LEVEL II SCOUR ANALYSIS FOR BRIDGE 8 (WELLTH00020008) on TOWN HIGHWAY 2, crossing WELLS BROOK, WELLS, VERMONT

Open-File Report 97-770

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 8 (WELLTH00020008) on TOWN HIGHWAY 2, crossing WELLS BROOK, WELLS, VERMONT

By LORA K. STRIKER AND MICHAEL A. IVANOFF

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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 8 (WELLTH00020008) ON TOWN HIGHWAY 2, CROSSING WELLS BROOK, WELLS, VERMONT

By Lora K. Striker and Michael A. Ivanoff

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WELLTH00020008 on Town Highway 2 crossing the Wells Brook, Wells, 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 Taconic section of the New England physiographic province in southwestern Vermont. The 14.4-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover on the right overbanks is predominantly suburban while the immediate banks are vegetated with trees and brush. The left bank upstream and downstream is predominantly pasture.

In the study area, the Wells Brook has an incised, straight channel with a slope of approximately 0.005 ft/ft, an average channel top width of 51 ft and an average bank height of 7 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 48.6 mm (0.159 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 19, 1995, indicated that the reach was stable.

The Town Highway 2 crossing of the Wells Brook is a 35-ft-long, two-lane bridge consisting of one 32-foot concrete span (Vermont Agency of Transportation, written communication, March 22, 1995). The opening length of the structure parallel to the bridge face is 31.7 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is 5 degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed along the left abutment during the Level I assessment. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the left bank upstream, and type-5 (placed stone wall) at the upstream end of the upstream left wingwall, at the downstream end of the downstream left wingwall, and along the downstream 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) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge is determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 0.8 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge, which was less than the 100-year discharge. Abutment scour ranged from 5.6 to 10.0 ft at the left abutment and from 3.1 to 4.2 ft at the right abutment. The worst-case abutment scour occurred at the incipient roadway-overtopping discharge at the left abutment. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Wells, VT. Quadrangle, 1:24,000, 1967

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 WELLTH00020008 ***Stream*** Wells Brook

County Windsor ***Road*** TH2 ***District*** 3

Description of Bridge

Bridge length 35 ***ft*** ***Bridge width*** 32 ***ft*** ***Max span length*** 23.3 ***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*** 09/19/95

Description of stone fill Type-5, stone walls, one located at the upstream end of the upstream left wingwall and one located at the downstream end of the downstream left wingwall.

The abutments and wingwalls are concrete. There is a 1.5 ft deep scour hole in front of the left abutment. The left abutment footing is exposed 4.0 ft while the right abutment footing is exposed 2.2 ft.

Yes

5 No

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

09/19/95

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	0	0	09/19/
Level II	95	0	0

Potential for debris Moderate. The bank upstream are stable but heavily vegetated with trees.

None as of 09/19/95.

Describe any features near or at the bridge that may affect flow (include observation date)

Description of the Geomorphic Setting

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

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

Date of inspection 09/19/95

DS left: Steep channel bank to flood plain

DS right: Steep channel bank to flood plain

US left: Steep channel bank to flood plain

US right: Steep channel bank to flood plain

Description of the Channel

Average top width 51 ***ft*** ***Average depth*** 7 ***ft***

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

Straight, incised, and stable with semi-alluvial channel boundaries and no braiding nor anabranching.

09/19/95

Vegetative co Placed stone wall to yard and house on overbank

DS left: Trees and brush

DS right: Brush and a few trees with pasture on the overbank

US left: Trees and brush

US right:

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

None as of 09/19/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 14.4 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None.

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 2,500 ***ft³/s*** ***Q500*** 3,050 ***ft³/s***

The 100- and 500-year discharges are based on the median value of several empirical discharge values that were graphically extrapolated to the 500-year discharge (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 None.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X inside a chiseled square on top of the upstream end of the left abutment (elev. 501.57 ft, arbitrary survey datum). RM2 is the center point of a chiseled X in top of concrete on the downstream end of the right abutment (elev. 501.60 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	-29	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	12	1	Road Grade section
APPRO	59	1	Approach section as surveyed.

[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 0.040 to 0.045, and overbank "n" values ranged from 0.045 to 0.060.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.005 ft/ft, which was computed from survey points taken downstream of the bridge site on September 19, 1995.

The surveyed approach section (APPRO) was taken one bridge length upstream of the upstream face to establish the modelled approach section as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 502.3 ***ft***
Average low steel elevation 499.5 ***ft***

100-year discharge 2,500 ***ft^3/s***
Water-surface elevation in bridge opening 499.6 ***ft***
Road overtopping? Yes ***Discharge over road*** 364 ***ft^3/s***
Area of flow in bridge opening 280 ***ft^2***
Average velocity in bridge opening 7.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.7 ***ft/s***

Water-surface elevation at Approach section with bridge 500.7
Water-surface elevation at Approach section without bridge 499.0
Amount of backwater caused by bridge 1.7 ***ft***

500-year discharge 3,050 ***ft^3/s***
Water-surface elevation in bridge opening 499.6 ***ft***
Road overtopping? Yes ***Discharge over road*** 670 ***ft^3/s***
Area of flow in bridge opening 281 ***ft^2***
Average velocity in bridge opening 8.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.9 ***ft/s***

Water-surface elevation at Approach section with bridge 501.0
Water-surface elevation at Approach section without bridge 499.6
Amount of backwater caused by bridge 1.4 ***ft***

Incipient overtopping discharge 2,470 ***ft^3/s***
Water-surface elevation in bridge opening 498.0 ***ft***
Area of flow in bridge opening 235 ***ft^2***
Average velocity in bridge opening 10.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.1 ***ft/s***

Water-surface elevation at Approach section with bridge 499.7
Water-surface elevation at Approach section without bridge 498.9
Amount of backwater caused by bridge 0.8 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 100-year and 500-year discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). 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. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

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

Abutment scour was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. Variables for the HIRE equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and 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	0.2	0.8
Depth to armoring	1.7	1.7	9.0
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	5.6	6.5	10.0
Right abutment	4.2	4.2	3.1
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.4	1.4	2.1
Right abutment	1.4	1.4	2.1
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

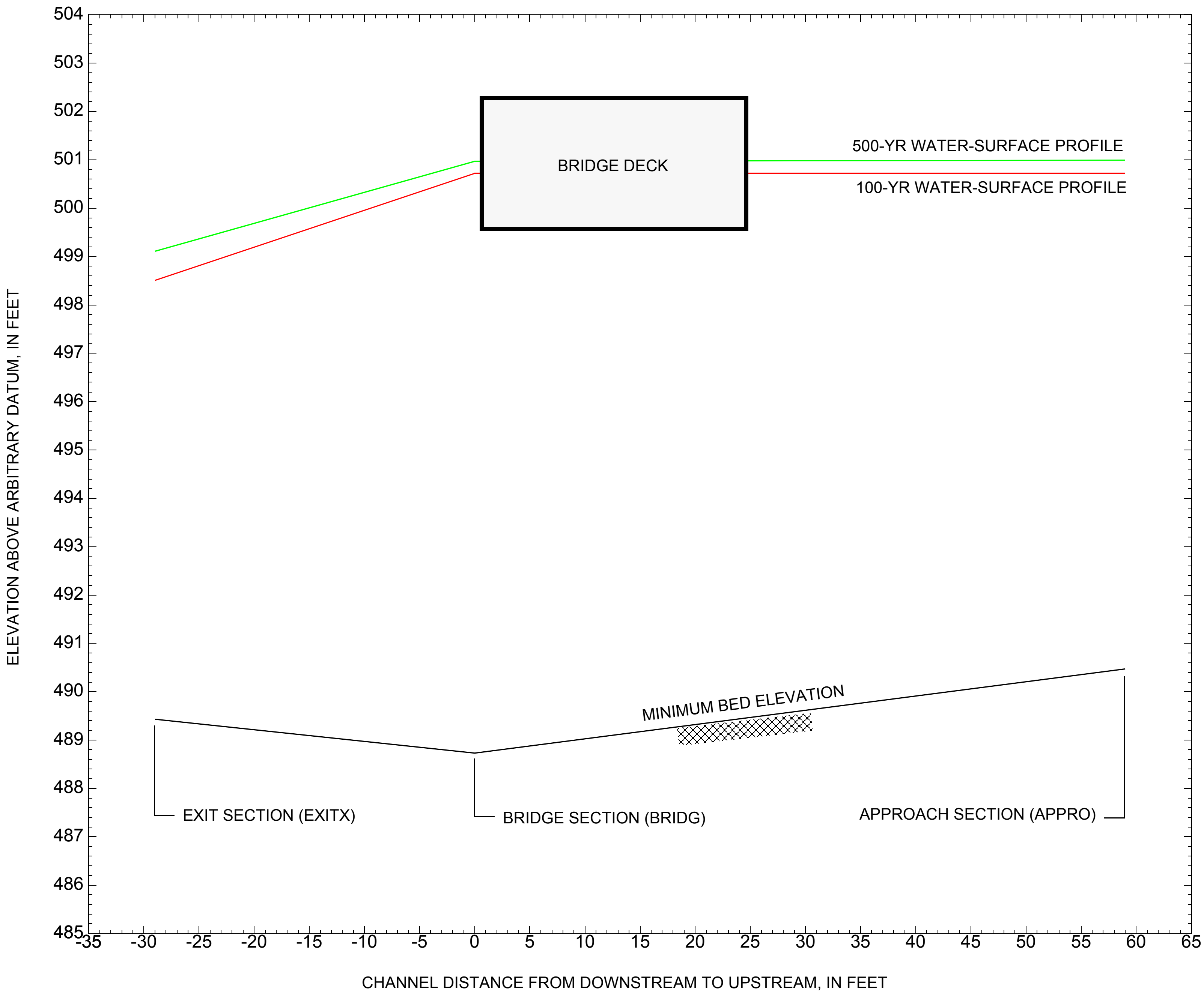

Figure 7. Water-surface profiles for the 100-year and 500-year discharges at structure WELLTH00020008 on Town Highway 2, crossing Wells Brook, Wells, Vermont.

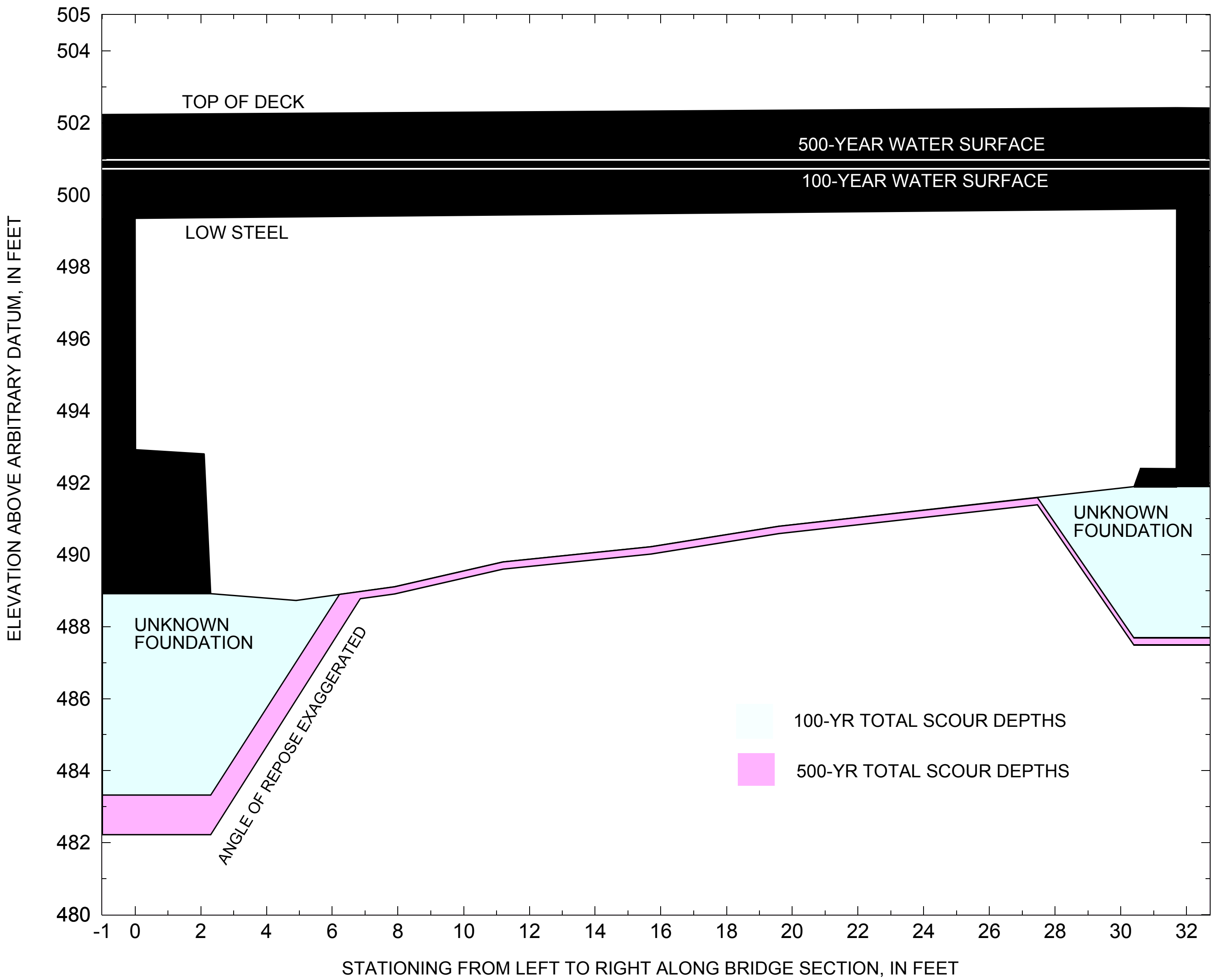

Figure 8. Scour elevations for the 100-year and 500-year discharges at structure WELLTH00020008 on Town Highway 2, crossing Wells Brook, Wells, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WELLTH00020008 on Town Highway 2, crossing Wells Brook, Wells, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 2,500 cubic-feet per second											
Left abutment footing	0.0	--	499.4	--	488.9	0.0	5.6	--	5.6	483.3	--
Right abutment footing	31.7	--	499.6	--	491.9	0.0	4.2	--	4.2	487.7	--

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 WELLTH00020008 on Town Highway 2, crossing Wells Brook, Wells, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 3,050 cubic-feet per second											
Left abutment footing	0.0	--	499.4	--	488.9	0.2	6.5	--	6.7	482.2	--
Right abutment footing	31.7	--	499.6	--	491.9	0.2	4.2	--	4.4	487.5	--

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, 1967, Wells, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

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T1        U.S. Geological Survey WSPRO Input File well008.wsp
T2        Hydraulic analysis for structure WELLTH00020008   Date: 10-SEP-97
T3        TH 2 crossing Wells Brook, Wells, VT, LKS
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2500.0   3050.0   2470.0
SK          0.0050   0.0050   0.0050
*
XS   EXITX    -29           0.
* GR         -319.5, 498.65   -234.2, 499.94   -192.5, 499.61   -160.5, 497.90
* GR         -127.7, 498.41    -80.5, 497.65    -41.1, 498.21
GR            0.0, 499.33
GR           10.1, 498.72     10.4, 493.95     16.3, 491.34     20.3, 491.60
GR           23.9, 490.18     25.5, 490.07     28.4, 489.77     32.2, 489.91
GR           36.1, 489.68     38.0, 489.43     40.5, 489.99     45.6, 491.28
GR           47.2, 493.33     56.6, 497.62     75.9, 497.63    105.6, 498.39
GR          113.3, 497.16    140.6, 497.55    192.9, 498.88    238.6, 499.39
* GR        300.3, 499.10
*
N           0.045        0.045        0.060
SA                  10.1         56.6
*
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    499.48       5.0
GR            0.0, 499.35      0.2, 492.92      2.1, 492.80      2.1, 490.79
GR            2.3, 488.92      4.9, 488.73      7.9, 489.11     11.2, 489.80
GR           15.7, 490.22     19.6, 490.79     30.4, 491.89     30.6, 492.40
GR           31.5, 492.39     31.7, 499.61      0.0, 499.35
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD          1      31.0 * *     64.7      4.8
N           0.040
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     12      23.3     1
GR         -318.2, 500.39   -219.7, 501.07   -133.8, 501.25    -80.4, 501.34
GR          -33.3, 501.94      0.0, 502.24      0.1, 502.62      1.8, 502.88
GR           35.0, 502.98     35.0, 502.42     35.3, 502.47    114.8, 500.19
GR          147.7, 499.97    283.3, 500.41    320.4, 501.23
*
*
AS   APPRO     59           0.
GR         -290.8, 500.03   -206.5, 500.31   -150.0, 500.61   -109.0, 500.24
GR          -99.3, 499.35    -73.3, 498.77    -56.9, 499.19    -24.0, 498.95
GR          -19.8, 496.95    -13.0, 492.05    -11.1, 491.51     -5.7, 490.81
GR           -1.7, 490.56      0.0, 490.83      2.2, 490.86      3.6, 490.65
GR            5.2, 490.47      7.0, 490.83      8.7, 491.08     18.8, 494.90
GR           21.8, 495.09     31.9, 497.61     98.7, 499.26    135.6, 499.11
GR          212.6, 498.85    304.2, 500.74    341.5, 501.21
*
N           0.045        0.045        0.060
SA                -24.0          31.9
*
HP 1 BRIDG   499.56 1 499.56
HP 2 BRIDG   499.56 * * 2170
HP 1 BRIDG   498.77 1 498.77
HP 2 RDWAY   500.72 * *  364
HP 1 APPRO   500.72 1 500.72
HP 2 APPRO   500.72 * * 2500
*
HP 1 BRIDG   499.61 1 499.61
HP 2 BRIDG   499.61 * * 2363
HP 1 BRIDG   499.39 1 499.39
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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        U.S. Geological Survey WSPRO Input File well008.wsp
        Hydraulic analysis for structure WELLTH00020008   Date: 10-SEP-97
        TH 2 crossing Wells Brook, Wells, VT, LKS
           *** RUN DATE & TIME: 10-27-97  16:12
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      280     25272     6     75                        10819
   499.56           280     25272     6     75  1.00      0     32    10819

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       499.56     0.0    31.7   280.5   25272.    2170.   7.74

X STA.         0.0        3.4        4.9        6.2        7.5        8.8
  A(I)            26.5       15.7       14.2       13.3       13.1
  V(I)            4.10       6.90       7.66       8.18       8.30

X STA.         8.8       10.1       11.3       12.7       14.0       15.3
  A(I)            12.7       12.3       12.7       12.4       12.3
  V(I)            8.55       8.80       8.52       8.72       8.82

X STA.        15.3       16.7       18.1       19.5       21.1       22.6
  A(I)            12.7       12.4       12.8       13.2       13.0
  V(I)            8.54       8.72       8.51       8.25       8.33

X STA.        22.6       24.2       25.8       27.2       28.8       31.7
  A(I)            12.9       13.4       11.2       12.4       21.3
  V(I)            8.38       8.10       9.71       8.74       5.09

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      258     29665    32     48                         4193
   498.77           258     29665    32     48  1.00      0     32     4193

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      12.
         WSEL     LEW     REW    AREA        K        Q    VEL
       500.72  -318.2   297.3   107.9    1637.     364.   3.37

X STA.      -318.2      103.6      119.5      128.2      135.5      142.2
  A(I)             8.6        6.7        5.1        4.7        4.6
  V(I)            2.11       2.72       3.54       3.88       3.95

X STA.       142.2      148.0      153.7      159.8      166.0      172.6
  A(I)             4.3        4.3        4.4        4.3        4.5
  V(I)            4.26       4.26       4.18       4.19       4.05

X STA.       172.6      179.5      186.9      194.9      203.3      212.7
  A(I)             4.6        4.7        4.9        4.9        5.2
  V(I)            3.99       3.89       3.72       3.71       3.49

X STA.       212.7      223.2      234.9      248.5      265.2      297.3
  A(I)             5.5        5.7        6.1        6.6        8.3
  V(I)            3.33       3.21       3.00       2.76       2.19

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      59.
     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      208      5828   267    268                         1043
             2      406     48492    56     59                         6203
             3      428     14401   271    271                         3050
   500.72          1042     68721   594    598  2.39   -290    303     5069

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      59.
         WSEL     LEW     REW    AREA        K        Q    VEL
       500.72  -290.8   303.2  1041.9   68721.    2500.   2.40

X STA.      -290.8      -64.4      -18.4      -12.9       -9.9       -7.1
  A(I)           141.6       84.2       36.9       27.9       25.9
  V(I)            0.88       1.48       3.39       4.49       4.83

X STA.        -7.1       -4.6       -2.3        0.1        2.5        4.9
  A(I)            24.6       24.0       23.6       24.2       23.9
  V(I)            5.08       5.21       5.29       5.18       5.23

X STA.         4.9        7.3        9.9       13.1       17.4       23.3
  A(I)            24.0       25.1       27.5       30.8       33.8
  V(I)            5.21       4.98       4.55       4.06       3.70

X STA.        23.3       36.3       67.7      128.6      189.0      303.2
  A(I)            49.4       82.1      102.6      102.0      127.9
  V(I)            2.53       1.52       1.22       1.23       0.98
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      U.S. Geological Survey WSPRO Input File well008.wsp
      Hydraulic analysis for structure WELLTH00020008   Date: 10-SEP-97
      TH 2 crossing Wells Brook, Wells, VT, LKS
         *** RUN DATE & TIME: 10-27-97  16:12
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      281     23998      0     81                            0
 499.61           281     23998      0     81  1.00      0     32        0

  VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
       WSEL     LEW     REW    AREA         K        Q    VEL
     499.61     0.0    31.7   280.6   23998.    2363.   8.42

X STA.        0.0        3.3        4.7        6.0        7.2        8.4
  A(I)            25.4       14.9       13.5       12.6       12.5
  V(I)            4.65       7.92       8.77       9.35       9.47

X STA.        8.4        9.6       10.8       12.1       13.4       14.6
  A(I)            11.9       11.9       11.9       12.1       11.9
  V(I)            9.92       9.94       9.89       9.78       9.89

X STA.       14.6       15.9       17.3       18.7       20.1       21.6
  A(I)            12.1       12.2       12.4       12.5       13.1
  V(I)            9.79       9.66       9.56       9.47       9.01

X STA.       21.6       23.2       24.8       26.5       28.5       31.7
  A(I)            12.9       13.5       14.4       15.5       23.4
  V(I)            9.15       8.78       8.22       7.62       5.04

  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      278     30918     27     54                         5081
 499.39           278     30918     27     54  1.00      0     32     5081

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      12.
       WSEL     LEW     REW    AREA         K        Q    VEL
     500.97  -318.2   308.6   177.1    3317.     670.   3.78

X STA.     -318.2     -303.3     -278.2      115.5      126.0      134.9
  A(I)             7.9        9.8       17.8        8.6        7.9
  V(I)            4.26       3.42       1.88       3.89       4.23

X STA.      134.9      142.9      150.1      157.4      164.9      172.7
  A(I)             7.5        7.1        7.1        7.2        7.3
  V(I)            4.46       4.69       4.72       4.63       4.61

X STA.      172.7      180.9      189.5      198.6      208.3      218.8
  A(I)             7.4        7.6        7.7        8.0        8.2
  V(I)            4.55       4.41       4.34       4.20       4.09

X STA.      218.8      229.9      242.5      256.2      272.5      308.6
  A(I)             8.4        8.9        9.2       10.2       13.3
  V(I)            3.99       3.75       3.65       3.29       2.52

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      59.
   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      280      9558    267    268                         1629
           2      421     51535     56     59                         6553
           3      504     18001    292    292                         3756
 500.99          1205     79094    615    619  2.37   -290    324     6221

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      59.
       WSEL     LEW     REW    AREA         K        Q    VEL
     500.99  -290.8   324.0  1205.0   79094.    3050.   2.53

X STA.     -290.8      -89.9      -42.6      -16.1      -11.7       -8.6
  A(I)           150.2       93.3       69.1       36.1       30.3
  V(I)            1.02       1.63       2.21       4.22       5.04

X STA.       -8.6       -5.8       -3.0       -0.5        2.2        4.8
  A(I)            28.1       27.8       26.5       27.0       26.6
  V(I)            5.43       5.48       5.74       5.64       5.73

X STA.        4.8        7.4       10.3       14.0       19.1       26.1
  A(I)            27.2       28.3       31.5       35.8       39.2
  V(I)            5.60       5.38       4.83       4.26       3.89

X STA.       26.1       46.2       81.6      141.3      196.8      324.0
  A(I)            69.5       91.7      110.7      110.7      145.3
  V(I)            2.20       1.66       1.38       1.38       1.05
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        U.S. Geological Survey WSPRO Input File well008.wsp
        Hydraulic analysis for structure WELLTH00020008   Date: 10-SEP-97
        TH 2 crossing Wells Brook, Wells, VT, LKS
           *** RUN DATE & TIME: 10-27-97  16:12
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      235     25924     31     46                         3648
   498.04           235     25924     31     46  1.00      0     32     3648

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.04     0.0    31.7   235.2  25924.    2470.  10.50
X STA.        0.0        3.7        5.1        6.3        7.5        8.7
  A(I)           24.2       13.3       11.4       10.6       10.1
  V(I)           5.10       9.29      10.79      11.63      12.20

X STA.        8.7        9.8       11.0       12.1       13.3       14.5
  A(I)            9.8        9.8        9.4        9.5        9.4
  V(I)          12.59      12.57      13.08      12.96      13.13

X STA.       14.5       15.7       17.0       18.3       19.7       21.1
  A(I)            9.6        9.7        9.8       10.0       10.3
  V(I)          12.85      12.70      12.62      12.31      11.96

X STA.       21.1       22.6       24.2       26.0       28.0       31.7
  A(I)           10.7       10.9       12.0       13.0       21.4
  V(I)          11.58      11.32      10.29       9.50       5.76

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      59.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       47      1091     79     79                          204
             2      347     37274     56     59                         4896
             3      168      3473    220    220                          830
   499.66           561     41838    355    358  1.86   -102    252     2934

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      59.
         WSEL     LEW     REW    AREA        K        Q    VEL
       499.66  -102.7   251.9   560.8  41838.    2470.   4.40

X STA.     -102.7      -16.6      -12.8      -10.4       -8.2       -6.2
  A(I)           66.1       24.0       19.9       18.0       17.0
  V(I)           1.87       5.14       6.20       6.86       7.27

X STA.       -6.2       -4.4       -2.6       -0.9        0.9        2.7
  A(I)           16.2       16.1       15.9       16.0       15.9
  V(I)           7.65       7.69       7.76       7.74       7.78

X STA.        2.7        4.5        6.3        8.1       10.2       12.7
  A(I)           15.9       16.1       16.3       17.6       18.8
  V(I)           7.78       7.68       7.58       7.00       6.57

X STA.       12.7       15.9       20.5       27.1       61.1      251.9
  A(I)           20.6       23.3       27.0       62.0      118.3
  V(I)           5.99       5.31       4.57       1.99       1.04
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File well008.wsp
        Hydraulic analysis for structure WELLTH00020008   Date: 10-SEP-97
        TH 2 crossing Wells Brook, Wells, VT, LKS
           *** RUN DATE & TIME: 10-27-97  16:12

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

EXITX:XS   ******     10      400  0.85 *****  499.36  496.06    2500  498.51
       -28 ******    178    35345  1.41 ***** *******    0.85    6.25

FULLV:FV       29      9      447  0.73  0.13  499.50 *******    2500  498.77
         0     29    189    38590  1.50  0.00    0.01    0.77    5.60
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.96     498.96     497.25

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   498.27     501.21    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   498.27     501.21     497.25

APPRO:AS       59    -81      348  0.97  0.31  499.94  497.25    2500  498.96
        59     59    218    31108  1.22  0.12    0.00    0.97    7.18
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   498.06     499.56     499.75     499.48

 ===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       29      0      280  0.93 *****  500.49  495.85    2170  499.56
         0 ******     32    25296  1.00 ***** *******    0.46    7.74

