed	**ed**	**its**		**-**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**some**	**base**		**-**	
95. Cross-members	**scou**	**and**		**-**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**r.**	**the**		**-**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**Ther**	**old**		**-**	
98. Exposure depth	**e is**	**foot-**		**-**	

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 **2** *(US, UB, DS)* positioned **3** %LB to **7** %RB

Material: **7**

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

1
1
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: **The** feet **DS** *(US, UB, DS)* to **LB** feet **pro** *(US, UB, DS)*

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

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

tion is a stone wall from the wingwall to 178 feet downstream where riprap has been placed. The DSRB is a stone wall from the wingwall to 142 feet downstream where it is eroded, and at 205 feet downstream the protection is a concrete wall.

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

Scour dimensions: Length **bank** Width **wall** Depth: **is** Positioned **ero** %LB to **ded** %RB

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

from 66 feet downstream to 88 feet downstream.

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)*:

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: BENNCYSCHL0042		Town:	Bennington
Road Number: School Street		County:	Bennington
Stream: Walloomsac River			

Initials SAO Date: 1/28/97 Checked: EB 2/3/97

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	1620
Main Channel Area, ft2	344	395	229
Left overbank area, ft2	15	22	0
Right overbank area, ft2	351	548	0
Top width main channel, ft	46	46	46
Top width L overbank, ft	6	6	2
Top width R overbank, ft	176	176	0
D50 of channel, ft	0.435	0.435	0.435
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.5	8.6	5.0
y1, average depth, LOB, ft	2.5	3.7	0.0
y1, average depth, ROB, ft	2.0	3.1	ERR
Total conveyance, approach	56289	86381	18980
Conveyance, main channel	37454	47212	18979
Conveyance, LOB	500	856	1
Conveyance, ROB	18335	38313	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	3260.4	4137.4	1619.9
Ql, discharge, LOB, cfs	43.5	75.0	0.1
Qr, discharge, ROB, cfs	1596.1	3357.6	0.0
Vm, mean velocity MC, ft/s	9.5	10.5	7.1
Vl, mean velocity, LOB, ft/s	2.9	3.4	ERR
Vr, mean velocity, ROB, ft/s	4.5	6.1	ERR
Vc-m, crit. velocity, MC, ft/s	11.9	12.2	11.1
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?			
Main Channel	0	0	0

ARMORING (bridge section)

D90	0.9936	0.9936	0.9936

D95	1.124	1.124	1.124
Critical grain size,Dc, ft	0.2299	0.2307	0.4611
Decimal-percent coarser than Dc	0.7387	0.7378	0.4741
Depth to armoring,ft	0.24	0.25	1.53

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	344	395	229
Main channel width, ft	46	46	46
y1, main channel depth, ft	7.48	8.59	4.98
Bridge Section			
(Q) total discharge, cfs	4900	7570	1620
(Q) discharge thru bridge, cfs	1144	1146	1620
Main channel conveyance	10762	10762	12409
Total conveyance	10762	10762	12409
Q2, bridge MC discharge,cfs	1144	1146	1620
Main channel area, ft2	177	177	177
Main channel width (skewed), ft	30.1	30.1	30.1
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	30.1	30.1	30.1
y_bridge (avg. depth at br.), ft	5.88	5.88	5.88
Dm, median (1.25*D50), ft	0.54375	0.54375	0.54375
y2, depth in contraction,ft	3.33	3.33	4.49
ys, scour depth (y2-ybridge), ft	-2.55	-2.55	-1.39

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	4900	7570	1620
Q, thru bridge, cfs	1144	1146	1620
Total Conveyance, bridge	10762	10762	12409
Main channel(MC) conveyance, bridge	10762	10762	12409
Q, thru bridge MC, cfs	1144	1146	1620
Vc, critical velocity, ft/s	11.88	12.15	11.10
Vc, critical velocity, m/s	3.62	3.70	3.38
Main channel width (skewed), ft	30.1	30.1	30.1
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	30.1	30.1	30.1
qbr, unit discharge, ft2/s	38.0	38.1	53.8
qbr, unit discharge, m2/s	3.5	3.5	5.0
Area of full opening, ft2	177.0	177.0	177.0
Hb, depth of full opening, ft	5.88	5.88	5.88
Hb, depth of full opening, m	1.79	1.79	1.79
Fr, Froude number, bridge MC	0.47	0.47	0.66

Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	496.9	496.9	496.9
Elevation of Bed, ft	491.02	491.02	491.02
Elevation of Approach, ft	501.47	502.59	498.95
Friction loss, approach, ft	0.45	0.67	0.2
Elevation of WS immediately US, ft	501.02	501.92	498.75
ya, depth immediately US, ft	10.00	10.90	7.73
ya, depth immediately US, m	3.05	3.32	2.36
Mean elevation of deck, ft	499.31	499.31	499.31
w, depth of overflow, ft (>=0)	1.71	2.61	0.00
Cc, vert contrac correction (<=1.0)	0.91	0.91	0.93
Ys, depth of scour, ft	-2.37	-2.45	-0.68

Comparison of Chang and Laursen results (for unsubmerged orifice flow)

y2, from Laursen's equation, ft	3.329381	3.33437	4.486094
Full valley WSEL, ft	0	0	496.4
Full valley depth, ft	-491.02	-491.02	5.380399
Ys, depth of scour (y2-yfullv), ft	N/A	N/A	-0.8943

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	1620	4900	7570	1620
a', abut.length blocking flow, ft	12.2	12.2	14.2	3.5	3.5	3.4
Ae, area of blocked flow ft2	36.4	36.4	37.4	2.8	4.2	8.3
Qe, discharge blocked abut.,cfs	--	--	179.1	--	--	33.6
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	7.19	8.04	4.79	5.07	7.02	4.05
ya, depth of f/p flow, ft	2.98	2.98	2.63	0.80	1.20	2.44
--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	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.562	0.569	0.520	0.511	0.579	0.457
ys, scour depth, ft	10.14	10.20	9.42	2.67	3.74	5.69

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)	12.2	12.2	14.2	3.5	3.5	3.4
y1 (depth f/p flow, ft)	2.98	2.98	2.63	0.80	1.20	2.44
a'/y1	4.09	4.09	5.39	4.38	2.92	1.39
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.56	0.57	0.52	0.51	0.58	0.46
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.47	0.47	0.66	0.47	0.47	0.66
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5.88	5.88	5.88	5.88	5.88	5.88
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	0.80	0.80	1.58	0.80	0.80	1.58
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR