LEVEL II SCOUR ANALYSIS FOR BRIDGE 4 (ARLITH00010004) on TOWN HIGHWAY 1, crossing WARM BROOK, ARLINGTON, VERMONT

U.S. Geological Survey
Open-File Report 97-182

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

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By SCOTT A. OLSON and MICHAEL A. IVANOFF

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Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
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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 4 (ARLITH00010004) ON TOWN HIGHWAY 1, CROSSING WARM BROOK, ARLINGTON, VERMONT

By **Scott A. Olson** *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 ARLITH00010004 on Town Highway 1 crossing Warm Brook, Arlington, 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 12.1-mi^2 drainage area consists of a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is brush except for the upstream and downstream right banks which are covered by brush and grass.

In the study area, Warm Brook has an incised, straight channel with a slope of approximately 0.003 ft/ft, an average channel top width of 19 ft and an average bank height of 1 ft. The channel bed material ranges from sand to cobble with a median grain size (D_{50}) of 33.3 mm (0.109 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 30, 1996, indicated that the reach was stable.

The Town Highway 1 crossing of Warm Brook is a 49-ft-long, two-lane bridge consisting of one 44-foot steel-beam span (Vermont Agency of Transportation, written communication, January 30, 1996). The bridge is supported by vertical, concrete abutments with wingwalls. The abutments have been placed on top of the previous stone abutments. The channel is skewed approximately 0 degrees to the opening while the opening-skew-to-roadway is 20 degrees.

A scour hole approximately 1.0 ft deeper than the mean thalweg depth was observed mid-channel in the upstream reach within 30 ft of the bridge. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the upstream left bank approach to the bridge. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 1.7 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 8.3 to 11.9 ft. The worst-case abutment scour also occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Arlington, 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 ARLITH00010004 ***Stream*** Warm Brook

County Bennington ***Road*** TH1 ***District*** 1

Description of Bridge

Bridge length 49 ***ft*** ***Bridge width*** 27.6 ***ft*** ***Max span length*** 44 ***ft***

Alignment of bridge to road (on curve or straight) Right, straight; Left, curve.

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

Stone fill on abutment? No ***Date of inspection*** 7/30/96

Description of stone fill Type-2, along the upstream left bank approach to the bridge.

Brief description of piers/abutments Abutments and wingwalls are concrete. The abutments sit on the previous stone abutments.

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

Is there a channel bend in the reach? If so, describe (mild, moderate, severe) There is a mild channel bend through the reach.

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	7/30/96	0	0
Level II	7/30/96	0	0

Potential for debris Moderate. There is a beaver dam upstream of the bridge.

Describe any features near or at the bridge that may affect flow (include observation date) July 30, 1996. The beaver dam upstream may affect flow. There is a dam approximately 700 ft downstream of the bridge as well as a comparable sized tributary approximately 500 ft downstream of the bridge.

Description of the Geomorphic Setting

General topography The channel is located within an approximately 1000 foot-wide, flat to slightly irregular valley with moderate relief on either side.

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

Date of inspection 7/30/96

DS left: Moderately sloped overbank with road embankment.

DS right: Flood plain.

US left: Swamp.

US right: Flood plain.

Description of the Channel

Average top width 19 ***ft*** ***Average depth*** 1 ***ft***

Predominant bed material Gravel ***Bank material*** Sand & Gravel

Straight, alluvial, and probably incised. The upstream left overbank is swampy.

7/30/96

Vegetative co Brush.

DS left: Brush and grass.

DS right: Brush.

US left: Grass.

US right:

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

Describe any obstructions in channel and date of observation. July 30, 1996. The abutments to a previous structure are located under the bridge. The old abutments significantly restrict flow (see Figure 8).

Hydrology

Drainage area 12.1 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***:

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 2,020 ***ft³/s*** ***Q500*** 2,730 ***ft³/s***

The 100- and 500-year discharges were taken from the Flood Insurance Study for the Town of Arlington (Federal Emergency Management Agency, 1986). The 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 223.31 ft. to the arbitrary USGS survey datum to obtain sea level.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the right abutment (elev. 498.26 ft, arbitrary survey datum). RM2 is a bronze USGS tablet set in the downstream sidewalk at the left end of the bridge (elev. 500.10 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
USDAM	-500	2	Section between confluence with Fayville Branch and DS dam. The section matches a section from the flood insurance study model (templated from EXITX)
XSEC1	-300	2	Section upstream of the confluence with Fayville Branch (templated from EXITX)
EXITX	-41	1	Exit section (also named EXTEM)
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	15	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 0.043 to 0.048, and overbank "n" values ranged from 0.040 to 0.080.

The starting water surface elevations were taken from a rating curve developed from model output of a section between a dam and the confluence of Warm Brook and Fayville Branch downstream of this bridge for the Flood Insurance Study for the Town of Arlington (Federal Emergency Management Agency, 1986). The surveyed exit section (EXITX) was templated to a location just upstream of the confluence (XSEC1) and to the location in between the confluence and the downstream dam (USDAM) matching the rated section.

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

Bridge Hydraulics Summary

Average bridge embankment elevation 499.0 *ft*
Average low steel elevation 495.6 *ft*

100-year discharge 2,020 *ft³/s*
Water-surface elevation in bridge opening 496.2 *ft*
Road overtopping? Y *Discharge over road* 929 *ft³/s*
Area of flow in bridge opening 141 *ft²*
Average velocity in bridge opening 7.9 *ft/s*
Maximum WSPRO tube velocity at bridge 10.7 *ft/s*

Water-surface elevation at Approach section with bridge 498.0
Water-surface elevation at Approach section without bridge 495.5
Amount of backwater caused by bridge 2.5 *ft*

500-year discharge 2,730 *ft³/s*
Water-surface elevation in bridge opening 495.9 *ft*
Road overtopping? Y *Discharge over road* 1,420 */s*
Area of flow in bridge opening 140 *ft²*
Average velocity in bridge opening 9.6 *ft/s*
Maximum WSPRO tube velocity at bridge 13.0 */s*

Water-surface elevation at Approach section with bridge 498.3
Water-surface elevation at Approach section without bridge 496.1
Amount of backwater caused by bridge 2.2

Incipient overtopping discharge 900 *ft³/s*
Water-surface elevation in bridge opening 496.2 *ft*
Area of flow in bridge opening 141 *ft²*
Average velocity in bridge opening 6.3 *ft/s*
Maximum WSPRO tube velocity at bridge 8.7 *ft/s*

Water-surface elevation at Approach section with bridge 496.8
Water-surface elevation at Approach section without bridge 494.2
Amount of backwater caused by bridge 2.6 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

The 100-year and the incipient road-overflow discharges resulted in unsubmerged orifice flow. The 500-year discharge resulted in submerged 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). Therefore, contraction scour for each modeled discharge was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). The results of Laursen’s clear-water contraction scour (Richardson and others, 1995, p. 32, equation 20) for all the modeled events were also computed and can be found in appendix F. The 500-year discharge model resulted in the worst contraction scour. The computed depths to streambed armoring suggest armoring will not limit the depth of contraction scour.

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.7	1.7	0.0
Depth to armoring	5.1	12.8	1.4
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
Abutment scour			
Left abutment	10.8	11.9	8.3
Right abutment	10.9	11.6	8.8
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.3	1.4	0.8
Right abutment	1.3	1.4	0.8
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

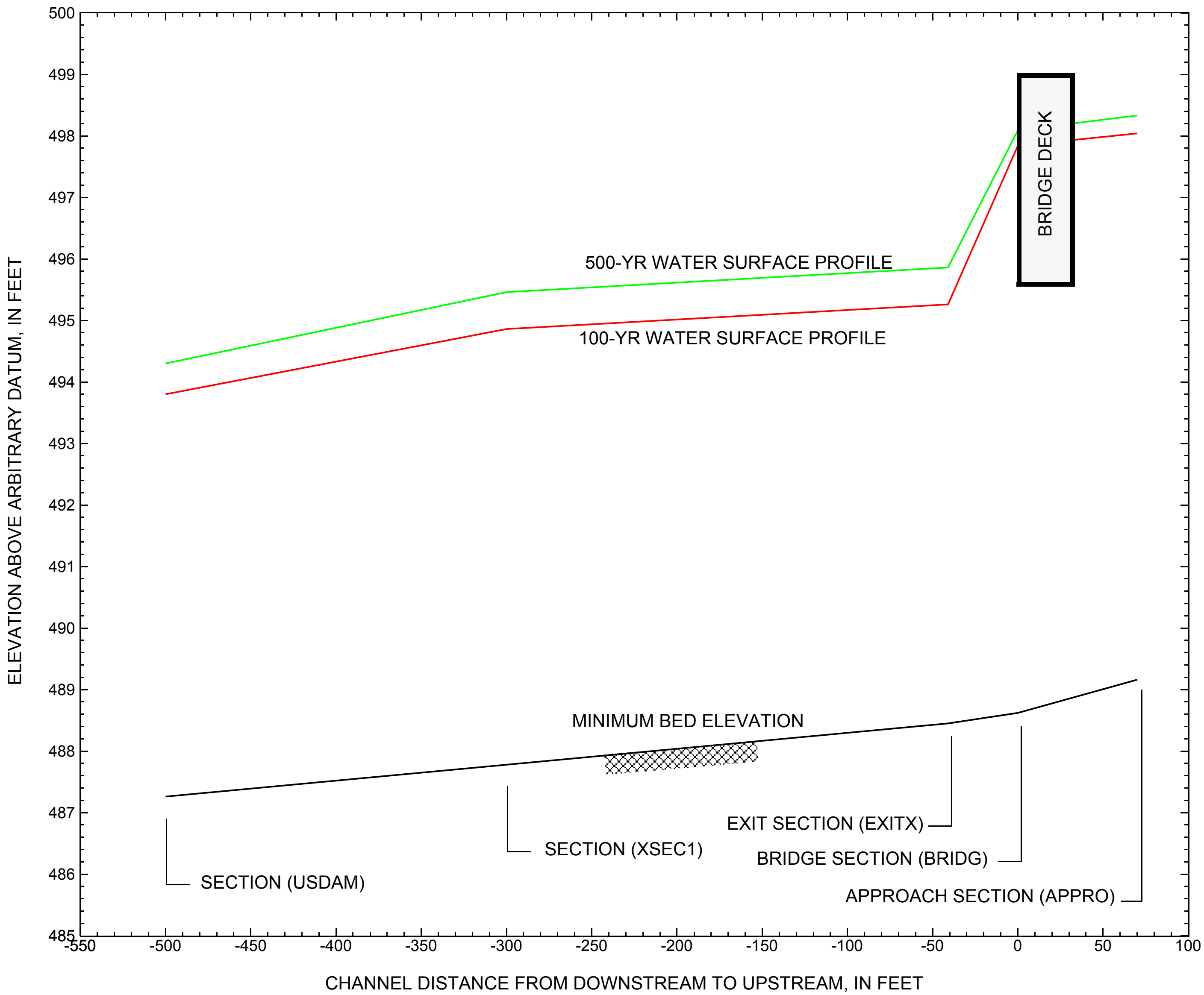

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure ARLITH00010004 on Town Highway 1, crossing Warm Brook, Arlington, Vermont.

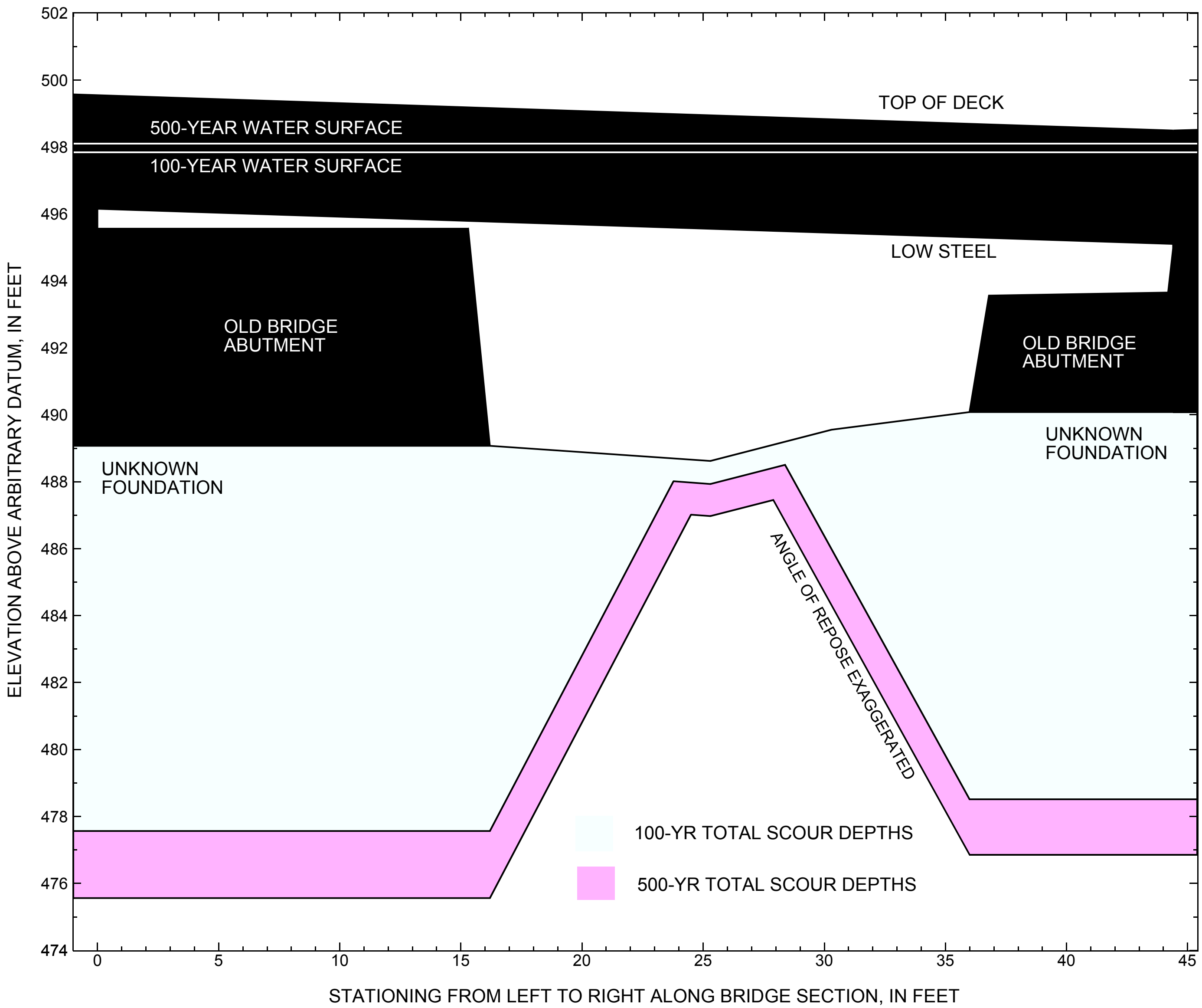

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure ARLITH00010004 on Town Highway 1, crossing Warm Brook, Arlington, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ARLITH00010004 on Town Highway 1, crossing Warm Brook, Arlington, 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 2,020 cubic-feet per second											
Left abutment	0.0	--	496.2	--	489.1	0.7	10.8	--	11.5	477.6	--
Right abutment	44.4	--	495.1	--	490.1	0.7	10.9	--	11.6	478.5	--

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 ARLITH00010004 on Town Highway 1, crossing Warm Brook, Arlington, 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 2,730 cubic-feet per second											
Left abutment	0.0	--	496.2	--	489.1	1.7	11.9	--	13.6	475.5	--
Right abutment	44.4	--	495.1	--	490.1	1.7	11.6	--	13.3	476.8	--

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, Arlington, 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 arli004.wsp
T2        Hydraulic analysis for structure ARLITH00010004   Date: 20-DEC-96
T3        ARLINGTON BRIDGE #4 OVER WARM BROOK  (FAS 114)    SAO
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3400 4600 1510
WS          493.8 494.3 492.9
*
XT   EXTEM    -41
GR         -157.8, 504.28    -51.8, 497.02    -32.8, 496.20    -27.3, 494.22
GR           -6.3, 491.96      6.1, 492.08     15.2, 491.26     15.3, 489.92
GR           20.6, 488.45     24.7, 488.48     29.7, 489.07     30.9, 489.42
GR           31.1, 490.67     35.9, 491.80    102.9, 491.98    252.3, 494.98
GR          505.6, 499.55
*
XS   USDAM    -500
GT           -1.19
N           0.060        0.048        0.040
SA                  15.2         35.9
*
XS   XSEC1    -300
GT           -0.67
N           0.060        0.048        0.040
SA                  15.2         35.9
*
Q           2020 2730 900
*
XS   EXITX     -41
GT             0
N           0.060        0.048        0.040
SA                  15.2         35.9
*
XS   FULLV      0
GT          0.14
N           0.060        0.048        0.040
SA                  15.2         35.9
*
BR   BRIDG     0 495.62 20
GR            0.0, 496.15      0.0, 495.57     15.3, 495.56     16.2, 489.07
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GR           44.2, 493.65     44.4, 494.97     44.4, 495.10      0.0, 496.15
N            0.043
CD           1 35.3 * * 75 3.3
*
XR   RDWAY     15       28
GR         -383.9, 514.98   -300.6, 511.04   -173.4, 505.66    -93.5, 502.11
GR          -18.4, 500.40     -2.6, 499.55     -2.4, 500.48     45.9, 499.47
GR           46.1, 498.49    130.3, 497.30    290.2, 496.81    401.6, 497.20
GR          492.3, 498.70    557.1, 499.58    576.4, 500.06
*
AS   APPRO     70
GR         -101.2, 503.77    -42.8, 491.42    -11.7, 491.95     15.3, 491.43
GR           16.2, 489.34     18.4, 489.21     23.0, 489.16     28.1, 489.38
GR           31.9, 490.19     32.3, 490.87     32.8, 491.17     51.5, 491.65
GR           53.6, 493.39    105.5, 494.49    135.2, 494.65    194.7, 494.79
GR          274.9, 496.27    366.4, 495.88    460.9, 497.26    482.2, 498.71
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GR          498.7, 498.67
N           0.080        0.048        0.044
SA                  15.3         32.8
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HP 1 BRIDG    496.15 1 496.15
HP 2 BRIDG    496.15 * * 1112
HP 2 RDWAY    497.84 * * 929
HP 1 APPRO    498.04 1 498.04
HP 2 APPRO    498.04 * * 2020
*
HP 1 BRIDG    495.94 1 495.94
HP 2 BRIDG    495.94 * * 1335
HP 2 RDWAY    498.09 * * 1421
HP 1 APPRO    498.33 1 498.33
HP 2 APPRO    498.33 * * 2730
*
HP 1 BRIDG    496.15 1 496.15
HP 2 BRIDG    496.15 * * 900
HP 1 APPRO    496.77 1 496.77
HP 2 APPRO    496.77 * * 900
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File arli004.wsp
       Hydraulic analysis for structure ARLITH00010004   Date: 20-DEC-96
       ARLINGTON BRIDGE #4 OVER WARM BROOK  (FAS 114)    SAO

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     141.    6377.    0.    94.                            0.
  496.15          141.    6377.    0.    94.  1.00     0.    44.       0.

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      496.15     0.0    44.4   140.6    6377.    1112.   7.91
 X STA.        0.0      17.8       19.2       20.5       21.5       22.5
  A(I)            18.5        9.4        7.9        6.8        6.3
  V(I)            3.00       5.94       7.07       8.23       8.83

 X STA.       22.5      23.4       24.3       25.1       25.9       26.7
  A(I)             5.9        5.6        5.4        5.3        5.2
  V(I)            9.45      10.00      10.30      10.47      10.73

 X STA.       26.7      27.6       28.4       29.3       30.3       31.3
  A(I)             5.2        5.2        5.2        5.3        5.4
  V(I)           10.74      10.70      10.69      10.48      10.22

 X STA.       31.3      32.3       33.5       34.7       36.4       44.4
  A(I)             5.6        5.9        6.6        7.9       12.2
  V(I)            9.89       9.39       8.49       7.03       4.56

   VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = RDWAY;  SRD =      15.
        WSEL     LEW     REW    AREA        K        Q    VEL
      497.84    92.1   440.3   241.2    7036.     929.   3.85
 X STA.       92.1     146.0      168.8      188.1      204.7      219.7
  A(I)            19.2       14.2       13.3       12.3       11.9
  V(I)            2.42       3.27       3.50       3.76       3.91

 X STA.      219.7     233.1      245.5      257.4      268.2      278.6
  A(I)            11.1       10.9       10.8       10.2       10.2
  V(I)            4.17       4.27       4.29       4.56       4.55

 X STA.      278.6     288.4      298.3      308.5      319.4      331.0
  A(I)             9.9       10.0       10.1       10.3       10.6
  V(I)            4.68       4.65       4.59       4.53       4.38

 X STA.      331.0     343.8      358.1      373.6      392.3      440.3
  A(I)            11.0       11.7       11.9       13.2       18.5
  V(I)            4.22       3.98       3.89       3.53       2.51

   CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = APPRO;  SRD =      70.
    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     473.   26582.   89.    90.                         6168.
            2     150.   18083.   17.    19.                         2480.
            3    1173.   76390.  440.   440.                        10880.
  498.04         1796.  121054.  546.   550.  1.22   -74.   472.  16709.

   VELOCITY DISTRIBUTION:  ISEQ =  7;  SECID = APPRO;  SRD =      70.
        WSEL     LEW     REW    AREA        K        Q    VEL
      498.04   -74.1   472.4  1795.7  121054.    2020.   1.12
 X STA.      -74.1     -37.8      -21.9       -5.5        9.5       19.3
  A(I)           136.7      101.4      101.1       95.8       72.3
  V(I)            0.74       1.00       1.00       1.05       1.40

 X STA.       19.3      24.6       30.1       37.9       46.6       58.8
  A(I)            46.4       47.3       56.1       57.3       67.3
  V(I)            2.18       2.14       1.80       1.76       1.50

 X STA.       58.8      76.2       96.6      120.8      147.0      174.0
  A(I)            75.9       80.6       86.2       89.2       89.9
  V(I)            1.33       1.25       1.17       1.13       1.12

 X STA.      174.0     202.7      241.1      304.5      364.1      472.4
  A(I)            93.1      105.7      124.5      120.7      148.3
  V(I)            1.09       0.96       0.81       0.84       0.68
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          U.S. Geological Survey WSPRO Input File arli004.wsp
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          ARLINGTON BRIDGE #4 OVER WARM BROOK  (FAS 114)    SAO

      CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.
       WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
               1     140.    6726.     8.    85.                       3246.
     495.94          140.    6726.     8.    85.  1.00     0.    44.   3246.

      VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = BRIDG;  SRD =       0.
           WSEL     LEW     REW    AREA        K        Q    VEL
         495.94     0.0    44.4   139.8    6726.    1335.   9.55
  X STA.        0.0       17.6       19.0       20.2       21.2       22.1
    A(I)            16.8        8.9        7.3        6.7        6.1
    V(I)            3.98       7.51       9.12      10.01      10.96

  X STA.       22.1       23.0       23.9       24.7       25.5       26.4
    A(I)             5.7        5.5        5.4        5.3        5.2
    V(I)           11.65      12.04      12.41      12.53      12.76

  X STA.       26.4       27.2       28.1       29.0       30.0       31.0
    A(I)             5.2        5.3        5.3        5.6        5.5
    V(I)           12.95      12.50      12.67      11.95      12.04

  X STA.       31.0       32.0       33.2       34.5       36.1       44.4
    A(I)             5.9        6.2        6.7        7.7       13.4
    V(I)           11.38      10.74       9.94       8.62       4.99

      VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = RDWAY;  SRD =      15.
           WSEL     LEW     REW    AREA        K        Q    VEL
         498.09    74.4   455.4   332.4   11304.    1421.   4.28
  X STA.       74.4      136.8      159.7      178.8      196.4      212.0
    A(I)            27.2       19.4       17.4       16.9       15.9
    V(I)            2.61       3.67       4.08       4.19       4.47

  X STA.      212.0      226.6      240.2      253.0      264.9      276.4
    A(I)            15.5       15.1       14.6       14.1       14.1
    V(I)            4.58       4.71       4.87       5.03       5.04

  X STA.      276.4      287.3      298.2      309.6      321.6      334.3
    A(I)            13.7       13.8       14.1       14.3       14.5
    V(I)            5.20       5.14       5.06       4.97       4.89

  X STA.      334.3      348.3      363.2      379.8      399.5      455.4
    A(I)            15.5       15.7       16.5       18.4       25.8
    V(I)            4.60       4.53       4.31       3.87       2.75

      CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = APPRO;  SRD =      70.
       WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
               1     499.   28777.    91.    92.                       6636.
               2     155.   19117.    17.    19.                       2607.
               3    1302.   90204.   444.   445.                      12648.
     498.33         1955.  138098.   552.   555.  1.19   -75.   477.  19120.

      VELOCITY DISTRIBUTION:  ISEQ =  7;  SECID = APPRO;  SRD =      70.
           WSEL     LEW     REW    AREA        K        Q    VEL
         498.33   -75.5   476.6  1954.9  138098.    2730.   1.40
  X STA.      -75.5      -37.4      -20.1       -3.3       12.9       20.8
    A(I)           150.1      115.3      108.8      108.0       66.0
    V(I)            0.91       1.18       1.25       1.26       2.07

  X STA.       20.8       26.5       33.3       42.0       51.5       67.9
    A(I)            52.0       57.1       60.9       64.8       80.8
    V(I)            2.62       2.39       2.24       2.11       1.69

  X STA.       67.9       86.7      109.3      134.2      160.1      187.1
    A(I)            83.3       90.7       93.2       94.7       96.9
    V(I)            1.64       1.51       1.46       1.44       1.41

  X STA.      187.1      217.5      259.4      320.6      374.4      476.6
    A(I)           102.8      114.4      132.7      127.1      155.5
    V(I)            1.33       1.19       1.03       1.07       0.88
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    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = BRIDG;  SRD =      0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     141.    6377.     0.    94.                          0.
   496.15          141.    6377.     0.    94.  1.00     0.    44.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = BRIDG;  SRD =      0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       496.15     0.0    44.4   140.6    6377.     900.   6.40
X STA.        0.0        17.8        19.2        20.5        21.5        22.5
  A(I)            18.5         9.4         7.9         6.8         6.3
  V(I)            2.43        4.81        5.73        6.66        7.14

X STA.       22.5        23.4        24.3        25.1        25.9        26.7
  A(I)             5.9         5.6         5.4         5.3         5.2
  V(I)            7.65        8.09        8.34        8.48        8.68

X STA.       26.7        27.6        28.4        29.3        30.3        31.3
  A(I)             5.2         5.2         5.2         5.3         5.4
  V(I)            8.69        8.66        8.65        8.48        8.27

X STA.       31.3        32.3        33.5        34.7        36.4        44.4
  A(I)             5.6         5.9         6.6         7.9        12.2
  V(I)            8.00        7.60        6.87        5.69        3.69

    CROSS-SECTION PROPERTIES:  ISEQ =  7;  SECID = APPRO;  SRD =     70.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     363.   17940.    83.    84.                       4297.
             2     127.   13829.    17.    19.                       1948.
             3     634.   29383.   395.   395.                       4555.
   496.77         1124.   61152.   495.   499.  1.49   -68.   427.   7861.

    VELOCITY DISTRIBUTION:  ISEQ =  7;  SECID = APPRO;  SRD =     70.
         WSEL     LEW     REW    AREA        K        Q    VEL
       496.77   -68.1   427.3  1123.8   61152.     900.   0.80
X STA.      -68.1       -40.3       -28.7       -17.1        -5.1         6.1
  A(I)            81.0        60.7        58.1        58.2        56.6
  V(I)            0.56        0.74        0.77        0.77        0.80

X STA.        6.1        16.5        20.2        23.5        27.0        30.7
  A(I)            56.2        27.7        25.7        26.1        26.7
  V(I)            0.80        1.63        1.75        1.72        1.69

X STA.       30.7        36.8        43.8        51.7        67.5        88.2
  A(I)            35.3        38.2        41.0        52.9        59.2
  V(I)            1.28        1.18        1.10        0.85        0.76

X STA.       88.2       114.3       147.0       182.6       232.1       427.3
  A(I)            62.5        70.3        73.0        85.4       129.0
  V(I)            0.72        0.64        0.62        0.53        0.35
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 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS      Q    WSEL
      SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

USDAM:XS   ******   -29.     656.  0.48 *****  494.28  493.19   3400.  493.80
     -500. ******   253.   40692.  1.16 ***** *******    0.65    5.18

XSEC1:XS     200.   -31.     817.  0.11  0.66  494.97 *******   2020.  494.86
     -300.   200.   283.   54442.  1.13  0.00    0.02    0.29    2.47

EXITX:XS     259.   -30.     735.  0.13  0.41  495.40 *******   2020.  495.26
      -41.   259.   268.   47308.  1.14  0.01    0.01    0.33    2.75

FULLV:FV      41.   -30.     717.  0.14  0.08  495.48 *******   2020.  495.34
        0.    41.   264.   45751.  1.15  0.00    0.00    0.34    2.82
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.66

APPRO:AS      70.   -62.     610.  0.28  0.21  495.76 *******   2020.  495.48
       70.    70.   232.   30345.  1.65  0.07    0.00    0.52    3.31
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   500.88       0.00     495.35     496.81

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   495.69     497.86     497.99     495.62

 ===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      41.     0.     141.  0.97 *****  497.12  494.22   1112.  496.15
        0. ******    44.    6377.  1.00 ***** *******    0.78    7.91

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****    5.  0.500  0.000  495.62 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.    42.  0.01  0.02  498.05    0.01    929.  497.84

          Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    0.     3.    -6.    -3.   0.2   0.1   3.7  19.9   0.7   3.0
   RT:  929.   349.    92.   441.   1.0   0.7   4.4   3.8   0.9   3.1

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

APPRO:AS      35.   -74.    1795.  0.02  0.14  498.06  494.24   2020.  498.04
       70.    44.   472.  121027.  1.22  1.01    0.01    0.12    1.13

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

  FIRST USER DEFINED TABLE.
    XSID:CODE     SRD    LEW    REW       Q         K      AREA     VEL   WSEL
   USDAM:XS     -500.   -29.   253.   3400.   40692.      656.    5.18  493.80
   XSEC1:XS     -300.   -31.   283.   2020.   54442.      817.    2.47  494.86
   EXITX:XS      -41.   -30.   268.   2020.   47308.      735.    2.75  495.26
   FULLV:FV        0.   -30.   264.   2020.   45751.      717.    2.82  495.34
   BRIDG:BR        0.     0.    44.   1112.    6377.      141.    7.91  496.15
   RDWAY:RG       15.*******     0.    929.        0.*********    1.00  497.84
   APPRO:AS       70.   -74.   472.   2020.  121027.     1795.    1.13  498.04

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF     HO   VHD     EGL    WSEL
   USDAM:XS     493.19    0.65  487.26  503.09************  0.48  494.28  493.80
   XSEC1:XS   ********    0.29  487.78  503.61  0.66  0.00  0.11  494.97  494.86
   EXITX:XS   ********    0.33  488.45  504.28  0.41  0.01  0.13  495.40  495.26
   FULLV:FV   ********    0.34  488.59  504.42  0.08  0.00  0.14  495.48  495.34
   BRIDG:BR     494.22    0.78  488.62  496.15************  0.97  497.12  496.15
   RDWAY:RG   ****************  496.81  514.98  0.01******  0.02  498.05  497.84
   APPRO:AS     494.24    0.12  489.16  503.77  0.14  1.01  0.02  498.06  498.04
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 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

USDAM:XS   ******   -31.     804.  0.58 *****  494.88  493.63   4600.  494.30
     -500. ******   281.   53360.  1.13 ***** *******    0.67    5.72

XSEC1:XS     200.   -33.    1015.  0.12  0.69  495.58 *******   2730.  495.46
     -300.   200.   316.   72827.  1.11  0.00    0.02    0.29    2.69

EXITX:XS     259.   -32.     924.  0.15  0.41  496.01 *******   2730.  495.86
      -41.   259.   301.   64233.  1.11  0.01    0.00    0.33    2.95

FULLV:FV      41.   -32.     904.  0.16  0.08  496.10 *******   2730.  495.94
        0.    41.   298.   62333.  1.12  0.00    0.01    0.34    3.02
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "APPRO"     KRATIO =  0.66

APPRO:AS      70.   -65.     800.  0.29  0.20  496.36 *******   2730.  496.07
       70.    70.   379.   40909.  1.63  0.07   -0.01    0.53    3.41
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                     WS3N,LSEL =    495.94      495.62

            <<<<<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      41.     0.     140.  1.42 *****  497.36  494.71   1335.  495.94
        0. ******    44.    6726.  1.00 ***** *******    0.95    9.55

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  495.62 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       15.    42.  0.02  0.04  498.35    0.01   1421.  498.09

           Q   WLEN    LEW    REW  DMAX  VAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0. ****** ****** ****** ***** ***** ***** ***** ***** *****
   RT:   1421.   381.    74.   455.   1.3   0.9   5.0   4.3   1.1   3.1

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

APPRO:AS      35.   -75.    1953.  0.04  0.21  498.36  495.13   2730.  498.33
       70.    47.   477.  137845.  1.19  1.01    0.01    0.14    1.40

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

  FIRST USER DEFINED TABLE.
    XSID:CODE     SRD    LEW     REW        Q         K      AREA     VEL    WSEL
   USDAM:XS     -500.   -31.    281.    4600.    53360.      804.    5.72  494.30
   XSEC1:XS     -300.   -33.    316.    2730.    72827.     1015.    2.69  495.46
   EXITX:XS      -41.   -32.    301.    2730.    64233.      924.    2.95  495.86
   FULLV:FV        0.   -32.    298.    2730.    62333.      904.    3.02  495.94
   BRIDG:BR        0.     0.     44.    1335.     6726.      140.    9.55  495.94
   RDWAY:RG       15.*******      0.    1421.        0.*********    1.00  498.09
   APPRO:AS       70.   -75.    477.    2730.   137845.     1953.    1.40  498.33

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   USDAM:XS     493.63    0.67  487.26  503.09************  0.58  494.88  494.30
   XSEC1:XS   ********    0.29  487.78  503.61  0.69  0.00  0.12  495.58  495.46
   EXITX:XS   ********    0.33  488.45  504.28  0.41  0.01  0.15  496.01  495.86
   FULLV:FV   ********    0.34  488.59  504.42  0.08  0.00  0.16  496.10  495.94
   BRIDG:BR     494.71    0.95  488.62  496.15************  1.42  497.36  495.94
   RDWAY:RG   ****************  496.81  514.98  0.02******  0.04  498.35  498.09
   APPRO:AS     495.13    0.14  489.16  503.77  0.21  1.01  0.04  498.36  498.33
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 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

USDAM:XS   ******   -26.     423.  0.25 *****  493.15  492.22   1510.  492.90
     -500. ******   208.   22675.  1.26 ***** *******    0.52    3.57

XSEC1:XS     200.   -27.     464.  0.07  0.50  493.66 *******    900.  493.59
     -300.   200.   216.   25580.  1.23  0.00    0.01    0.28    1.94

EXITX:XS     259.   -25.     398.  0.10  0.39  494.08 *******    900.  493.98
      -41.   259.   202.   20920.  1.27  0.01    0.01    0.34    2.26

FULLV:FV      41.   -24.     384.  0.11  0.08  494.17 *******    900.  494.06
        0.    41.   199.   19948.  1.28  0.00    0.00    0.36    2.35
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      70.   -56.     317.  0.21  0.19  494.41 *******    900.  494.19
       70.    70.    91.   14667.  1.70  0.05   -0.01    0.45    2.84
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   493.71     496.19     496.32     495.62

 ===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      41.     0.     141.  0.61 *****  496.76  493.28    884.  496.15
        0. ******    44.    6377.  1.00 ***** *******    0.62    6.28

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.480  0.000  495.62 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.         <<<<<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      35.   -68.    1122.  0.01  0.08  496.78  492.97    900.  496.77
       70.    40.   427.   61009.  1.49  0.87   -0.02    0.11    0.80

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   496.76

                     <<<<<END OF BRIDGE COMPUTATIONS>>>>>
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL   WSEL
   USDAM:XS    -500.   -26.   208.   1510.   22675.     423.    3.57  492.90
   XSEC1:XS    -300.   -27.   216.    900.   25580.     464.    1.94  493.59
   EXITX:XS     -41.   -25.   202.    900.   20920.     398.    2.26  493.98
   FULLV:FV       0.   -24.   199.    900.   19948.     384.    2.35  494.06
   BRIDG:BR       0.     0.    44.    884.    6377.     141.    6.28  496.15
   RDWAY:RG      15.**************      0.       0.*********    1.00********
   APPRO:AS      70.   -68.   427.    900.   61009.    1122.    0.80  496.77

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   USDAM:XS    492.22    0.52  487.26  503.09************  0.25  493.15  492.90
   XSEC1:XS  ********    0.28  487.78  503.61  0.50  0.00  0.07  493.66  493.59
   EXITX:XS  ********    0.34  488.45  504.28  0.39  0.01  0.10  494.08  493.98
   FULLV:FV  ********    0.36  488.59  504.42  0.08  0.00  0.11  494.17  494.06
   BRIDG:BR    493.28    0.62  488.62  496.15************  0.61  496.76  496.15
   RDWAY:RG  ****************  496.81  514.98************  0.01  496.90********
   APPRO:AS    492.97    0.11  489.16  503.77  0.08  0.87  0.01  496.78  496.77
```
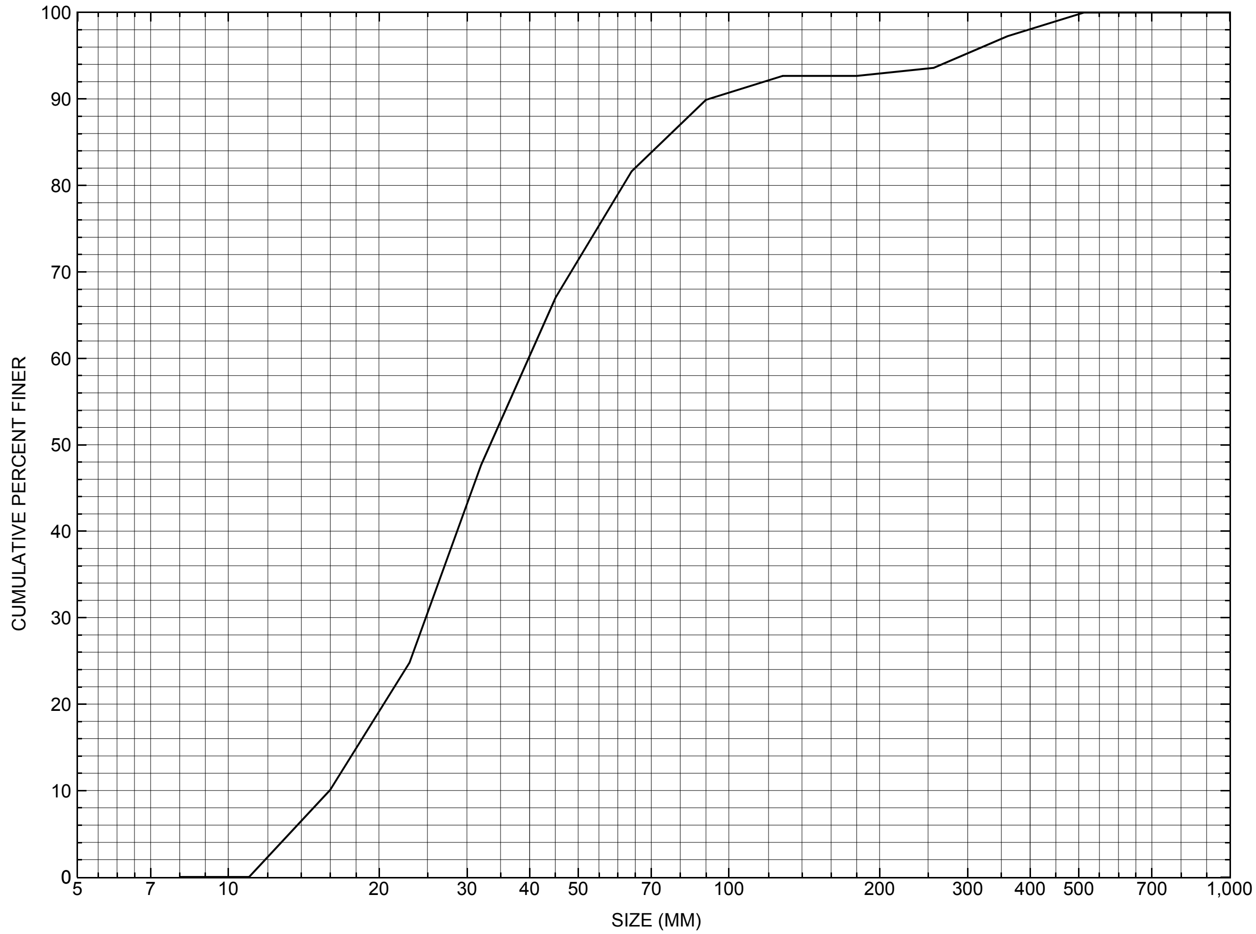

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure ARLITH00010004, in Arlington, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ARLITH00010004

General Location Descriptive

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

Date *(MM/DD/YY)* 01 / 30 / 96

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

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

Town *(FIPS place code; I - 4; nnnnn)* 01375

Mile marker *(I - 11; nnn.nnn)* 000950

Waterway *(I - 6)* WARM BROOK

Road Name *(I - 7)*: TR 01

Route Number FAS 114

Vicinity *(I - 9)* 0.9 MI E JCT. U.S.7 S

Topographic Map Arlington

Hydrologic Unit Code: 2020003

Latitude *(I - 16; nnnn.n)* 43038

Longitude *(i - 17; nnnnn.n)* 73088

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20011400040201

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

Maximum span length *(I - 48; nnnn)* 0044

Year built *(I - 27; YYYY)* 1934

Structure length *(I - 49; nnnnnn)* 000049

Average daily traffic, ADT *(I - 29; nnnnnn)* 001987

Deck Width *(I - 52; nn.n)* 276

Year of ADT *(I - 30; YY)* 91

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

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

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

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

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

Structure type *(I - 43; nnn)* 302

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 44

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

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

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

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

Comments:

According to the structural inspection report dated 7/21/94, the structure is a single span rolled beam bridge. The curtain wall at the left abutment has some minor cracking and scaling. The stem of the left abutment has some cracking with leakage at the fascia lines. The wingwalls of both abutments are in good condition with only minor cracking and scaling. The curtain wall at the right abutment has some leakage at the top and some cracking and heavy scaling at the bottom. The stem of the right abutment has some hairline vertical cracking. There has been additional fill and stone fill placed along the edge of the channel at the upstream left wingwall. The channel takes a slight turn into and out of **(continued on page 34)**

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*)

<u>Water Surface Elevation Estimates for Existing Structure:</u>

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:

the structure. There is some minor debris in the channel. There are laid up stone retaining walls from an earlier structure left in place in front of the abutments. A memo in the inspection folder notes that a new subfooting at the east abutment was poured on 9/26/91.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **12.06** mi^2 Lake and pond area **0.08** mi^2

Watershed storage *(ST)* **0.7** %

Bridge site elevation **720** ft Headwater elevation **1481** ft

Main channel length **6.56** mi

10% channel length elevation **740** ft 85% channel length elevation **930** ft

Main channel slope *(S)* **21.7** 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#29 Minimum channel bed elevation: -

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

Benchmark location description:

B.M. #7, paint spot on corner of downstream right abutment, elev. 178.07

Reference Point (*MSL, Arbitrary, Other*): Unknown 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: ______ (*1-regolith, 2-bedrock, 3-unknown*)

Briefly describe material at foundation bottom elevation or around piles:

Comments:

***Not sure whether these plans correspond with Arlington Bridge 4.**
According to Project No - 70 - 30 (T.H. #1) PWA-6114 (Record Plans) 1935,
Sheet 6 shows road over unnamed brook, with the following information:
Concrete bridge S.A. #29; constructed 1931; clear span 44'; roadway width 20'; concrete sidewalk 4'
The sketch also shows a barn very close (within several feet) to the upstream right bank and roadway.

Cross-sectional Data

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

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											

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

Comments:

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 10/1/96
Computerized by: EW Date: 10/1/96
Reviewd by: SAO Date: 2/7/97

Structure Number ARLITH00010004

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. IVANOFF Date *(MM/DD/YY)* 07 / 30 / 1996
2. Highway District Number 01 Mile marker 000950
County BENNINGTON 003 Town ARLINGTON 01375
Waterway *(I - 6)* WARM BROOK Road Name TR1
Route Number FAS114 Hydrologic Unit Code: 2020003
3. Descriptive comments:
LOCATED 0.9 MILES EAST OF JUNCTION WITH US 7 SOUTH.

B. Bridge Deck Observations

4. Surface cover... LBUS 5 RBUS 4 LBDS 5 RBDS 5 Overall 5
*(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 1 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 49 *(feet)* Span length 44 *(feet)* Bridge width 27.6 *(feet)*

Road approach to bridge:

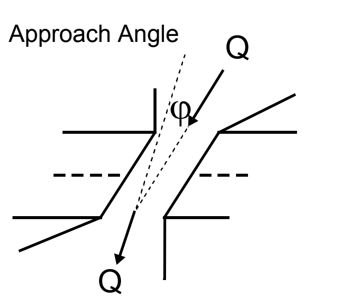
8. LB 2 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

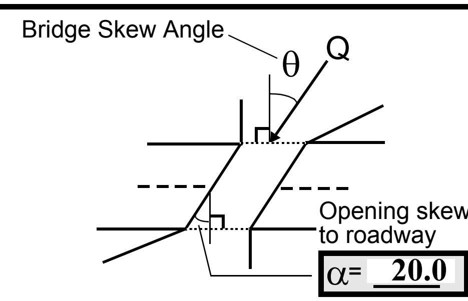
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	2	1
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

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



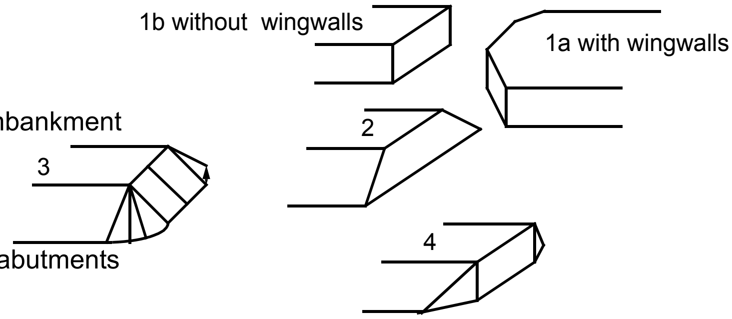


17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 15 feet UB *(US, UB, DS)* to 60 feet DS
Channel impact zone 2: Exist? N *(Y or N)*
Where? ____ *(LB, RB)* Severity ____
Range? ____ feet ____ *(US, UB, DS)* to ____ feet ____

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

18. Bridge Type: **1a**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

#4: Right over-bank is cut grass with some residential homes.

#5: Left bank includes shrub and brush and marsh upstream. Beyond 100 feet left of the left edge of water the surface cover is forest.

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
39.0	**0.5**			**0.5**	**1**	**1**	**231**	**231**	**1**	**1**

23. Bank width **20.0** 24. Channel width **30.0** 25. Thalweg depth **17.5** 29. Bed Material **342**

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.):

Beaver dam is 250 feet upstream.

Left bank protection extends from 24 feet upstream to 5 feet upstream.

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: 20

47. Scour dimensions: Length 15 Width 8 Depth : 1 Position 10 %LB to 90 %RB

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

Thalweg is 1.5 feet.

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES
Beaver dam has created many seeps along the left bank.

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
15.5		1.5		2	7	7	-

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

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

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

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

3421

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

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

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

70. Debris and Ice Comments:

2

Beaver dam is upstream with some dead trees in pond area.

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		10	90	2	2	0	7.0	90.0
RABUT	1	0	90			2	2	41.5

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.):

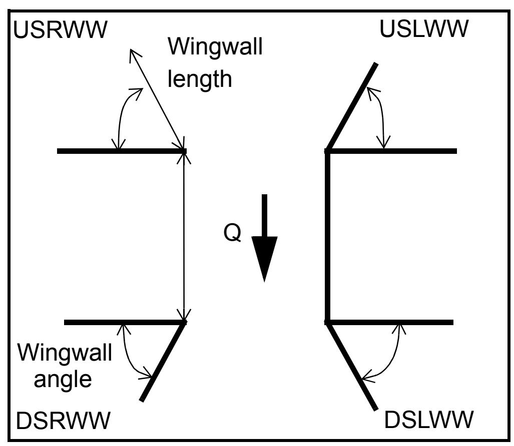
0
3.0
1

Left abutment footing begins 5 feet under bridge from upstream bridge face and extends to 0 feet downstream. The old stone abutment protruding into channel extends from 8 feet under bridge to 8 feet downstream.

Right abutment footing and old stone abutment extends from 15 feet under bridge from upstream bridge face to 13 feet downstream.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						41.5	
USRWW:	Y		1		0	2.0	
DSLWW:	-		-		Y	30.5	
DSRWW:	1		0		-	30.5	



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	-	0	Y	0	-	-	3	1
Condition	Y	-	1	4.0	-	-	4	4
Extent	1	-	2	0	0	5	5	-

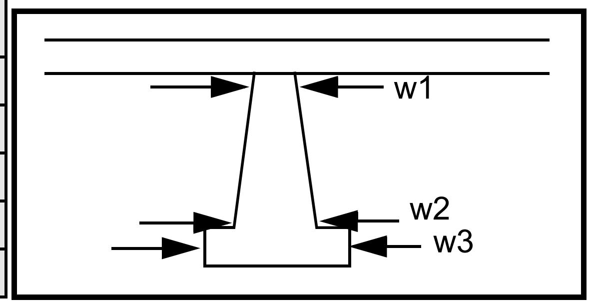
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		**8.5**	**4.5**	**40.0**	**110.0**	**110.0**
Pier 2	**4.0**	**5.0**	-	**75.0**	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e old**	**to be**		-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**abut**	**abut**		-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**ment**	**ment**		-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**s to a**	**pro-**		-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**pre-**	**tec-**		-	*Y- yes; N- no*
91. Attack ∠ (BF)	**vious**	**tion**		-	
92. Pushed	**struc**	**at**		-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**ture**	**this**	**N**	-	
95. Cross-members	**are**	**site.**	-	-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**con-**		-	-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**sid-**		-	-	
98. Exposure depth	**ered**		-	-	

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

NO PIERS

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):

1
1

106. Point/Side bar present? 13 (Y or N. if N type ctrl-n pb) Mid-bar distance: 13 Mid-bar width: 2

Point bar extent: 0 feet 32 (US, UB, DS) to 5 feet 5 (US, UB, DS) positioned 1 %LB to 1 %RB

Material: Lef

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

t bank protection consists of the old abutment which extends from the bridge face to 8 feet downstream. Right bank protection consists of the old abutment which extends from bridge face to 13 feet downstream.

The confluence of Warm Brook and Fayville Branch is 526 feet downstream of bridge. A dam exists approxi-

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

Cut bank extent: 770 feet feet (US, UB, DS) to dow feet nst (US, UB, DS)

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

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

m of bridge.

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

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

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

N

-

NO DROP STRUCTURE

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

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

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

Confluence comments (eg. confluence name):

-

-

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)*:

-

-

-

NO POINT BARS

Y

LB

60

12

DS

90

109. G. Plan View Sketch

\- D

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: ARLI004TH00010004 Town: ARLINGTON
Road Number: TH1 County: BENNINGTON
Stream: WARM BROOK

Initials SAO Date: 1/14/97 Checked:

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	2020	2730	900
Main Channel Area, ft2	150	155	127
Left overbank area, ft2	473	499	363
Right overbank area, ft2	1173	1302	634
Top width main channel, ft	17	17	17
Top width L overbank, ft	89	91	83
Top width R overbank, ft	440	444	395
D50 of channel, ft	0.109	0.109	0.109
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.8	9.1	7.5
y1, average depth, LOB, ft	5.3	5.5	4.4
y1, average depth, ROB, ft	2.7	2.9	1.6
Total conveyance, approach	121054	138098	61152
Conveyance, main channel	18083	19117	13829
Conveyance, LOB	26582	28777	17940
Conveyance, ROB	76390	90204	29383
Percent discrepancy, conveyance	-0.0008	0.0000	0.0000
Qm, discharge, MC, cfs	301.7	377.9	203.5
Ql, discharge, LOB, cfs	443.6	568.9	264.0
Qr, discharge, ROB, cfs	1274.7	1783.2	432.4
Vm, mean velocity MC, ft/s	2.0	2.4	1.6
Vl, mean velocity, LOB, ft/s	0.9	1.1	0.7
Vr, mean velocity, ROB, ft/s	1.1	1.4	0.7
Vc-m, crit. velocity, MC, ft/s	7.7	7.7	7.5
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?			
Main Channel	0	0	0
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

ARMORING			
D90	0.299	0.299	0.299
D95	0.959	0.959	0.959
Critical grain size,Dc, ft	0.2584	0.3788	0.1692
Decimal-percent coarser than Dc	0.133	0.0814	0.273
Depth to armoring,ft	5.05	12.82	1.35

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	150	155	127
Main channel width, ft	17	17	17
y1, main channel depth, ft	8.82	9.12	7.47
Bridge Section			
(Q) total discharge, cfs	2020	2730	900
(Q) discharge thru bridge, cfs	1112	1335	900
Main channel conveyance	6377	6726	6377
Total conveyance	6377	6726	6377
Q2, bridge MC discharge,cfs	1112	1335	900
Main channel area, ft2	141	140	141
Main channel width (skewed), ft	41.7	41.7	41.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	41.7	41.7	41.7
y_bridge (avg. depth at br.), ft	3.38	3.36	3.38
Dm, median (1.25*D50), ft	0.13625	0.13625	0.13625
y2, depth in contraction,ft	3.65	4.27	3.04
ys, scour depth (y2-ybridge), ft	0.27	0.91	-0.34

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	2020	2730	900
Q, thru bridge, cfs	1112	1335	900
Total Conveyance, bridge	6377	6726	6377
Main channel(MC) conveyance, bridge	6377	6726	6377
Q, thru bridge MC, cfs	1112	1335	900
Vc, critical velocity, ft/s	7.70	7.74	7.49
Vc, critical velocity, m/s	2.35	2.36	2.28
Main channel width (skewed), ft	41.7	41.7	41.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	41.7	41.7	41.7
qbr, unit discharge, ft2/s	26.7	32.0	21.6
qbr, unit discharge, m2/s	2.5	3.0	2.0
Area of full opening, ft2	141.0	140.0	141.0
Hb, depth of full opening, ft	3.38	3.36	3.38
Hb, depth of full opening, m	1.03	1.02	1.03
Fr, Froude number, bridge MC	0.78	0.95	0.62

Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	495.62	495.62	495.62
Elevation of Bed, ft	492.24	492.26	492.24
Elevation of Approach, ft	498.04	498.33	496.77
Friction loss, approach, ft	0.14	0.21	0.08
Elevation of WS immediately US, ft	497.90	498.12	496.69
ya, depth immediately US, ft	5.66	5.86	4.45
ya, depth immediately US, m	1.73	1.79	1.36
Mean elevation of deck, ft	499.98	499.98	499.98
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.85	0.83	0.93
Ys, depth of scour, ft	0.69	1.65	-0.29

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

y2, from Laursen's equation, ft	3.64913	4.268019	3.044039
Full valley WSEL, ft	495.34	0	494.06
Full valley depth, ft	3.101295	-492.263	1.821295
Ys, depth of scour (y2-yfullv), ft	0.547835	N/A	1.222744

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	2020	2730	900	2020	2730	900
a', abut.length blocking flow, ft	74.1	75.5	68.1	31	19.5	385.6
Ae, area of blocked flow ft2	374.3	396.2	238.8	160.2	114.7	584.8
Qe, discharge blocked abut.,cfs	340	437.3	200.5	238.6	221.9	373.5
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	0.91	1.10	0.84	1.49	1.93	0.64
ya, depth of f/p flow, ft	5.05	5.25	3.51	5.17	5.88	1.52
--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	70	70	70	110	110	110
K2	0.97	0.97	0.97	1.03	1.03	1.03
Fr, froude number f/p flow	0.071	0.085	0.079	0.115	0.141	0.091
ys, scour depth, ft	10.82	11.86	8.32	10.88	11.57	8.80

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)	74.1	75.5	68.1	31	19.5	385.6
y1 (depth f/p flow, ft)	5.05	5.25	3.51	5.17	5.88	1.52
a'/y1	14.67	14.39	19.42	6.00	3.32	254.25
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.07	0.08	0.08	0.12	0.14	0.09
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	5.01
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	4.11
spill-through	ERR	ERR	ERR	ERR	ERR	2.75

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.78	0.95	0.62	0.78	0.95	0.62
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	3.38	3.36	3.38	3.38	3.36	3.38
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.27	ERR	0.80	1.27	ERR	0.80
Fr>0.8 (vertical abut.)	ERR	1.38	ERR	ERR	1.38	ERR
Fr<=0.8 (spillthrough abut.)	1.11	ERR	0.70	1.11	ERR	0.70
Fr>0.8 (spillthrough abut.)	ERR	1.22	ERR	ERR	1.22	ERR