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.401  0.000  499.48 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.    36.  0.05  0.21  500.89    0.01    364.  500.72

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     28.    48.  -318.  -270.   0.3   0.2   2.6   3.4   0.3   3.0
   RT:    336.   201.    96.   297.   0.8   0.5   3.8   3.3   0.7   3.1

===140 AT SECID "APPRO":  END OF CROSS SECTION EXTENDED VERTICALLY.
                             WSEL,YLT,YRT =   500.72      500.0      501.2

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

APPRO:AS       28   -290     1044  0.21  0.11  500.94  497.25    2500  500.72
        59     34    303    68849  2.39  0.29    0.01    0.49    2.39

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

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -29.    10.   178.   2500.   35345.     400.    6.25  498.51
   FULLV:FV       0.     9.   189.   2500.   38590.     447.    5.60  498.77
   BRIDG:BR       0.     0.    32.   2170.   25296.     280.    7.74  499.56
   RDWAY:RG      12.*******    28.    364.       0.*********    1.00  500.72
   APPRO:AS      59.  -291.   303.   2500.   68849.    1044.    2.39  500.72

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    496.06    0.85  489.43  499.39************  0.85  499.36  498.51
   FULLV:FV  ********    0.77  489.43  499.39  0.13  0.00  0.73  499.50  498.77
   BRIDG:BR    495.85    0.46  488.73  499.61************  0.93  500.49  499.56
   RDWAY:RG  ***************  499.97  502.98  0.05******  0.21  500.89  500.72
   APPRO:AS    497.25    0.49  490.47  501.21  0.11  0.29  0.21  500.94  500.72
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        U.S. Geological Survey WSPRO Input File well008.wsp
        Hydraulic analysis for structure WELLTH00020008   Date: 10-SEP-97
        TH 2 crossing Wells Brook, Wells, VT, LKS
           *** RUN DATE & TIME: 10-27-97  16:12

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******      4      512  0.90 ***** 500.01  496.80    3050  499.11
       -28 ******    214    43129  1.63 ***** *******    0.86    5.96

 ===140 AT SECID "FULLV":  END OF CROSS SECTION EXTENDED VERTICALLY.
                           WSEL,YLT,YRT =    499.39     499.33     499.39

FULLV:FV       29      0      575  0.77  0.13  500.16 *******    3050  499.39
         0     29    239    47259  1.75  0.00    0.01    0.80    5.31
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     1.08     499.61     497.99
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   498.89     501.21     0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   498.89     501.21     497.99

APPRO:AS       59   -101      549  0.88  0.28  500.51  497.99    3050  499.63
        59     59    250    41185  1.84  0.06    0.01    1.06    5.55
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   501.08       0.00     498.42     499.97
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   498.92     500.43     500.58     499.48
 ===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       29      0      281  1.10 ***** 500.71  496.16    2363  499.61
         0 ******     32    23998  1.00 ***** *******    0.50    8.42

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.427  0.000  499.48 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.    36.  0.05  0.23  501.18   -0.01    670.  500.97

           Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    89.    85.  -318.  -233.   0.6   0.3   3.2   3.6   0.5   3.0
   RT:   581.   221.    87.   309.   1.0   0.7   4.4   3.8   0.9   3.1

===140 AT SECID "APPRO":  END OF CROSS SECTION EXTENDED VERTICALLY.
                           WSEL,YLT,YRT =   500.99      500.0      501.2

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS       28   -290     1207  0.23  0.14  501.23  497.99    3050  500.99
        59     35    324    79247  2.37  0.24   -0.01    0.49    2.53

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

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q         K     AREA     VEL   WSEL
   EXITX:XS      -29.     4.   214.   3050.   43129.     512.    5.96  499.11
   FULLV:FV        0.     0.   239.   3050.   47259.     575.    5.31  499.39
   BRIDG:BR        0.     0.    32.   2363.   23998.     281.    8.42  499.61
   RDWAY:RG       12.*******    89.    670.        0.*********   1.00  500.97
   APPRO:AS       59.  -291.   324.   3050.   79247.    1207.    2.53  500.99

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS     496.80    0.86  489.43  499.39************  0.90  500.01  499.11
   FULLV:FV  ********    0.80  489.43  499.39  0.13  0.00  0.77  500.16  499.39
   BRIDG:BR     496.16    0.50  488.73  499.61************  1.10  500.71  499.61
   RDWAY:RG  ***************  499.97  502.98  0.05******  0.23  501.18  500.97
   APPRO:AS     497.99    0.49  490.47  501.21  0.14  0.24  0.23  501.23  500.99
```

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        U.S. Geological Survey WSPRO Input File well008.wsp
        Hydraulic analysis for structure WELLTH00020008   Date: 10-SEP-97
        TH 2 crossing Wells Brook, Wells, VT, LKS
           *** RUN DATE & TIME: 10-27-97  16:12

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

EXITX:XS   ******     10      394  0.85 *****  499.32  496.02    2470  498.47
       -28 ******    177    34919  1.39 ***** *******    0.85    6.27

FULLV:FV       29     10      440  0.73  0.13  499.47 *******    2470  498.74
         0     29    187    38114  1.49  0.00    0.01    0.77    5.61
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.91     498.92     497.21

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   498.24     501.21    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   498.24     501.21     497.21

APPRO:AS       59    -79      343  0.96  0.31  499.89  497.21    2470  498.93
        59     59    216    30778  1.19  0.12    0.00    0.92    7.21
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<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       29      0      235  1.72  0.20  499.75  496.32    2470  498.04
         0     29     32    25900  1.00  0.24    0.00    0.68   10.51

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  499.48 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      12.        <<<<<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       28   -102      561  0.56  0.19  500.22  497.21    2470  499.66
        59     34    252    41872  1.86  0.28    0.01    0.84    4.40

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.893  0.199   33370.   -13.    19.   499.54

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K      AREA     VEL    WSEL
   EXITX:XS     -29.    10.   177.   2470.   34919.     394.    6.27  498.47
   FULLV:FV       0.    10.   187.   2470.   38114.     440.    5.61  498.74
   BRIDG:BR       0.     0.    32.   2470.   25900.     235.   10.51  498.04
   RDWAY:RG      12.**************      0.******************    1.00********
   APPRO:AS      59.  -103.   252.   2470.   41872.     561.    4.40  499.66

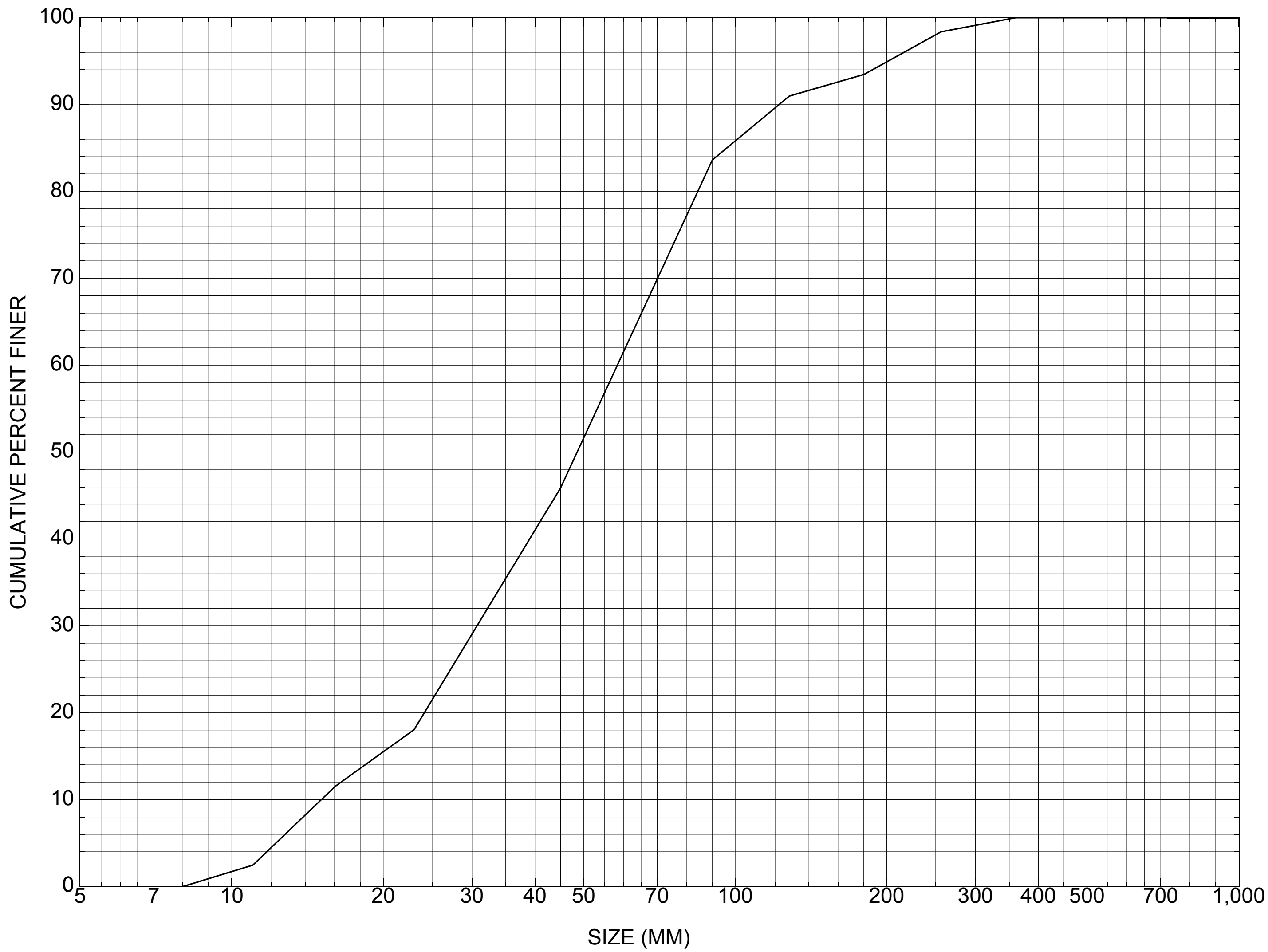
    XSID:CODE   XLKQ   XRKQ      KQ
   APPRO:AS     -13.    19.   33370.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    496.02    0.85  489.43  499.39************  0.85  499.32  498.47
   FULLV:FV  ********    0.77  489.43  499.39  0.13  0.00  0.73  499.47  498.74
   BRIDG:BR    496.32    0.68  488.73  499.61  0.20  0.24  1.72  499.75  498.04
   RDWAY:RG  ****************  499.97  502.98**********************************
   APPRO:AS    497.21    0.84  490.47  501.21  0.19  0.28  0.56  500.22  499.66
  ER
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WELLTH00020008, in Wells , Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WELLTH00020008

General Location Descriptive

Data collected by *(First Initial, Full last name)* E. BOEHMLER

Date *(MM/DD/YY)* 03 / 22 / 95

Highway District Number *(I - 2; nn)* 03

County *(FIPS county code; I - 3; nnn)* 021

Town *(FIPS place code; I - 4; nnnnn)* 77950

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

Waterway *(I - 6)* WELLS BROOK

Road Name *(I - 7):* -

Route Number TH002

Vicinity *(I - 9)* 0.05 MI TO JCT VT 30

Topographic Map Wells

Hydrologic Unit Code: 02010001

Latitude *(I - 16; nnnn.n)* 43250

Longitude *(i - 17; nnnnn.n)* 73123

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10112600081126

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

Maximum span length *(I - 48; nnnn)* 0032

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

Structure length *(I - 49; nnnnnn)* 000035

Average daily traffic, ADT *(I - 29; nnnnnn)* 001070

Deck Width *(I - 52; nn.n)* 233

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

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

Opening skew to Roadway *(I - 34; nn)* 05

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)* 1964

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

Clear span (*nnn.n ft*) 030.1

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

Vertical clearance from streambed (*nnn.n ft*) 009.2

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

Waterway of full opening (*nnn.n ft*^{2}) 276.8

Comments:

The structural inspection report of 6/29/94 indicates the structure is a concrete T-beam type bridge with an asphalt roadway surface. The abutment walls and wingwalls are concrete. The right abutment has some spalling along its footing on the upstream end and at the upstream wingwall. The downstream wingwall has some fine, small spalls reported. The upstream left wingwall has some map cracking with signs of leaking through the cracks noted. The report indicates there is some local scour at the upstream end of the left abutment footing and its upstream wingwall footing, which extends out to about the centerline of the channel. Most of the flow is indicated as flowing against the upstream left wingwall **(Continued, page 33)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

Q_{50} - Q_{100} - Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): -

Comments:

and the upstream end of the left abutment wall. While the footings are exposed at the surface, the report indicates there has been no undermining or settling of the abutment walls or wingwalls. There is vegetation growth on the banks upstream noted in the report. The streambed consists of mainly gravel and boulders.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **14.35** mi^2 Lake/pond/swamp area **0** mi^2
Watershed storage *(ST)* **0** %
Bridge site elevation **501** ft Headwater elevation **2835** ft
Main channel length **9.069** mi
10% channel length elevation **518** ft 85% channel length elevation **1779** ft
Main channel slope *(S)* **170.691** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in
Maximum 2yr-24hr precipitation event *(I24,2)* - in
Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number - Minimum channel bed elevation: -

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

Benchmark location description:
There is no benchmark information available.

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

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

If 1: Footing Thickness ____ Footing bottom elevation: ____

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

