LEVEL II SCOUR ANALYSIS FOR BRIDGE 2 (BENNCYPARK0002) on PARK STREET, crossing FURNACE BROOK, BENNINGTON, VERMONT

U.S. Geological Survey
Open-File Report 97-341

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

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By SCOTT A. OLSON

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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 2 (BENNCYPARK0002) ON PARK STREET, CROSSING FURNACE BROOK, 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 BENNCYPARK0002 on the Park Street crossing of Furnace Brook, 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 12.8-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, homes, lawns, and pavement on the overbanks.

In the study area, Furnace Brook has a mildly sinuous channel located on a delta and has a slope of approximately 0.01 ft/ft, an average channel top width of 35 ft and an average bank height of 4 ft. The predominant channel bed materials are gravel and cobble with a median grain size (D_{50}) of 58.4 mm (0.192 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 unstable. However, in the immediate vicinity of the bridge the reach has been stabilized with bank protection. Upstream of the protection, there is bank cutting and channel scour.

The Park Street crossing of Furnace Brook is a 29-ft-long, two-lane bridge consisting of one 26-foot concrete span (Vermont Agency of Transportation, written communication, December 14, 1995). The width of the bridge opening parallel to the downstream bridge face is 25.3 feet. The bridge is supported by vertical, concrete abutments with no wingwalls. The upstream channel is skewed approximately 45 degrees to the opening while the opening-skew-to-roadway is 10 degrees.

Scour countermeasures at the site include type-2 stone fill (less than 36 inches diameter) on the right banks upstream and downstream of the bridge and type-3 stone fill (less than 48 inches diameter) on the upstream left bank. 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.

There was no contraction scour computed for any of the modelled flows. Computed left abutment scour ranged from 2.5 to 5.6 ft. with the worst-case scour occurring at the 500-year discharge. Computed right abutment scour ranged from 5.6 to 8.4 ft. with the worst-case scour also occurring at the 100-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

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 BENNCYPARK0002 ***Stream*** Furnace Brook

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

Description of Bridge

Bridge length 29 ***ft*** ***Bridge width*** 27 ***ft*** ***Max span length*** 26 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 8/6/96

Description of stone fill Type-2, along the upstream and downstream right banks. Type-3, along the upstream left bank.

Brief description of piers/abutments Abutments are concrete. There is 1.5 feet of scour below the mean thalweg depth along the right abutment.

N 45

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

There is a moderate channel bend at the bridge. The bend results in a channel impact zone on the right abutment and causes scour.

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 wide flood plains, but no valley.

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

Date of inspection 8/6/96

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

DS right: Roadway embankment and 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 35 *ft* ***Average depth*** 4 *ft*

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

Mildly sinuous in an alluvial setting with channel boundaries of man-placed materials on all but the DSLB.

8/6/96

Vegetative co Grass, trees, and residences. More forested further downstream.

DS left: Grass and brush on banks. Grass and a street on the overbank.

DS right: Grass. Forested further upstream.

US left: Grass and a street with some brush in the immediate vicinity of the bridge.

US right:

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

August 6, 1996. Except for the downstream left, the banks in the immediate vicinity of the bridge are protected. However, cut banks and point bars upstream of the protection resulted in a geomorphic assessment of laterally unstable.

Describe any obstructions in channel and date of observation.

August 6, 1996. At the downstream face of the bridge there is a narrow concrete slab exposed across most of the channel. This concrete is flush with the channel bed and will not obstruct flow. However, it may impede scour.

Hydrology

Drainage area 12.8 ***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? No

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

--

Calculated Discharges

Q100 2,760 ***ft³/s*** ***Q500*** 5,400 ***ft³/s***

The 100- and 500-year discharges were estimated using a drainage area relationship ([12.8/11.0]to the 0.67 power) with flood frequency estimates for bridge 24 over Furnace Brook in Bennington found in the VTAOT database (written communication, May 1994). 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).

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 500.1 ft to USGS survey datum to obtain VTAOT plans' datum. Add 147.5 ft to USGS survey to obtain NGVD.

Description of reference marks used to determine USGS datum.

RM1 is a chiseled X on top of the downstream left corner of the left abutment (elev. 501.57 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream right corner of the right abutment (elev. 501.37 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	-24	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	21	1	Road Grade section
APPRO	70	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 0.045, and overbank "n" values ranged from 0.035 to 0.070.

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 0.0149 ft/ft which determined from surveyed thalweg points downstream of the bridge. The resulting normal water-surface elevations for the 100- and 500-year discharges were within 0.5 ft below critical depth.

For the 100- and 500-year discharges modelled at this site, 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 500.3 ***ft***
Average low steel elevation 498.2 ***ft***

100-year discharge 2,760 ***ft^3/s***
Water-surface elevation in bridge opening 498.3 ***ft***
Road overtopping? Y ***Discharge over road*** 2,100 ***ft^3/s***
Area of flow in bridge opening 104 ***ft^2***
Average velocity in bridge opening 6.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 8.6 ***ft/s***

Water-surface elevation at Approach section with bridge 501.4
Water-surface elevation at Approach section without bridge 501.0
Amount of backwater caused by bridge 0.4 ***t***

500-year discharge 5,400 ***ft^3/s***
Water-surface elevation in bridge opening 498.3 ***ft***
Road overtopping? Y ***Discharge over road*** 4,650 ***ft^3/s***
Area of flow in bridge opening 104 ***ft^2***
Average velocity in bridge opening 6.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 7.8 ***/s***

Water-surface elevation at Approach section with bridge 502.2
Water-surface elevation at Approach section without bridge 501.8
Amount of backwater caused by bridge 0.4

Incipient overtopping discharge 770 ***ft^3/s***
Water-surface elevation in bridge opening 498.3 ***ft***
Area of flow in bridge opening 104 ***ft^2***
Average velocity in bridge opening 7.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.4 ***ft/s***

Water-surface elevation at Approach section with bridge 499.7
Water-surface elevation at Approach section without bridge 498.7
Amount of backwater caused by bridge 1.0 ***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 contraction scour results for all modelled flows using the Chang equation was zero feet. 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.

Scour at the right abutment was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	0.0
Depth to armoring	0.8	0.4	6.4
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	4.7	5.6	2.5
Right abutment	8.4	8.1	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	0.9	0.8	1.4
Right abutment	0.9	0.8	1.4
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

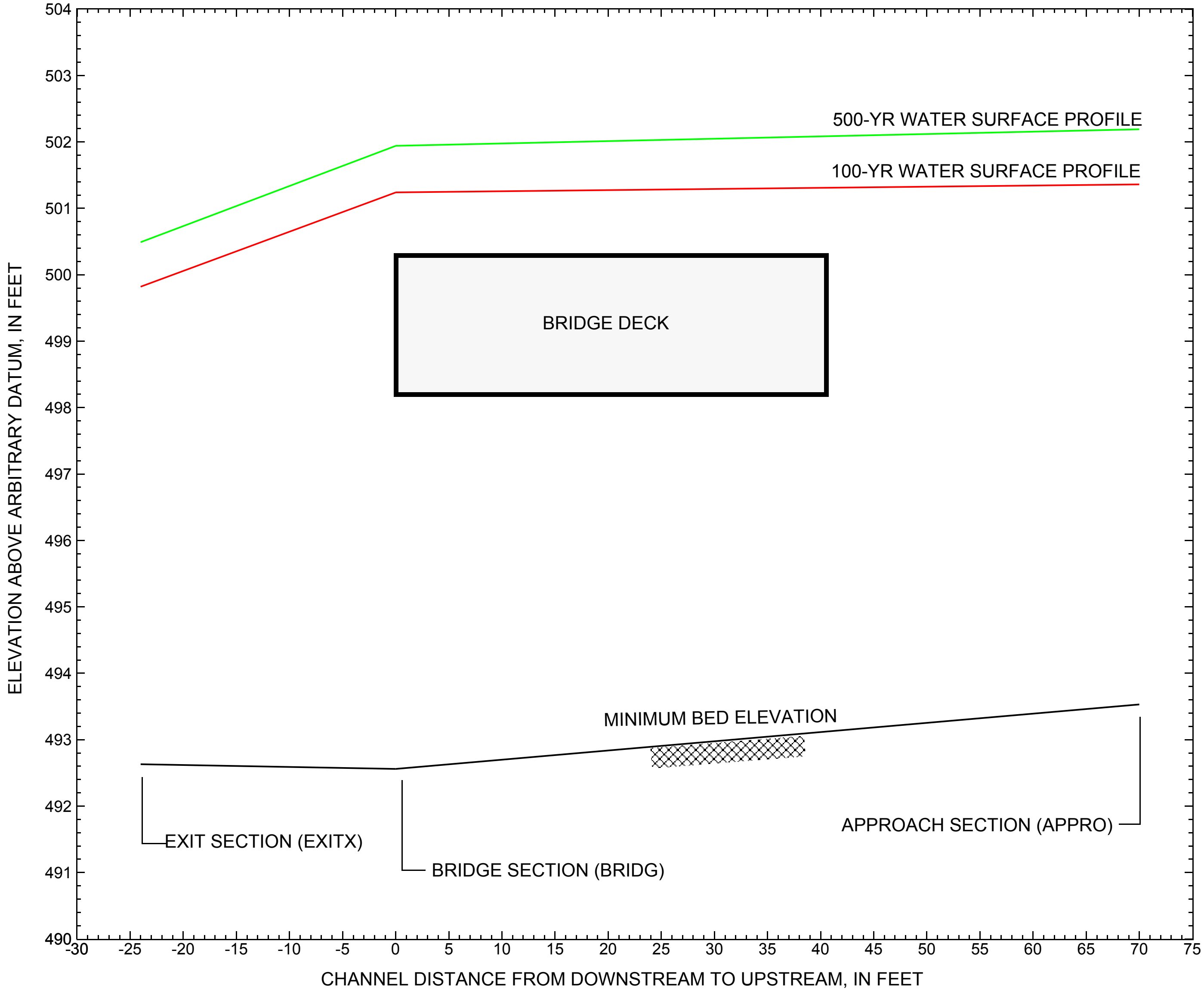

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure BENNCYPARK0002 on Park Street, crossing Furnace Brook, Bennington, Vermont.

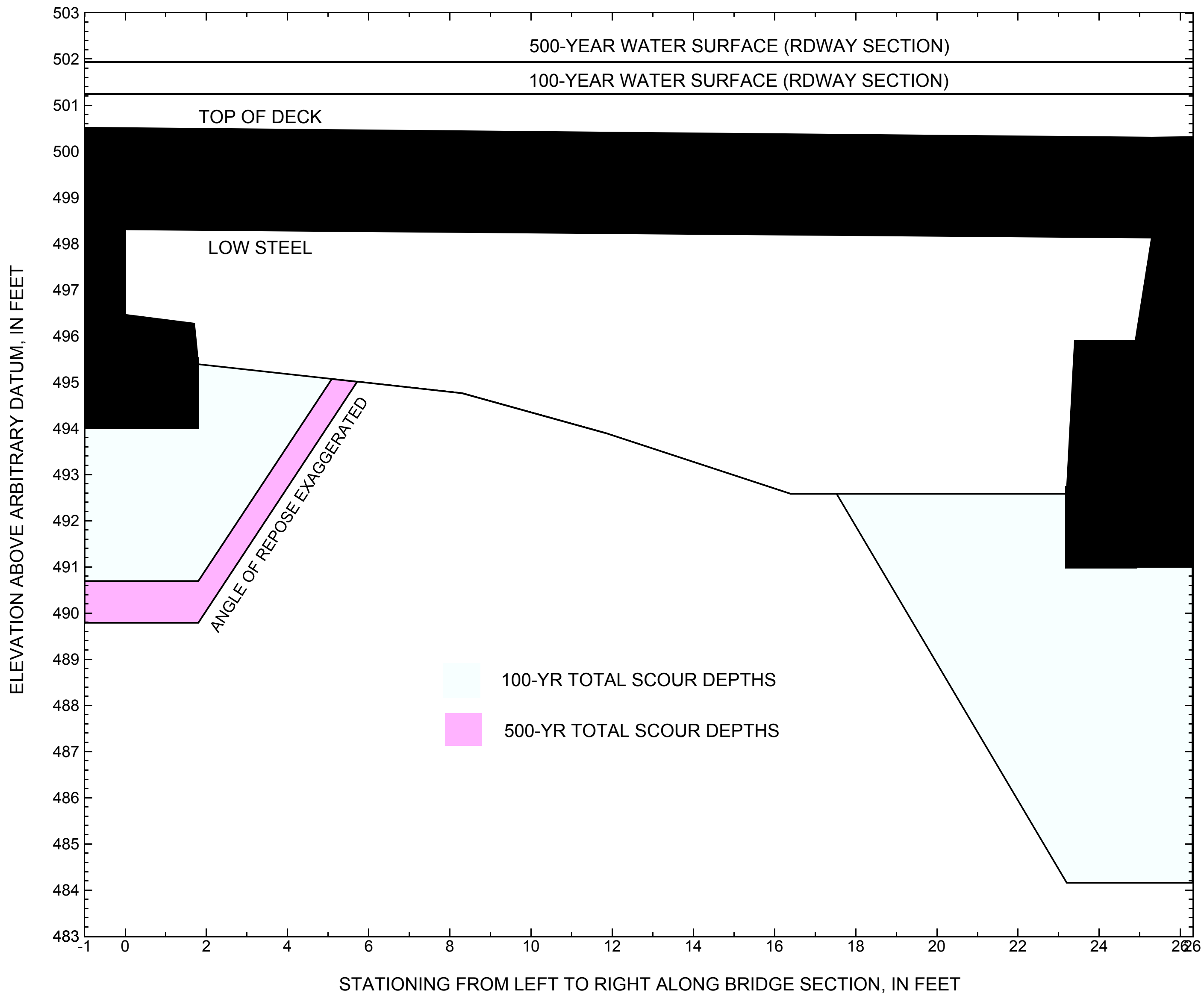

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure BENNCYPARK0002 on Park Street, crossing Furnace Brook, Bennington, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure BENNCYPARK0002 on Park Street, crossing Furnace Brook, 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 2,760 cubic-feet per second											
Left abutment	0.0	998.4	498.3	494	495.4	0.0	4.7	--	4.7	490.7	-3
Right abutment	25.3	998.3	498.1	491	492.6	0.0	8.4	--	8.4	484.2	-7

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 BENNCYPARK0002 on Park Street, crossing Furnace Brook, 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 5,400 cubic-feet per second											
Left abutment	0.0	998.4	498.3	494	495.4	0.0	5.6	--	5.6	489.8	-4
Right abutment	25.3	998.3	498.1	491	492.6	0.0	8.1	--	8.1	484.5	-7

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

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U.S. Geological Survey, 1954, Bennington, 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 benn002.wsp
T2        Hydraulic analysis for structure BENNCYPARK0002   Date: 23-JAN-97
T3        Park Street bridge over Furnace Brook    SAO
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2760 5400 770
SK          0.0149 0.0149 0.0149
*
XS   EXITX    -24
GR         -582.6, 504.63   -356.5, 502.51   -139.4, 499.16     -8.6, 496.67
GR            0.0, 496.12      3.6, 493.71      7.2, 492.93      9.5, 492.83
GR           12.7, 493.02     18.3, 492.63     20.0, 493.59     29.1, 499.10
GR          114.5, 498.58    288.1, 499.39    378.7, 503.65    467.7, 512.08
N           0.070        0.045        0.035
SA                   0.0         29.1
*
XS   FULLV     0 * * * 0.0149
*
BR   BRIDG     0 498.22 10
GR            0.0, 498.31      0.0, 496.46      1.7, 496.27      1.8, 495.39
GR            8.3, 494.76     11.9, 493.88     16.4, 492.58     23.2, 492.56
GR           23.4, 493.94     24.9, 495.90     25.3, 498.13      0.0, 498.31
N             0.035
CD           1 41.3
*
*
XR   RDWAY     21 27
GR         -568.7, 506.03    -84.2, 499.62     -6.4, 500.57     -6.3, 501.58
GR            0.0, 501.54     25.8, 501.44     32.1, 501.16     32.4, 499.93
GR           97.5, 499.52    339.7, 501.85    493.9, 513.42
*
*             one bridge length is approximately SRD=66
*
AS   APPRO     70
GR        -1388.8, 525.47   -521.0, 506.17   -366.1, 502.80   -191.3, 500.01
GR         -110.1, 499.52     -6.2, 498.97      0.0, 494.88      2.0, 493.89
GR            5.7, 493.70      8.6, 493.53     13.5, 493.82     16.7, 494.29
GR           17.7, 494.85     25.5, 496.79     34.5, 500.49    371.7, 501.09
GR          525.2, 513.29
N           0.040      0.040       0.040
SA                -6.2      34.5
*
HP 1 BRIDG     498.31 1 498.31
HP 2 BRIDG     498.31 * * 707
HP 2 RDWAY     501.24 * * 2100
HP 1 APPRO     501.36 1 501.36
HP 2 APPRO     501.36 * * 2760
*
HP 1 BRIDG     498.31 1 498.31
HP 2 BRIDG     498.31 * * 640
HP 2 RDWAY     501.94 * * 4654
HP 1 APPRO     502.19 1 502.19
HP 2 APPRO     502.19 * * 5400
*
HP 1 BRIDG     498.31 1 498.31
HP 2 BRIDG     498.31 * * 770
```

APPENDIX B:

WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File benn002.wsp
      Hydraulic analysis for structure BENNCYPARK0002   Date: 23-JAN-97
      Park Street bridge over Furnace Brook    SAO
         *** RUN DATE & TIME: 03-20-97  11:49
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     104.    6578.     0.    57.                          0.
  498.31           104.    6578.     0.    57.  1.00     0.    25.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.31     0.0    25.3   103.6    6578.     707.   6.83
 X STA.         0.0         3.5         5.6         7.4         9.1        10.5
   A(I)             8.6         6.5         5.9         5.8         5.4
   V(I)            4.11        5.48        6.00        6.13        6.53

 X STA.        10.5        11.7        12.9        13.9        14.8        15.6
   A(I)             5.1         4.9         4.6         4.6         4.4
   V(I)            6.97        7.19        7.63        7.74        8.10

 X STA.        15.6        16.4        17.2        17.9        18.7        19.4
   A(I)             4.3         4.1         4.1         4.2         4.2
   V(I)            8.22        8.59        8.52        8.39        8.44

 X STA.        19.4        20.2        21.0        21.9        22.8        25.3
   A(I)             4.4         4.4         4.7         5.1         8.3
   V(I)            8.10        7.99        7.50        6.93        4.24

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      21.
         WSEL     LEW     REW    AREA        K        Q    VEL
       501.24  -206.6   276.3   441.0   14759.    2100.   4.76
 X STA.      -206.6      -119.5       -93.8       -74.2       -52.6       -18.5
   A(I)            50.3        33.9        30.6        29.5        34.9
   V(I)            2.09        3.09        3.43        3.56        3.01

 X STA.       -18.5        42.4        52.4        61.9        70.8        79.5
   A(I)            22.7        14.1        14.0        13.6        13.7
   V(I)            4.63        7.47        7.51        7.71        7.68

 X STA.        79.5        87.9        96.0       104.3       113.3       123.7
   A(I)            13.7        13.7        14.1        14.5        15.7
   V(I)            7.68        7.68        7.44        7.26        6.68

 X STA.       123.7       135.5       149.4       167.2       191.7       276.3
   A(I)            16.7        17.9        20.2        22.9        34.4
   V(I)            6.30        5.86        5.19        4.59        3.05

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      70.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     406.   19894.   270.   270.                       2830.
             2     227.   25585.    41.    43.                       3050.
             3     193.    4909.   341.   341.                        822.
  501.36           826.   50387.   651.   654.  2.00  -276.   375.   3736.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      70.
         WSEL     LEW     REW    AREA        K        Q    VEL
       501.36  -275.9   375.1   826.4   50387.    2760.   3.34

 X STA.      -275.9      -174.5      -137.0      -107.9       -82.7       -60.6
   A(I)            80.7        58.7        51.3        48.3        45.3
   V(I)            1.71        2.35        2.69        2.86        3.05

 X STA.       -60.6       -40.1       -21.8        -4.6         0.6         3.3
   A(I)            44.1        41.4        41.5        26.6        19.7
   V(I)            3.13        3.34        3.33        5.19        7.01

 X STA.         3.3         5.8         8.2        10.5        13.0        15.7
   A(I)            18.8        18.6        18.5        18.5        20.1
   V(I)            7.33        7.43        7.44        7.46        6.86

 X STA.        15.7        18.8        23.1        31.5       136.9       375.1
   A(I)            21.3        24.3        31.6        84.3       112.9
   V(I)            6.47        5.69        4.36        1.64        1.22
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        U.S. Geological Survey WSPRO Input File benn002.wsp
        Hydraulic analysis for structure BENNCYPARK0002   Date: 23-JAN-97
        Park Street bridge over Furnace Brook    SAO
           *** RUN DATE & TIME: 03-20-97  11:49
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#    AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1     104.    6578.    0.    57.                          0.
   498.31          104.    6578.    0.    57.  1.00     0.    25.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.31     0.0    25.3   103.6    6578.     640.   6.18
 X STA.         0.0         3.5         5.6         7.4         9.1        10.5
  A(I)              8.6         6.5         5.9         5.8         5.4
  V(I)             3.72        4.96        5.43        5.55        5.91

 X STA.        10.5        11.7        12.9        13.9        14.8        15.6
  A(I)              5.1         4.9         4.6         4.6         4.4
  V(I)             6.31        6.51        6.91        7.01        7.33

 X STA.        15.6        16.4        17.2        17.9        18.7        19.4
  A(I)              4.3         4.1         4.1         4.2         4.2
  V(I)             7.44        7.77        7.71        7.60        7.64

 X STA.        19.4        20.2        21.0        21.9        22.8        25.3
  A(I)              4.4         4.4         4.7         5.1         8.3
  V(I)             7.34        7.24        6.79        6.27        3.84

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      21.
         WSEL     LEW     REW    AREA        K        Q    VEL
       501.94  -259.6   340.9   813.7   33799.    4654.   5.72
 X STA.      -259.6      -140.2      -105.2       -80.1       -54.5       -23.2
  A(I)             94.2        63.4        55.2        54.1        55.3
  V(I)             2.47        3.67        4.22        4.30        4.21

 X STA.       -23.2        38.7        50.6        62.0        73.1        83.8
  A(I)             55.9        25.0        24.6        24.6        24.6
  V(I)             4.16        9.30        9.46        9.44        9.45

 X STA.        83.8        94.2       104.6       115.8       128.4       142.4
  A(I)             24.6        24.9        25.9        27.4        28.7
  V(I)             9.46        9.35        8.98        8.49        8.11

 X STA.       142.4       158.8       177.9       201.9       236.4       340.9
  A(I)             31.3        33.2        36.7        43.2        60.6
  V(I)             7.43        7.00        6.33        5.38        3.84

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      70.
     WSEL  SA#    AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1     652.   38873.   322.   322.                      5264.
             2     261.   32228.    41.    43.                      3755.
             3     480.   22002.   351.   351.                      3182.
   502.19         1393.   93103.   713.   716.  1.62  -328.   386.   8668.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      70.
         WSEL     LEW     REW    AREA        K        Q    VEL
       502.19  -327.9   385.5  1392.7   93103.    5400.   3.88
 X STA.      -327.9      -200.8      -161.6      -129.2      -101.6       -76.8
  A(I)            128.9        87.4        79.5        72.8        68.9
  V(I)             2.09        3.09        3.40        3.71        3.92

 X STA.       -76.8       -53.8       -32.5       -12.8        -0.1         4.1
  A(I)             67.1        64.3        61.8        52.8        34.0
  V(I)             4.02        4.20        4.37        5.11        7.94

 X STA.         4.1         7.8        11.5        15.4        20.2        27.9
  A(I)             31.5        31.8        32.3        36.0        43.4
  V(I)             8.57        8.49        8.35        7.50        6.22

 X STA.        27.9        74.8       133.4       201.2       278.3       385.5
  A(I)             87.5        92.4        99.2       102.9       118.2
  V(I)             3.09        2.92        2.72        2.62        2.28
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File benn002.wsp
        Hydraulic analysis for structure BENNCYPARK0002   Date: 23-JAN-97
        Park Street bridge over Furnace Brook    SAO
           *** RUN DATE & TIME: 03-20-97  11:49
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     104.    6578.     0.    57.                          0.
   498.31          104.    6578.     0.    57.  1.00     0.    25.      0.

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      87.    7488.    25.    31.                        931.
   497.57           87.    7488.    25.    31.  1.00     0.    25.    931.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       498.31     0.0    25.3   103.6    6578.     770.   7.43
X STA.        0.0        3.5         5.6         7.4         9.1        10.5
  A(I)           8.6         6.5         5.9         5.8         5.4
  V(I)          4.48        5.97        6.53        6.68        7.11

X STA.       10.5       11.7        12.9        13.9        14.8        15.6
  A(I)           5.1         4.9         4.6         4.6         4.4
  V(I)          7.59        7.84        8.31        8.43        8.82

X STA.       15.6       16.4        17.2        17.9        18.7        19.4
  A(I)           4.3         4.1         4.1         4.2         4.2
  V(I)          8.96        9.35        9.28        9.14        9.19

X STA.       19.4       20.2        21.0        21.9        22.8        25.3
  A(I)           4.4         4.4         4.7         5.1         8.3
  V(I)          8.83        8.71        8.17        7.55        4.62

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      70.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      51.    1001.   135.   135.                        179.
             2     161.   14860.    39.    41.                       1861.
   499.71          212.   15861.   174.   177.  1.43  -142.    33.   1111.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      70.
         WSEL     LEW     REW    AREA        K        Q    VEL
       499.71  -141.6    32.6   212.3   15861.     770.   3.63
X STA.     -141.6      -17.9        -1.5         0.7         2.1         3.4
  A(I)          43.0        19.2         9.7         8.1         7.6
  V(I)          0.89        2.01        3.97        4.74        5.05

X STA.        3.4        4.7         5.8         7.0         8.1         9.2
  A(I)           7.2         7.1         6.9         6.9         6.9
  V(I)          5.32        5.46        5.59        5.59        5.55

X STA.        9.2       10.4        11.5        12.7        14.0        15.3
  A(I)           7.0         7.0         7.2         7.3         7.6
  V(I)          5.47        5.53        5.35        5.25        5.06

X STA.       15.3       16.8        18.6        20.8        23.7        32.6
  A(I)           8.1         9.0         9.5        11.0        15.9
  V(I)          4.73        4.26        4.07        3.51        2.43
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        U.S. Geological Survey WSPRO Input File benn002.wsp
        Hydraulic analysis for structure BENNCYPARK0002   Date: 23-JAN-97
        Park Street bridge over Furnace Brook    SAO
           *** RUN DATE & TIME: 03-20-97  11:49

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                          WSI,CRWS =   499.39     499.82

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

EXITX:XS   ******  -182.     684.  0.56 *****  500.38  499.82   2760.  499.82
      -24. ******   297.   33174.  2.20 ***** *******    0.88    4.04

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   499.32     512.44    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   499.32     512.44     500.18
 ===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 =   500.18     512.44     500.18

FULLV:FV      24.  -182.     684.  0.56 *****  500.73  500.18   2760.  500.18
        0.    24.   297.   33174.  2.20 ***** *******    0.88    4.04
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   499.68     525.47    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   499.68     525.47     501.03
 ===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 =   501.03     525.47     501.03

APPRO:AS      70.  -255.     615.  0.62 *****  501.65  501.03   2760.  501.03
       70.    70.   336.   38441.  1.98 ***** *******    1.09    4.49
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                      WS3N,LSEL =   500.18     498.22
 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                 QRD,QRDMAX,RATIO =    2100.      1977.    1.06

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

BRIDG:BR      24.     0.     104.  0.72 *****  499.03  496.98    707.  498.31
        0. ******    25.    6578.  1.00 ***** *******    0.59    6.82

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  498.22 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       21.    43.  0.13  0.35  501.58    0.02   2100.  501.24

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    885.   200.  -206.    -6.   1.6   0.9   5.2   4.7   1.3   3.1
   RT:   1215.   245.    30.   276.   1.7   1.0   5.4   4.8   1.4   3.1

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

APPRO:AS      29.  -276.     828.  0.35  0.40  501.71  501.03   2760.  501.36
       70.    46.   375.   50462.  2.00  0.00    0.02    0.74    3.33

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -24.  -182.   297.   2760.   33174.     684.    4.04  499.82
   FULLV:FV       0.  -182.   297.   2760.   33174.     684.    4.04  500.18
   BRIDG:BR       0.     0.    25.    707.    6578.     104.    6.82  498.31
   RDWAY:RG      21.*******   885.   2100.******************    1.00  501.24
   APPRO:AS      70.  -276.   375.   2760.   50462.     828.    3.33  501.36

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    499.82    0.88  492.63  512.08************  0.56  500.38  499.82
   FULLV:FV    500.18    0.88  492.99  512.44************  0.56  500.73  500.18
   BRIDG:BR    496.98    0.59  492.56  498.31************  0.72  499.03  498.31
   RDWAY:RG  ****************  499.52  513.42  0.13******  0.35  501.58  501.24
   APPRO:AS    501.03    0.74  493.53  525.47  0.40  0.00  0.35  501.71  501.36
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File benn002.wsp
        Hydraulic analysis for structure BENNCYPARK0002   Date: 23-JAN-97
        Park Street bridge over Furnace Brook    SAO
           *** RUN DATE & TIME: 03-20-97  11:49

 ===015 WSI IN WRONG FLOW REGIME AT SECID “EXITX”:  USED WSI = CRWS.
                           WSI,CRWS =   500.17     500.49

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

EXITX:XS   ******  -226.    1024.  0.77 *****  501.26  500.49   5400.  500.49
      -24. ******   311.   55916.  1.78 ***** *******    0.90    5.27

 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   499.99     512.44    0.50
 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   499.99     512.44     500.85
 ===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 “FULLV”
                 WSBEG,WSEND,CRWS =   500.85     512.44     500.85

FULLV:FV      24.  -226.    1024.  0.77 *****  501.62  500.85   5400.  500.85
        0.    24.   311.   55916.  1.78 ***** *******    0.90    5.27
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   500.35     525.47    0.50
 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   500.35     525.47     501.79
 ===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 =   501.79     525.47     501.79

APPRO:AS      70.  -303.    1112.  0.66 *****  502.45  501.79   5400.  501.79
       70.    70.   380.   70306.  1.81 ***** *******    0.90    4.85
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                      WS3N,LSEL =   500.85     498.22
 ===265 ROAD OVERFLOW APPEARS EXCESSIVE.
                 QRD,QRDMAX,RATIO =    4654.      4571.    1.02

            <<<<<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      24.     0.     104.  0.59 *****  498.90  496.78    640.  498.31
        0. ******    25.    6578.  1.00 ***** *******    0.54    6.18

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  498.22 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      21.    43.  0.14  0.38  502.43   -0.02   4654.  501.94

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   2026.   275.  -260.    16.   2.3   1.3   6.2   5.7   1.8   3.1
   RT:   2628.   325.    16.   341.   2.4   1.4   6.4   5.7   1.9   3.1

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

APPRO:AS      29.  -328.    1395.  0.38  0.80  502.57  501.79   5400.  502.19
       70.    52.   386.   93280.  1.62  0.00   -0.02    0.62    3.87

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW     REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -24.  -226.    311.   5400.   55916.    1024.    5.27  500.49
   FULLV:FV       0.  -226.    311.   5400.   55916.    1024.    5.27  500.85
   BRIDG:BR       0.     0.     25.    640.    6578.     104.    6.18  498.31
   RDWAY:RG      21.*******   2026.   4654.*****************    1.00  501.94
   APPRO:AS      70.  -328.    386.   5400.   93280.    1395.    3.87  502.19

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    500.49    0.90  492.63  512.08************  0.77  501.26  500.49
   FULLV:FV    500.85    0.90  492.99  512.44************  0.77  501.62  500.85
   BRIDG:BR    496.78    0.54  492.56  498.31************  0.59  498.90  498.31
   RDWAY:RG  ****************  499.52  513.42  0.14******  0.38  502.43  501.94
   APPRO:AS    501.79    0.62  493.53  525.47  0.80  0.00  0.38  502.57  502.19
```
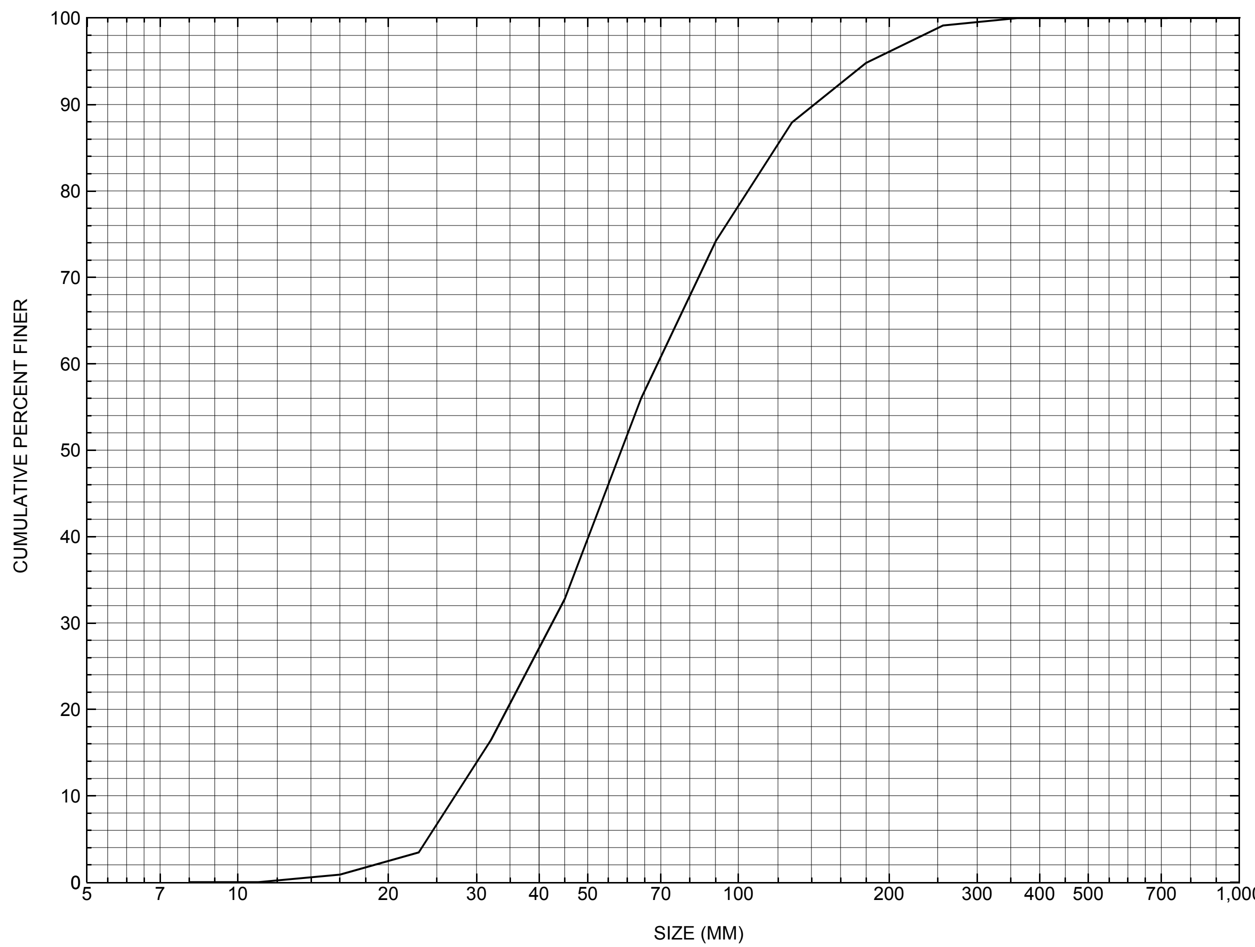

```
        U.S. Geological Survey WSPRO Input File benn002.wsp
        Hydraulic analysis for structure BENNCYPARK0002   Date: 23-JAN-97
        Park Street bridge over Furnace Brook    SAO
           *** RUN DATE & TIME: 03-20-97  11:49

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

EXITX:XS   ******   -35.     100.  1.13 *****  498.30  496.97    770.  497.17
      -24. ******    26.    6304.  1.24 ***** *******    1.17    7.67

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80     1.16     497.56     497.33
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.67     512.44    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.67     512.44     497.33

FULLV:FV      24.   -37.     103.  1.09  0.35  498.66  497.33    770.  497.57
        0.    24.    26.    6455.  1.26  0.00    0.01    1.15    7.46
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

APPRO:AS      70.    -6.     122.  0.62  0.65  499.29 *******    770.  498.68
       70.    70.    30.    9919.  1.00  0.00   -0.02    0.60    6.30
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   497.19     498.81     499.05     498.22
 ===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      24.     0.     104.  0.84 *****  499.15  497.13    761.  498.31
        0. ******    25.    6578.  1.00 ***** *******    0.64    7.35

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.479  0.000  498.22 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      21.        <<<<<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      29.  -142.     212.  0.29  0.17  500.00  497.52    770.  499.71
       70.    29.    33.   15863.  1.43  0.61   -0.01    0.69    3.63

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   499.61

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -24.   -35.    26.    770.    6304.     100.    7.67  497.17
   FULLV:FV       0.   -37.    26.    770.    6455.     103.    7.46  497.57
   BRIDG:BR       0.     0.    25.    761.    6578.     104.    7.35  498.31
   RDWAY:RG      21.**************      0.       0.       0.    1.00********
   APPRO:AS      70.  -142.    33.    770.   15863.     212.    3.63  499.71

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    496.97    1.17  492.63  512.08************  1.13  498.30  497.17
   FULLV:FV    497.33    1.15  492.99  512.44  0.35  0.00  1.09  498.66  497.57
   BRIDG:BR    497.13    0.64  492.56  498.31************  0.84  499.15  498.31
   RDWAY:RG  ****************  499.52  513.42************  0.29  499.90********
   APPRO:AS    497.52    0.69  493.53  525.47  0.17  0.61  0.29  500.00  499.71
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure BENNCYPARK0002, in Bennington, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number BENNCYPARK0002

General Location Descriptive

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

Date *(MM/DD/YY)* 12 / 14 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 04825

Mile marker *(I - 11; nnn.nnn)* 000660

Waterway *(I - 6)* FURNACE BROOK

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

Route Number -

Vicinity *(I - 9)* -

Topographic Map Bennington

Hydrologic Unit Code: 2020003

Latitude *(I - 16; nnnn.n)* 42536

Longitude *(i - 17; nnnnn.n)* 73115

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20103800020202

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

Maximum span length *(I - 48; nnnn)* 0026

Year built *(I - 27; YYYY)* 1960

Structure length *(I - 49; nnnnnn)* 000029

Average daily traffic, ADT *(I - 29; nnnnnn)* 008300

Deck Width *(I - 52; nn.n)* 270

Year of ADT *(I - 30; YY)* 94

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

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

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

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

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

Structure type *(I - 43; nnn)* 104

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 26

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

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

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

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

Comments:

***No info on vertical clearance or opening area. According to the structural inspection report dated 6/1/94, this structure is a single span concrete T-beam bridge. The widened portions of the abutments are in good condition, with only minor cracking and scaling. The original portions of the abutments have areas of staining and scaling. There is one full depth crack in the LAB toward the right end of the original portion. Both abutments have a concrete facing near the flow line. The channel takes a moderate turn into the structure. Flow is currently toward the right side of the channel, where there is some scour along the RAB facing, though no undermining noted. There is a sand build up along the LAB side of the channel.**

Bridge Hydrologic Data

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

Terrain character: ________

Stream character & type:

Streambed material: ________

Discharge Data *(cfs)*: $Q_{2.33}$ ________ Q_{10} ________ Q_{25} ________

Q_{50} ________ Q_{100} ________ Q_{500} ________

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes:

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

Relief Elevation (*ft*): ________ Discharge over roadway at Q_{100} (*ft³/ 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 (*ft²*): ________

Downstream distance (*miles*): ___________ Town: ___________________ Year Built: ______

Highway No. : ________________ Structure No. : ______ Structure Type: ______________________

Clear span (*ft*): _____ Clear Height (*ft*): ______ Full Waterway (ft^2): _______

Comments:

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **12.76** mi^2 Lake and pond area **0.001** mi^2

Watershed storage *(ST)* **0** %

Bridge site elevation **649** ft Headwater elevation **3418** ft

Main channel length **8.53** mi

10% channel length elevation **720** ft 85% channel length elevation **1330** ft

Main channel slope *(S)* **47.68** 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 SA 42 1958 Minimum channel bed elevation: -

Low superstructure elevation: USLAB 998.37 DSLAB 998.37 USRAB 998.07 DSRAB 998.28

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 2.0 Footing bottom elevation: 991.0

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:

Low steel elevation shown is an average overall low steel elevation. Footing bottom elevation for the RAB is 991'; for the LAB is 994'.

The low superstructure elevations are bridge seat elevations.

Cross-sectional Data

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

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

Comments:

Station	1607	1612	1618	1626	1630	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low cord elevation	646.6	646.6	646.6	646.6	646.6	-	-	-	-	-	-
Bed elevation	641.9	640.9	640.9	641.9	-	-	-	-	-	-	-
Low cord to bed length	4.7	5.7	5.7	5.5	-	-	-	-	-	-	-

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: **RB** Date: **10/7/96**
Computerized by: **RB** Date: **10/8/96**
Reviewd by: **SAO** Date: **4/2/97**

Structure Number **BENNCYPARK0002**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E**. **BOEHMLER** Date *(MM/DD/YY)* **08** / **06** / 19**96**

2. Highway District Number **01** Mile marker **0000**

County **003 BENNINGTON** Town **04825 BENNINGTON**

Waterway *(I - 6)* **FURNACE BROOK** Road Name **PARK STREET**

Route Number **-** Hydrologic Unit Code: **2020003**

3. Descriptive comments:
Located at the intersection of Park Street and North Branch Extension.

B. Bridge Deck Observations

4. Surface cover... LBUS **5** RBUS **4** LBDS **4** RBDS **4** Overall **4**
*(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 **1** UB **2** DS **1** *(**1**- pool; **2**- riffle)*

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

7. Bridge length **29** *(feet)* Span length **26** *(feet)* Bridge width **27** *(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)*

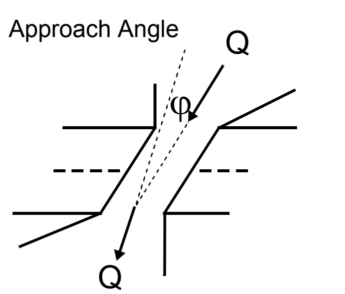
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

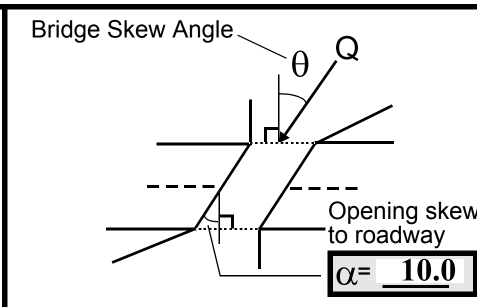
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	0	0
RBUS	1	1	0	0
RBDS	2	1	2	1
LBDS	0	-	0	0

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

Channel approach to bridge (BF):

15. Angle of approach: **30** 16. Bridge skew: **45**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **3**
Range? **15** feet **US** *(US, UB, DS)* to **15** feet **UB**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **0**
Range? **45** feet **DS** *(US, UB, DS)* to **70** feet **DS**

*Impact Severity: **0**- none to very slight; **1**- Slight; **2**- Moderate; **3**- Severe*

18. Bridge Type: **1b**

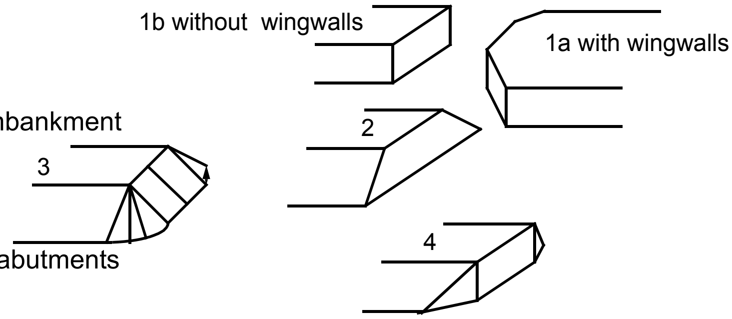
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

7. Values are from the VT AOT files. Measured bridge length is 30 ft., bridge width is 27, and clear span length is 27 ft. (at the DS face).
4. The North Branch Extension roadway runs along the US and DS right bank.
The US bridge face is curved with the US most concrete beam support in the shape of a "Y".

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
32.0	4.0			5.5	1	1	324	234	0	0

23. Bank width **35.0** 24. Channel width **20.0** 25. Thalweg depth **40.5** 29. Bed Material **342**

30 .Bank protection type: LB **3** RB **2** 31. Bank protection condition: LB **1** RB **1**

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

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

30. Both banks are protected with some placed channel material and fill of cobbles and boulders. The left bank side has at least 5 slabs of concrete laid on the cobble and boulder material and angled in toward the center of the channel. Bank protection extends from the bridge face to 95 ft. US.
27. Bank material assessment was made US of 100 ft. US.
There is a pooled area of the channel in the US reach between 2 riffle zones all within 100 ft. of the bridge. The gradient is moderate.

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

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

37. Material: -

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

NO POINT BARS

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

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

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

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

NO CUT BANKS

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 50

47. Scour dimensions: Length 35 Width 7 Depth : 1 Position 10 %LB to 65 %RB

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

The concrete slabs on the left bank and the stone fill on the right bank constrict the channel in the region of 30 ft. US to 65 ft. US and the channel responds with localized bed scouring.

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

51. Confluence 1: Distance 100 52. Enters on LB (LB or RB) 53. Type 1 (1- perennial; 2- ephemeral)

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

54. Confluence comments (eg. confluence name):

This confluence has no name and is very small.

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	RB	57 Angle (BF) LB	RB	61. Material (BF) LB	RB	62. Erosion (BF) LB	RB
17.5		1.5		2	7	7	0

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

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

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

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

342

The stream bed under the bridge drops at least 2 ft. in elevation between the US face and 8 ft. under the bridge. The flow shifts from covering the entire bed to only 25% of the bed under the bridge. A large bar has developed along the left abutment and the main channel flow is along the right abutment. The channel deepens from 0.5 ft. at the US face to 2 ft. deep at 8 ft. under the bridge from the US bridge face, and remains at this depth the remaining width of the bridge. The point bar extends from 4 ft. under the bridge to 0 ft. DS. It is positioned from 0% LB to 75% RB and is composed of mainly gravel with coarse sand and cobbles. The material coarsens toward the right abutment. The bar is 13 ft. wide at 16 ft. under the bridge from the DS

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

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

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

70. Debris and Ice Comments:

2
2
N
2

Ice and debris will likely get hung up on the bar under the bridge. Low chord is very low with only about 4

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	ft. of	clear	ance	at	the	US	face.	90.0
RABUT	Ther	e are	trees			on	the	24.0

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.):

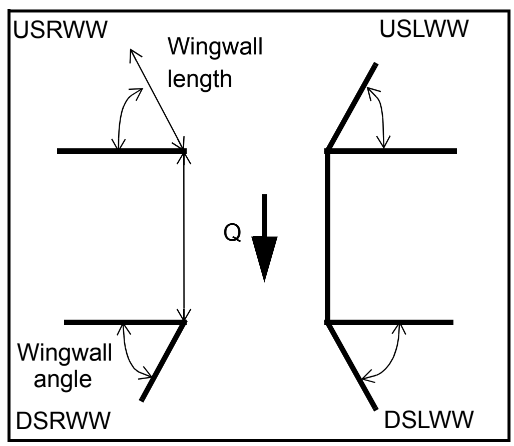
banks US.

-
90
2
2
0
1.0

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:	1		35		90	24.0	
USRWW:	2		2		1.5	1.5	
DSLWW:	4.5		1		Ther	33.5	
DSRWW:	e are		large		con-	49.0	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	cret	ngs	left	t	ts.	evi-	alon	righ
Condition	e	on	and	abut	Sco	dent	g	t
Extent	footi	the	righ	men	ur is	only	the	abut

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.):

ment and the scour depth ranges from 1 ft. to 1.5 ft. with an ambient thalweg depth elsewhere of 1 ft. The right abutment footing at the US most 8 ft. is angled at 35 degrees relative to the rest of the footing. This angled footing is in the direction of flow from the US reach. There is a concrete slab across the bed at the DS face on the right abutment side that appears to be built into the right abutment footing. This slab may impede localized scour.

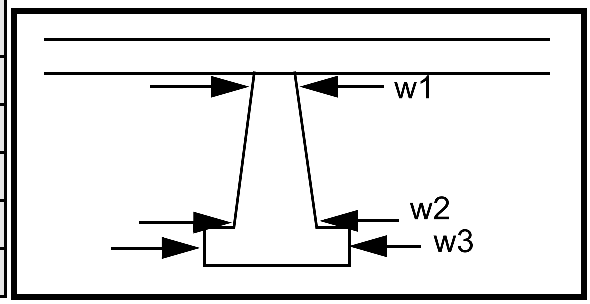
N

-

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		**9.0**	**6.0**	**35.0**	**35.0**	**180.0**
Pier 2	**6.0**		**-**	**30.0**	**10.5**	**-**
Pier 3	**-**	**-**	**-**	**-**	**-**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**-**	**N**	**-**	**-**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**-**	**-**	**-**	**-**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**N**	**-**	**0**	**0**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**-**	**-**	**-**	**-**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**-**	**-**	**-**	**-**	*Y- yes; N- no*
91. Attack ∠ (BF)	**-**	**0**	**-**	**No**	
92. Pushed	**-**	**-**	**-**	**wing**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**N**	**-**	**-**	**walls**	
95. Cross-members	**-**	**0**	**-**	**. On**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**-**	**-**	**-**	**the**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**-**	**-**	**-**	**right**	
98. Exposure depth	**-**	**0**	**0**	**abut**	

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

ment side where the bridge extension is present, there is type 2 protection around the end of the wall.

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
-	-			-	N	-	-	-	-	-

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? - (Y or if N type ctrl-n cb) Where? NO (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 234 Depth: 7 Positioned 2 %LB to 1 %RB

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

342
0
2
-

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

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

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

Confluence comments (eg. confluence name):

ut the same width as US and then narrows beyond 50 ft. DS. The DS reach is straight as it runs along the roadway of the North Branch Extension on the right bank. The right bank is protected with stone fill and the

F. Geomorphic Channel Assessment

107. Stage of reach evolution ba

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)*:

nk also acts as the road embankment. The left bank side shows more erosional evidence than the right bank. The water is pooled under the bridge near the DS face and then changes to riffle at 20 ft. DS and remains riffle for more than 200 ft. The slope is constant and moderate.

109. G. Plan View Sketch

- N

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: BENNCYPARK0002 Town: Bennington
Road Number: Park Street County: Bennington
Stream: Furnace Brook

Initials SAO Date: 3-20-97 Checked: MAI

Analysis of contraction scour, live-bed or clear water?

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	2760	5400	770
Main Channel Area, ft2	227	261	161
Left overbank area, ft2	406	652	51
Right overbank area, ft2	193	480	0
Top width main channel, ft	41	41	39
Top width L overbank, ft	270	322	135
Top width R overbank, ft	341	351	0
D50 of channel, ft	0.192	0.192	0.192
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.5	6.4	4.1
y1, average depth, LOB, ft	1.5	2.0	0.4
y1, average depth, ROB, ft	0.6	1.4	ERR
Total conveyance, approach	50387	93103	15861
Conveyance, main channel	25585	32228	14860
Conveyance, LOB	19894	38873	1001
Conveyance, ROB	4909	22002	0
Percent discrepancy, conveyance	-0.0020	0.0000	0.0000
Qm, discharge, MC, cfs	1401.4	1869.2	721.4
Ql, discharge, LOB, cfs	1089.7	2254.6	48.6
Qr, discharge, ROB, cfs	268.9	1276.1	0.0
Vm, mean velocity MC, ft/s	6.2	7.2	4.5
Vl, mean velocity, LOB, ft/s	2.7	3.5	1.0
Vr, mean velocity, ROB, ft/s	1.4	2.7	ERR
Vc-m, crit. velocity, MC, ft/s	8.6	8.8	8.2
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

(Q) total discharge, cfs	2760	5400	770
(Q) discharge thru bridge, cfs	707	640	770
Main channel conveyance	6578	6578	6578
Total conveyance	6578	6578	6578
Q2, bridge MC discharge,cfs	707	640	770
Main channel area, ft2	104	104	104
Main channel width (normal), ft	24.9	24.9	24.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	24.9	24.9	24.9
y_bridge (avg. depth at br.), ft	4.18	4.18	4.18
Dm, median (1.25*D50), ft	0.24	0.24	0.24
y2, depth in contraction,ft	3.28	3.01	3.52
ys, scour depth (y2-ybridge), ft	-0.90	-1.17	-0.65
ys, scour depth (y2-yfullv), ft	N/A	N/A	0.00

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	2760	5400	770
Q, thru bridge, cfs	707	640	770
Total Conveyance, bridge	6578	6578	6578
Main channel(MC) conveyance, bridge	6578	6578	6578
Q, thru bridge MC, cfs	707	640	770
Vc, critical velocity, ft/s	8.60	8.80	8.19
Vc, critical velocity, m/s	2.62	2.68	2.50
Main channel width (skewed), ft	24.9	24.9	24.9
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	24.9	24.9	24.9
qbr, unit discharge, ft2/s	28.4	25.7	30.9
qbr, unit discharge, m2/s	2.6	2.4	2.9
Area of full opening, ft2	104.0	104.0	104.0
Hb, depth of full opening, ft	4.18	4.18	4.18
Hb, depth of full opening, m	1.27	1.27	1.27
Fr, Froude number, bridge MC	0.59	0.54	0.64
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	498.22	498.22	498.22

Elevation of Bed, ft	494.04	494.04	494.04
Elevation of Approach, ft	501.36	502.19	499.71
Friction loss, approach, ft	0.4	0.8	0.17
Elevation of WS immediately US, ft	500.96	501.39	499.54
ya, depth immediately US, ft	6.92	7.35	5.50
ya, depth immediately US, m	2.11	2.24	1.68
Mean elevation of deck, ft	501.49	501.49	501.49
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.86	0.82	0.93
Ys, depth of scour, ft	-0.32	-0.61	-0.12

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	707	640	770
Main channel area (DS), ft2	104	104	87
Main channel width (normal), ft	24.9	24.9	24.9
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	24.9	24.9	24.9
D90, ft	0.4652	0.4652	0.4652
D95, ft	0.5989	0.5989	0.5989
Dc, critical grain size, ft	0.2113	0.1731	0.3869
Pc, Decimal percent coarser than Dc	0.436	0.567	0.153
Depth to armoring, ft	0.82	0.40	6.43

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	2760	5400	770	2760	5400	770
a', abut.length blocking flow, ft	276.1	328.1	141.8	9.4	9.4	7.5
Ae, area of blocked flow ft2	249.7	342.6	69.7	22.9	19.6	13.4
Qe, discharge blocked abut.,cfs	--	--	106.8	--	--	32.4
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.83	3.57	1.53	4.11	4.85	2.42
ya, depth of f/p flow, ft	0.90	1.04	0.49	2.44	2.09	1.79

--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)

K1	1	1	1	1	1	1

--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)

theta	80	80	80	100	100	100
K2	0.98	0.98	0.98	1.01	1.01	1.01
Fr, froude number f/p flow	0.396	0.435	0.385	0.431	0.494	0.319
ys, scour depth, ft	14.36	17.70	7.51	8.43	8.05	5.58

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)	276.1	328.1	141.8	9.4	9.4	7.5
y1 (depth f/p flow, ft)	0.90	1.04	0.49	2.44	2.09	1.79
a'/y1	305.29	314.21	288.48	3.86	4.51	4.20
Skew correction (p. 49, fig. 16)	0.97	0.97	0.97	1.02	1.02	1.02
Froude no. f/p flow	0.40	0.44	0.39	0.43	0.49	0.32
Ys w/ corr. factor K1/0.55:						
vertical	4.69	5.58	2.52	ERR	ERR	ERR
vertical w/ ww's	3.84	4.58	2.07	ERR	ERR	ERR
spill-through	2.58	3.07	1.39	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	Q100	Q500	Qother
Fr, Froude Number (DS)	0.59	0.54	0.83	0.59	0.54	0.83
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge (DS), ft	4.18	4.18	3.49	4.18	4.18	3.49
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	0.90	0.75	ERR	0.90	0.75	ERR
Fr>0.8 (vertical abut.)	ERR	ERR	1.39	ERR	ERR	1.39
Fr<=0.8 (spillthrough abut.)	0.78	0.66	ERR	0.78	0.66	ERR
Fr>0.8 (spillthrough abut.)	ERR	ERR	1.22	ERR	ERR	1.22