If 3: Footing bottom elevation: ____

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

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

Briefly describe material at foundation bottom elevation or around piles:
There is no foundation material information available.

Comments:
There are no bridge plans available.

Cross-sectional Data

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

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

Comments: **The low chord to bed, and station distances of this cross section are taken from a sketch dated 12/02/92 that is attached to a bridge inspection report. The low chord elevations were taken from the 09/19/95 survey done for this report.**

Station	**0**	**2.08**	**2.09**	**10.08**	**29.75**	-	-	-	-	-	-
Feature	**LAB**	-	-	-	**RAB**	-	-	-	-	-	-
Low chord elevation	**499.36**	**499.38**	**499.38**	**499.44**	**499.61**	-	-	-	-	-	-
Bed elevation	**492.78**	**492.80**	**488.38**	**489.94**	**492.44**	-	-	-	-	-	-
Low chord to bed	**6.58**	**6.58**	**11.00**	**9.50**	**7.17**	-	-	-	-	-	-

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

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

Comments: -
-

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **2/21/96**

Computerized by: **RB** Date: **2/21/96**

Reviewd by: **LKS** Date: **10/27/97**

Structure Number **WELLTH00020008**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. IVANOFF** Date *(MM/DD/YY)* **9** / **19** / 19**95**

2. Highway District Number **3**   Mile marker **0**

County **Rutland (021)**   Town **Wells (77950)**

Waterway *(I - 6)* **Wells Brook**   Road Name **-**

Route Number **TH2**   Hydrologic Unit Code: **02010001**

3. Descriptive comments:

The bridge is located 0.05 miles from the junction with VT 30.

B. Bridge Deck Observations

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

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

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

7. Bridge length **35** *(feet)*   Span length **32** *(feet)*   Bridge width **23.3** *(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 **--**   US right **--**

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

*Bank protection types: **0**- none; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

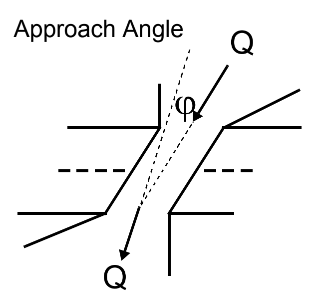
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

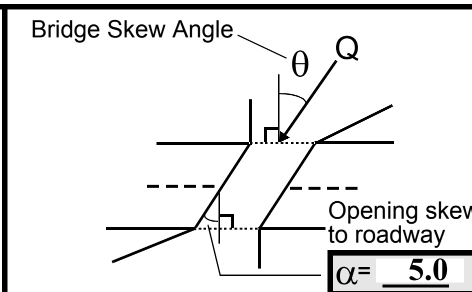
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

*Erosion Severity: **0** - none; **1**- slight; **2**- moderate; **3**- severe*

Channel approach to bridge (BF):

15. Angle of approach: **0**   16. Bridge skew: **10**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*

Where? **LB** *(LB, RB)*   Severity **1**

Range? **13** feet **US** *(US, UB, DS)* to **0** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*

Where? **RB** *(LB, RB)*   Severity **1**

Range? **8** feet **UB** *(US, UB, DS)* to **0** feet **DS**

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

18. Bridge Type: **1a/4**

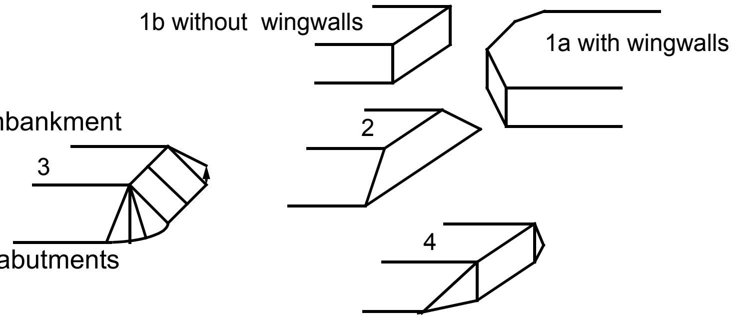
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

7. Bridge measurement values given are from VT AOT files.

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
30.5	**7.0**			**6.5**	**4**	**4**	**345**	**345**	**0**	**0**

23. Bank width **30.0** 24. Channel width **15.0** 25. Thalweg depth **56.0** 29. Bed Material **435**

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

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

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

30. The left bank protection extends 7 feet from the end of the wingwall.

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.):

There are no point bars upstream at this site.

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.):

There are no cut-banks upstream at this site.

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.):

There is no channel scour upstream at this site.

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):

There are no major confluences upstream at this site.

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
22.0		0.5		2	7	7	-

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

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

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

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

34

-

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

70. Debris and Ice Comments:

1

There are many trees along the US banks that pose a threat for potential debris problems.

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	1.5	4	90.0
RABUT	1	5	90			2	2	31.5

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*

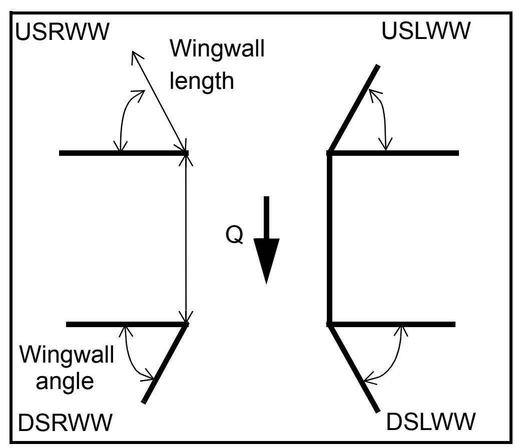
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0
2.2
1
The stream is impacting the US left wingwall and abutment.
74. Maximum exposure and scour is at the US end of the left abutment and DS end of the right abutment.
The scour extends for 12 feet along the left abutment and for 10 feet along the DS end of the right abutment.
The left abutment footing has 1964 engraved on the DS end.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						31.5	
USRWW:	Y		1		2	2.0	
DSLWW:	1.5		4.0		Y	24.0	
DSRWW:	1		2		0	24.5	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	.2	0	Y	.2	2	-	-	-
Condition	Y	-	1	2	2	-	-	-
Extent	1	-	3	5	0	0	0	-

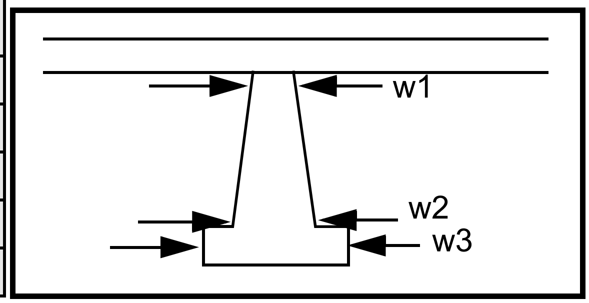
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
5
1
3
0
-
-

Piers:

84. Are there piers? **80.** (*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				**35.0**	**11.0**	**95.0**
Pier 2	**7.5**		**0.0**	**100.0**	**12.0**	**6.5**
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**The**	**flow**	**tion**	**is**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**US**	**with**	**with**	**unde**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**left**	**the**	**the**	**rmin**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**wing**	**max-**	**abut**	**ed**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**wall**	**imu**	**ment**	**0.2 ft**	*Y- yes; N- no*
91. Attack ∠ (BF)	**is**	**m**	**. The**	**at**	
92. Pushed	**impa**	**scou**	**DS**	**end**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**cted**	**r at**	**right**	**of**	
95. Cross-members	**by**	**the**	**wing**	**abut**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**the**	**cor-**	**wall**	**ment**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**strea**	**ner**	**cor-**	**foot-**	
98. Exposure depth	**m**	**junc-**	**ner**	**ing.**	

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

82. The US left wingwall protection consists of a laid-up stone wall extending 7 ft US.
The DS left wingwall protection consists of a laid-up stone wall extending from the end of the wingwall to 70 ft DS of the bridge.

N

E. Downstream Channel Assessment

100.

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

Bank width (BF) - Channel width - Thalweg depth - Bed Material -

Bank protection type (Qmax): LB - RB - Bank protection condition: LB - RB -

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

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

101. Is a drop structure present? - (*Y or N, if N type ctrl-n ds*) 102. Distance: - feet

103. Drop: - feet 104. Structure material: - (***1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other*)

105. Drop structure comments (eg. downstream scour depth):
-
-
-
-
-
-

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

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

Material: -

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

-
-
-
-

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

Cut bank extent: no feet pie (US, UB, DS) to rs. 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: ____

Scour dimensions: Length ____ Width 2 Depth: 3 Positioned 34 %LB to 34 %RB

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

0
1
435
5

Are there major confluences? 0 (Y or if N type ctrl-n mc) How many? 1

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

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

Confluence comments (eg. confluence name):

tected by a laid-up stone wall beginning at the end of the concrete wingwall and extending 70 ft DS.

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

- T

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: WELLTH00020008 Town: WELLS
Road Number: TOWN HIGHWAY 2 County: RUTLAND
Stream: WELLS BROOK

Initials LKS Date: 10/22/97 Checked: SAO

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	2500	3050	2470
Main Channel Area, ft2	406	421	347
Left overbank area, ft2	208	280	47
Right overbank area, ft2	428	504	168
Top width main channel, ft	56	56	56
Top width L overbank, ft	267	267	79
Top width R overbank, ft	271	292	220
D50 of channel, ft	0.1594	0.1594	0.1594
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.3	7.5	6.2
y1, average depth, LOB, ft	0.8	1.0	0.6
y1, average depth, ROB, ft	1.6	1.7	0.8
Total conveyance, approach	68721	79094	41838
Conveyance, main channel	48492	51535	37274
Conveyance, LOB	5828	9558	1091
Conveyance, ROB	14401	18001	3473
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1764.1	1987.3	2200.6
Ql, discharge, LOB, cfs	212.0	368.6	64.4
Qr, discharge, ROB, cfs	523.9	694.1	205.0
Vm, mean velocity MC, ft/s	4.3	4.7	6.3
Vl, mean velocity, LOB, ft/s	1.0	1.3	1.4
Vr, mean velocity, ROB, ft/s	1.2	1.4	1.2
Vc-m, crit. velocity, MC, ft/s	8.5	8.5	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	Q100	Q500	Other Q
(Q) total discharge, cfs	2500	3050	2470
(Q) discharge thru bridge, cfs	2170	2363	2470
Main channel conveyance	25272	23998	25924
Total conveyance	25272	23998	25924
Q2, bridge MC discharge,cfs	2170	2363	2470
Main channel area, ft2	281	281	235
Main channel width (normal), ft	31.6	31.6	31.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	31.6	31.6	31.6
y_bridge (avg. depth at br.), ft	8.88	8.88	7.44
Dm, median (1.25*D50), ft	0.19925	0.19925	0.19925
y2, depth in contraction,ft	7.36	7.92	8.23
ys, scour depth (y2-ybridge), ft	-1.51	-0.96	**0.79**

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	2170	2363	2470
Main channel area (DS), ft2	258	278	235.2
Main channel width (normal), ft	31.6	31.6	31.6
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	31.6	31.6	31.6
D90, ft	0.4007	0.4007	0.4007
D95, ft	0.6602	0.6602	0.6602
Dc, critical grain size, ft	0.2345	0.2332	0.3782
Pc, Decimal percent coarser than Dc	0.291	0.294	0.112
Depth to armoring, ft	**1.71**	**1.68**	**8.99**

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc Cf=1.5*Fr^0.43 (<=1) Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	2500	3050	2470
Q, thru bridge MC, cfs	2170	2363	2470
Vc, critical velocity, ft/s	8.46	8.51	8.24
Va, velocity MC approach, ft/s	4.35	4.72	6.34
Main channel width (normal), ft	31.6	31.6	31.6
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	31.6	31.6	31.6
qbr, unit discharge, ft2/s	68.7	74.8	78.2
Area of full opening, ft2	280.5	280.6	235.2
Hb, depth of full opening, ft	8.88	8.88	7.44
Fr, Froude number, bridge MC	0.46	0.5	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	258	278	N/A
**Hb, depth at downstream face, ft	8.16	8.80	N/A
**Fr, Froude number at DS face	0.52	0.51	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	499.48	499.48	0
Elevation of Bed, ft	490.60	490.60	-7.44
Elevation of Approach, ft	500.72	500.99	0
Friction loss, approach, ft	0.11	0.14	0
Elevation of WS immediately US, ft	500.61	500.85	0.00
ya, depth immediately US, ft	10.01	10.25	7.44
Mean elevation of deck, ft	502.3	502.3	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.97	0.97	1.00
**Cc, for downstream face (<=1.0)	0.949975	0.962717	ERR
Ys, scour w/Chang equation, ft	**-0.51**	**0.23**	N/A
Ys, scour w/Umbrell equation, ft	-1.50	-0.96	N/A

**=for UNsubmerged orifice flow using estimated downstream bridge face properties.

**Ys, scour w/Chang equation, ft	0.38	0.33	N/A

**Ys, scour w/Umbrell equation, ft	-0.78	-0.88	ERR

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

y2, from Laursen's equation, ft	7.36	7.92	8.23
WSEL at downstream face, ft	498.77	499.39	--
Depth at downstream face, ft	8.16	8.80	N/A
Ys, depth of scour (Laursen), ft	-0.80	-0.87	N/A

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	2500	3050	2470	2500	3050	2470
a', abut.length blocking flow, ft	290.9	290.9	102.8	271.5	292.3	220.2
Ae, area of blocked flow ft2	380.1	449.7	202.09	332.78	349.14	171.91
Qe, discharge blocked abut.,cfs	--	--	1056.61	--	--	230.29
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.57	2.68	5.23	1.26	1.42	1.34
ya, depth of f/p flow, ft	0.42	1.55	1.97	1.23	1.19	0.78
--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	85	85	85	95	95	95
K2	0.99	0.99	0.99	1.01	1.01	1.01
Fr, froude number f/p flow	0.392	0.373	0.657	0.176	0.189	0.267
ys, scour depth, ft	7.73	16.43	17.38	9.35	9.82	8.18

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)	290.9	290.9	102.8	271.5	292.3	220.2
y1 (depth f/p flow, ft)	1.31	1.55	1.97	1.23	1.19	0.78
a'/y1	222.63	188.18	52.29	221.50	244.71	282.05
Skew correction (p. 49, fig. 16)	0.98	0.98	0.98	1.01	1.01	1.01
Froude no. f/p flow	0.39	0.37	0.66	0.18	0.19	0.27
Ys w/ corr. factor K1/0.55:						
vertical	6.86	7.98	12.24	5.08	5.07	3.71
vertical w/ ww's	**5.62**	**6.54**	**10.03**	**4.17**	**4.16**	**3.05**
spill-through	3.77	4.39	6.73	2.79	2.79	2.04

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.52	0.51	0.68	0.52	0.51	0.68
y, depth of flow in bridge, ft	8.16	8.80	7.44	8.16	8.80	7.44
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	**1.36**	**1.41**	**2.13**	**1.36**	**1.41**	**2.13**
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR