LEVEL II SCOUR ANALYSIS FOR BRIDGE 37 (DUXBTH00120037) on TOWN HIGHWAY 12, crossing RIDLEY BROOK, DUXBURY, VERMONT

U.S. Geological Survey
Open-File Report 97-405

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 37 (DUXBTH00120037) on TOWN HIGHWAY 12, crossing RIDLEY BROOK, DUXBURY, VERMONT

By EMILY C. WILD 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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Box 25286
Denver, CO 80225-0286

CONTENTS

FIGURES

TABLES

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 37 (DUXBTH00120037) ON TOWN HIGHWAY 12, CROSSING RIDLEY BROOK, DUXBURY, VERMONT

By **Emily C. Wild 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 DUXBTH00120037 on Town Highway 12 crossing Ridley Brook, Duxbury, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the Green Mountain section of the New England physiographic province in north central Vermont. The 10.1-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest upstream and downstream of the bridge.

In the study area, Ridley Brook has an incised, straight channel with a slope of approximately 0.04 ft/ft, an average channel top width of 67 ft and an average bank height of 9 ft. The channel bed material ranges from gravel to boulders with a median grain size (D_{50}) of 123 mm (0.404 ft). The geomorphic assessment at the time of the Level I and Level II site visit on July 1, 1996, indicated that the reach was stable.

The Town Highway 12 crossing of Ridley Brook is a 33-ft-long, two-lane bridge consisting of five 30-ft steel rolled beams (Vermont Agency of Transportation, written communication, October 13, 1995). The opening length of the structure parallel to the bridge face is 30 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 50 degrees to the opening while the measured opening-skew-to-roadway is 20 degrees.

A scour hole 2 ft deeper than the mean thalweg depth was observed along the right abutment and downstream right wingwall during the Level I assessment. Scour countermeasures at the site include type-2 stone fill (less than 3 feet diameter) along the upstream and downstream left road embankments, and type-3 stone fill (less than 4 feet diameter) along the upstream right bank and upstream right wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.6 to 1.7 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 5.0 to 8.3 ft, with the worst-case occurring at the incipient-overtopping discharge. Right abutment scour ranged from 13.1 to 16.7 ft, with the worst-case occurring at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled "Scour Results". Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Plymouth, VT. Quadrangle, 1:24,000, 1966
Photoinspected 1983

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 DUXBTH00120037 ***Stream*** Ridley Brook

County Washington ***Road*** TH12 ***District*** 6

Description of Bridge

Bridge length 33 ***ft*** ***Bridge width*** 22.6 ***ft*** ***Max span length*** 30 ***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*** 07/01/96

Description of stone fill Type-2, along the upstream right wingwall, which has slumped into the channel.

Brief description of piers/abutments Abutments and wingwalls are concrete. There is a two foot deep scour hole along the downstream end of the right abutment and along the downstream right wingwall.

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 50

Is there a channel bend? If so, describe (mild, moderate, severe) There is a moderate channel bend in the upstream 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	07/01/96	0	0
Level II	07/01/96	0	0

Potential for debris Moderate. There are some trees leaning into the channel upstream of the bridge.

Describe any features near or at the bridge that may affect flow (include observation date) None 0 7/01/96.

Description of the Geomorphic Setting

General topography The channel is located within a steep valley.

07/01/96

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

Date of inspection Moderately

DS left: sloping overbank.

DS right: Steep channel bank with a steep valley wall.

US left: Steep channel bank with a moderately sloping overbank.

US right: Steep valley wall.

Description of the Channel

Average top width 67 ft ***Average depth*** 9 ft

Predominant bed material Boulders / Cobbles ***Bank material*** Boulders/ Cobbles

Straight and stable

with alluvial channel boundaries and a narrow flood plain.

07/01/96

Vegetative co Forest

DS left: Forest

DS right: Trees with Town Highway 12 along immediate bank.

US left: Forest

US right: Y

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

None. 07/01/96

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 10.1 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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 3,770 ***ft³/s*** ***Q500*** 5,500 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(10.1/12.8)exp 0.7] with bridge number 6 in Duxbury. Bridge number 6 crosses the Ridley Brook downstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 6 is 12.8 square miles. The values computed are within a range defined by several empirical flood frequency curves (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 on top of the downstream end of the left abutment (elev. 498.97 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the right abutment (elev. 498.78 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	-39	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	11	1	Road Grade section
APPRO	55	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 0.040 to 0.070, and overbank "n" values ranged from 0.065 to 0.070.

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 0.0426 ft/ft which was estimated from thalweg slopes surveyed downstream.

The approach section (APPRO) was modelled 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.

For the incipient roadway-overtopping discharge, WSPRO assumes critical depth at the bridge section. Supercritical models were developed for these discharges. After analyzing both the supercritical and subcritical profiles for each discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumptions of critical depth at the bridge are satisfactory solutions.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.5 ***ft***
Average low steel elevation 496.8 ***ft***

100-year discharge 3,770 ***ft³/s***
Water-surface elevation in bridge opening 497.0 ***ft***
Road overtopping? Y ***Discharge over road*** 767 ***ft³/s***
Area of flow in bridge opening 226 ***ft²***
Average velocity in bridge opening 13.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.5 ***ft/s***

Water-surface elevation at Approach section with bridge 500.8
Water-surface elevation at Approach section without bridge 498.5
Amount of backwater caused by bridge 2.3 ***ft***

500-year discharge 5,500 ***ft³/s***
Water-surface elevation in bridge opening 497.0 ***ft***
Road overtopping? Y ***Discharge over road*** 2,393 ***ft³/s***
Area of flow in bridge opening 226 ***ft²***
Average velocity in bridge opening 13.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 16.0 ***ft/s***

Water-surface elevation at Approach section with bridge 502.8
Water-surface elevation at Approach section without bridge 500.0
Amount of backwater caused by bridge 2.8 ***ft***

Incipient overtopping discharge 2,320 ***ft³/s***
Water-surface elevation in bridge opening 494.7 ***ft***
Area of flow in bridge opening 168 ***ft²***
Average velocity in bridge opening 13.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 16.9 ***ft/s***

Water-surface elevation at Approach section with bridge 497.7
Water-surface elevation at Approach section without bridge 496.8
Amount of backwater caused by bridge 0.9 ***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.

Contraction scour for the incipient roadway-overtopping discharge was computed by use of Laursen's 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 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). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Results of this analysis are presented in figure 8 and tables 1 and 2. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

Additional estimates of contraction scour for the 100-year and 500-year discharges also were computed by use of Laursen's clear-water scour equation (Richardson and others, 1995, p. 32, equation 20) and Umbrell's pressure-flow scour equation (Richardson and other, 1995, p. 144-146), and the results are presented in Appendix F.

Abutment scour for the left and right abutments 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	1.6	1.7	0.6
Depth to armoring	15.9	18.7	28.3
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour	5.0 6.2	8.3 16.1	16.7
Left abutment	13.1	---	---
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	3.2	3.2
Pier 3			

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(D_{50} in feet)		
Abutments:	2.5	3.2	3.2
Left abutment	2.5	--	--
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--		
Pier 2			

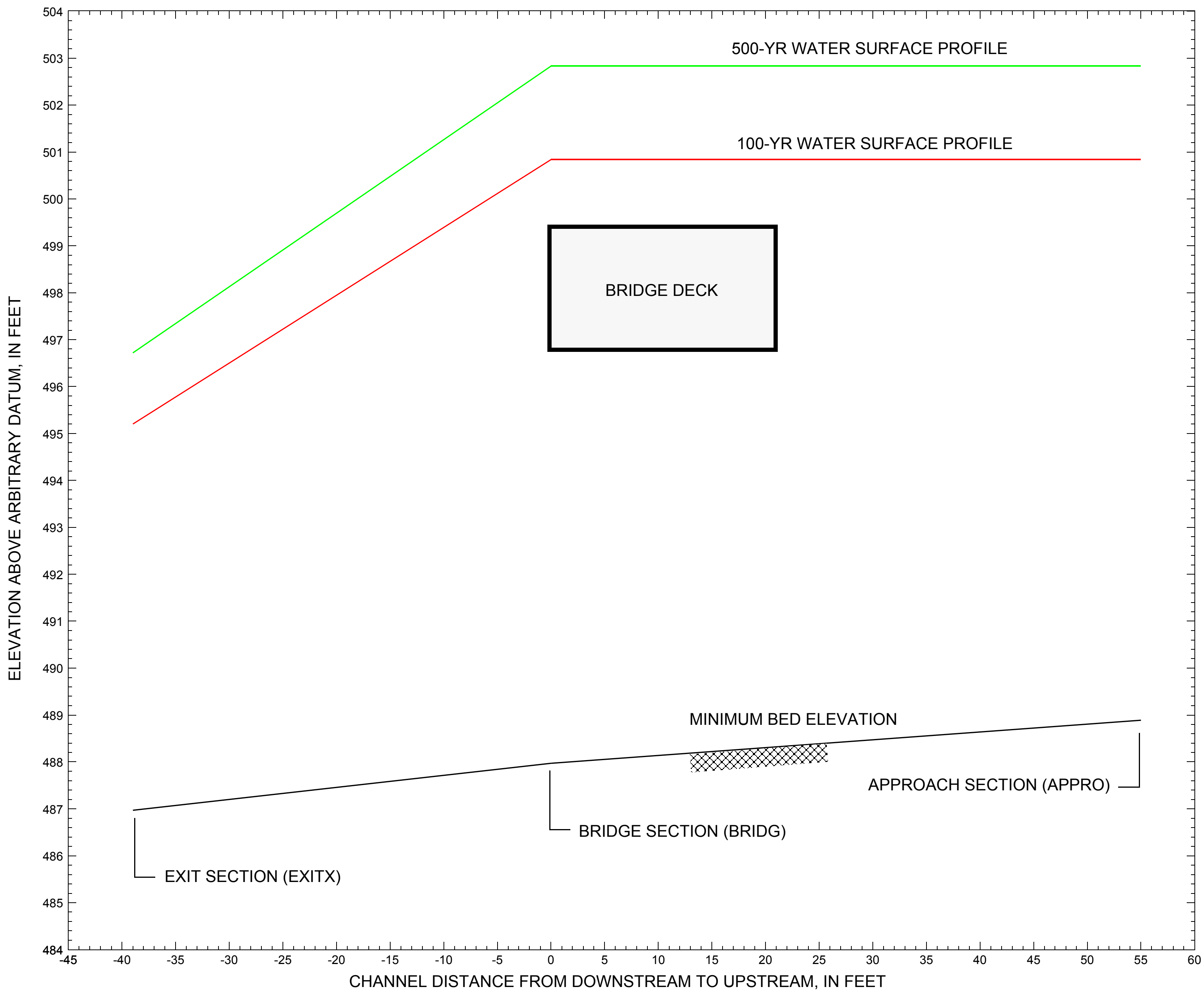

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure DUXBTH00120037 on Town Highway 12, crossing Ridley Brook, Duxbury, Vermont.

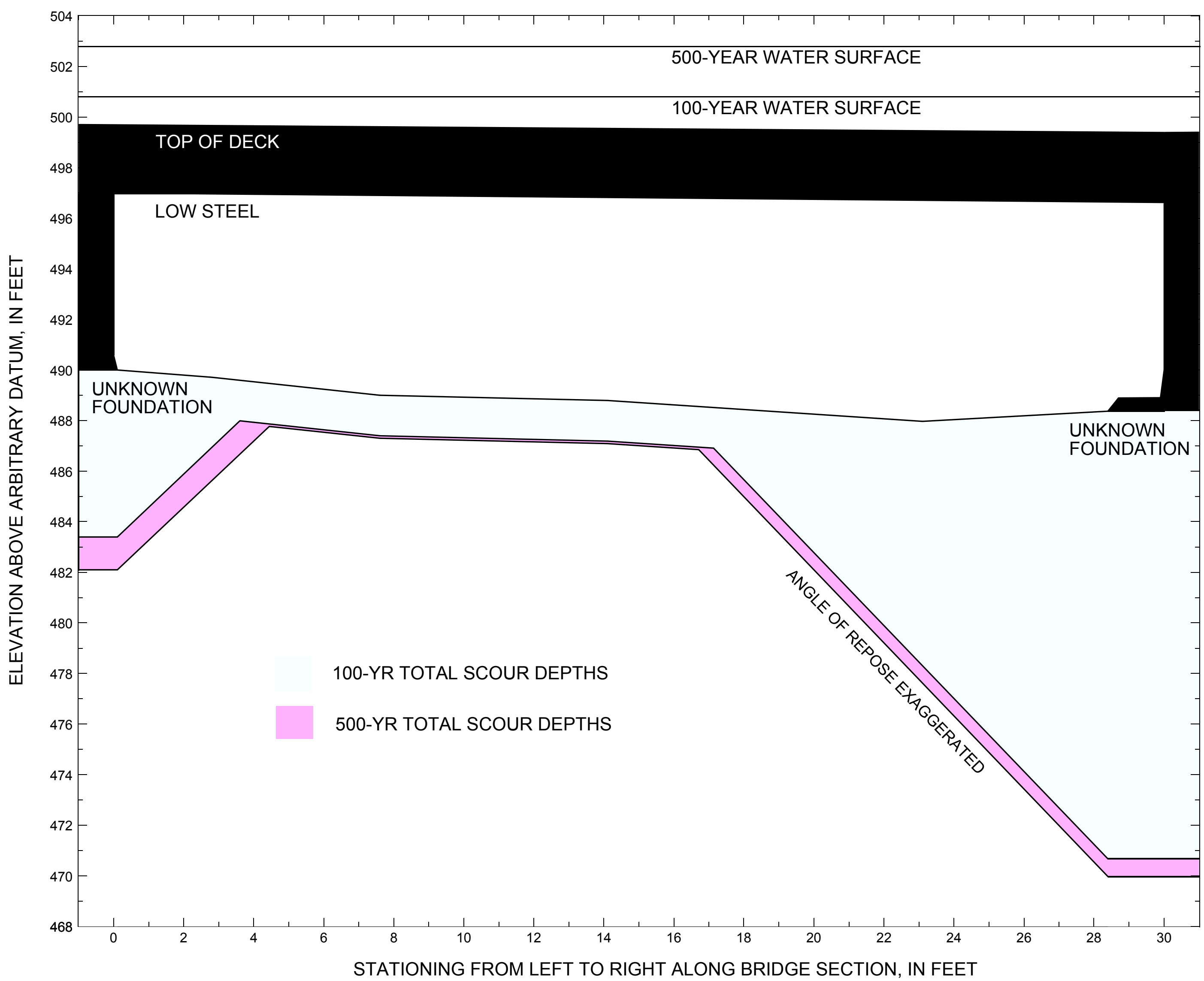

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure DUXBTH00120037 on Town Highway 12, crossing Ridley Brook, Duxbury, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure DUXBTH00120037 on Town Highway 12, crossing Ridley Brook, Duxbury, 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 3,770 cubic-feet per second											
Left abutment	0.0	--	497.0	--	490.0	1.6	5.0	--	6.6	483.4	--
Right abutment	30.0	--	496.6	--	488.4	1.6	16.1	--	17.7	470.7	--

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 DUXBTH00120037 on Town Highway 12, crossing Ridley Brook, Duxbury, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 5,500 cubic-feet per second											
Left abutment	0.0	--	497.0	--	490.0	1.7	6.2	--	7.9	482.1	--
Right abutment	30.0	--	496.6	--	488.4	1.7	16.7	--	18.4	470.0	--

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

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U.S. Geological Survey, 1948, Waterbury, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1980, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

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T1        U.S. Geological Survey WSPRO Input File duxb037.wsp
T2        Hydraulic analysis for structure DUXBTH00120037   Date: 16-MAY-97
T3        Town Highway 12, Ridley Brook, Duxbury, Vermont        by ECW
*
J1         * * 0.002
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3770.0   5500.0   2320.0
SK          0.0426   0.0426   0.0426
*
XS   EXITX    -39
GR          -84.8, 508.57    -39.7, 500.28    -28.1, 500.20      0.0, 493.54
GR            4.8, 490.45     13.7, 489.70     23.2, 489.04     25.9, 488.64
GR           31.7, 487.79     38.0, 486.97     43.4, 489.04     48.5, 491.18
GR           55.1, 496.99     64.5, 498.02     96.3, 498.33    105.4, 505.37
GR          134.7, 522.56
*
N           0.070       0.070      0.065
SA                -28.1       55.1
*
*
XS   FULLV      0  * * *   0.030
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.78      20.0
GR            0.0, 496.97      0.0, 490.59      0.1, 490.00      2.8, 489.71
GR            7.6, 489.00     14.1, 488.79     23.1, 487.97     28.4, 488.37
GR           28.7, 488.89     29.9, 488.90     30.0, 490.01     30.0, 496.60
GR            0.0, 496.97
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      30.0 * *     57.3      5.5
N           0.040
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     11      22.6     2
GR         -135.0, 511.55    -80.4, 504.71    -71.2, 500.09      0.0, 499.69
GR           32.4, 499.39     44.6, 505.72     66.7, 508.25     88.2, 522.30
*
*
AS   APPRO     55
GR         -148.3, 510.66    -75.0, 500.29    -26.1, 500.03     -6.4, 499.22
GR            0.0, 492.52      6.3, 490.27      9.3, 489.42     14.0, 488.89
GR           21.8, 490.00     24.7, 489.90     28.5, 490.68     36.7, 493.07
GR           44.6, 505.72     66.7, 508.25     88.2, 522.30
*
N             0.070       0.070
SA                 -6.4
*
HP 1 BRIDG 496.97 1 496.97
HP 2 BRIDG 496.97 * * 3004
HP 2 RDWAY 500.84 * * 767
HP 1 APPRO 500.84 1 500.84
HP 2 APPRO 500.84 * * 3770
*
HP 1 BRIDG 496.97 1 496.97
HP 2 BRIDG 496.97 * * 3107
HP 2 RDWAY 502.83 * * 2393
HP 1 APPRO 502.83 1 502.83
HP 2 APPRO 502.83 * * 5500
*
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File duxb037.wsp
        Hydraulic analysis for structure DUXBTH00120037   Date: 16-MAY-97
        Town Highway 12, Ridley Brook, Duxbury, Vermont        by ECW
           *** RUN DATE & TIME: 05-29-97  14:04
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      226     18132     0     71                            0
   496.97           226     18132     0     71  1.00      0     30        0


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.97     0.0    30.0   225.8   18132.    3004.  13.31

X STA.         0.0         2.8         4.6         6.2         7.7         9.1
  A(I)            18.9        12.3        11.5        10.7        10.6
  V(I)            7.94       12.25       13.02       14.05       14.18

X STA.         9.1        10.5        11.9        13.2        14.5        15.8
  A(I)            10.1        10.3        10.0         9.9        10.0
  V(I)           14.84       14.62       15.07       15.19       15.03

X STA.        15.8        17.1        18.3        19.6        20.8        22.0
  A(I)             9.7         9.8         9.7         9.8         9.8
  V(I)           15.45       15.26       15.44       15.35       15.39

X STA.        22.0        23.3        24.5        25.9        27.5        30.0
  A(I)            10.2        10.2        11.1        12.2        19.0
  V(I)           14.72       14.69       13.59       12.32        7.90



    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.84   -72.7    35.2   112.3    2479.     767.   6.83

X STA.       -72.7       -62.3       -54.4       -46.8       -39.9       -33.5
  A(I)             7.5         6.5         6.5         6.2         6.1
  V(I)            5.13        5.89        5.86        6.17        6.25

X STA.       -33.5       -27.3       -21.7       -16.2       -10.9        -6.0
  A(I)             6.0         5.7         5.8         5.6         5.4
  V(I)            6.41        6.68        6.67        6.82        7.07

X STA.        -6.0        -1.2         3.4         7.6        11.8        15.7
  A(I)             5.5         5.3         5.1         5.2         5.0
  V(I)            7.03        7.29        7.51        7.42        7.71

X STA.        15.7        19.3        23.0        26.4        29.7        35.2
  A(I)             4.8         4.9         4.7         4.7         5.9
  V(I)            7.98        7.87        8.15        8.12        6.53

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1       58      1071    72     73                          296
             2      432     35849    48     56                         7361
   500.84           490     36920   120    129  1.18    -78     42     5168


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.84   -78.9    41.6   490.4   36920.    3770.   7.69

X STA.       -78.9        -1.6         1.9         4.4         6.5         8.4
  A(I)            78.4        28.4        23.3        22.0        19.9
  V(I)            2.40        6.64        8.08        8.59        9.46

X STA.         8.4        10.0        11.7        13.2        14.7        16.3
  A(I)            19.0        18.7        18.4        18.1        18.4
  V(I)            9.92       10.08       10.27       10.44       10.26

X STA.        16.3        17.9        19.5        21.2        23.0        24.8
  A(I)            18.0        18.8        18.7        19.4        19.6
  V(I)           10.45       10.01       10.07        9.73        9.62

X STA.        24.8        26.7        28.8        31.1        34.1        41.6
  A(I)            20.5        21.1        23.2        26.1        40.4
  V(I)            9.19        8.93        8.14        7.22        4.66
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        U.S. Geological Survey WSPRO Input File duxb037.wsp
       Hydraulic analysis for structure DUXBTH00120037   Date: 16-MAY-97
       Town Highway 12, Ridley Brook, Duxbury, Vermont        by ECW
          *** RUN DATE & TIME: 05-29-97  14:04
     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      226     18132      0     71                            0
    496.97           226     18132      0     71  1.00      0     30        0


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

          WSEL     LEW     REW    AREA        K        Q    VEL
        496.97     0.0    30.0   225.8   18132.    3107.  13.76

 X STA.         0.0        2.8        4.6        6.2        7.7        9.1
   A(I)            18.9       12.3       11.5       10.7       10.6
   V(I)            8.21      12.67      13.47      14.53      14.67

 X STA.         9.1       10.5       11.9       13.2       14.5       15.8
   A(I)            10.1       10.3       10.0        9.9       10.0
   V(I)           15.35      15.12      15.58      15.71      15.54

 X STA.        15.8       17.1       18.3       19.6       20.8       22.0
   A(I)             9.7        9.8        9.7        9.8        9.8
   V(I)           15.98      15.79      15.97      15.87      15.91

 X STA.        22.0       23.3       24.5       25.9       27.5       30.0
   A(I)            10.2       10.2       11.1       12.2       19.0
   V(I)           15.23      15.19      14.05      12.74       8.17


     VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.

          WSEL     LEW     REW    AREA        K        Q    VEL
        502.83   -76.7    39.0   334.8   14378.    2393.   7.15

 X STA.       -76.7      -65.9      -59.7      -53.5      -47.5      -41.8
   A(I)            21.9       17.4       17.5       17.0       16.5
   V(I)            5.45       6.87       6.84       7.02       7.26

 X STA.       -41.8      -36.0      -30.4      -25.0      -19.6      -14.4
   A(I)            16.9       16.5       16.1       16.4       16.0
   V(I)            7.07       7.25       7.42       7.31       7.47

 X STA.       -14.4       -9.2       -4.0        1.0        5.9       10.8
   A(I)            15.9       16.0       15.8       15.6       15.8
   V(I)            7.54       7.47       7.58       7.68       7.56

 X STA.        10.8       15.5       20.2       24.8       29.6       39.0
   A(I)            15.2       15.6       15.4       16.3       20.8
   V(I)            7.86       7.65       7.78       7.33       5.74

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
              1      217      8479     87     87                         1943
              2      529     48836     49     59                         9838
    502.83           745     57315    136    145  1.27    -92     43     8803


     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

          WSEL     LEW     REW    AREA        K        Q    VEL
        502.83   -93.0    42.8   745.3   57315.    5500.   7.38

 X STA.       -93.0      -51.3      -25.9       -5.5        0.5        3.4
   A(I)            84.5       69.4       66.4       46.3       31.8
   V(I)            3.25       3.96       4.14       5.94       8.65

 X STA.         3.4        5.9        8.1       10.0       11.9       13.7
   A(I)            29.9       27.2       26.0       26.1       24.9
   V(I)            9.20      10.10      10.59      10.53      11.04

 X STA.        13.7       15.6       17.4       19.4       21.4       23.6
   A(I)            25.3       25.7       25.9       26.7       27.2
   V(I)           10.85      10.72      10.60      10.30      10.13

 X STA.        23.6       25.7       28.1       30.8       34.1       42.8
   A(I)            27.7       30.2       31.6       35.8       56.6
   V(I)            9.92       9.11       8.69       7.68       4.86
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     U.S. Geological Survey WSPRO Input File duxb037.wsp
     Hydraulic analysis for structure DUXBTH00120037   Date: 16-MAY-97
     Town Highway 12, Ridley Brook, Duxbury, Vermont        by ECW
        *** RUN DATE & TIME: 05-29-97  14:04
 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      168     16537     28     39                         2324
494.73           168     16537     28     39  1.00      0     30     2324


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

      WSEL     LEW     REW    AREA        K        Q    VEL
    494.73     0.0    30.0   167.8   16537.    2320.  13.82

X STA.         0.0         3.2         5.2         6.8         8.3         9.7
  A(I)            14.8         9.5         8.7         7.9         7.7
  V(I)             7.82       12.24       13.33       14.76       15.03

X STA.         9.7        11.1        12.4        13.7        15.0        16.2
  A(I)             7.5         7.3         7.3         7.0         7.1
  V(I)            15.48       15.93       15.99       16.58       16.28

X STA.        16.2        17.4        18.6        19.7        20.9        22.1
  A(I)             7.0         6.9         6.9         7.2         7.1
  V(I)            16.64       16.87       16.72       16.19       16.41

X STA.        22.1        23.2        24.4        25.7        27.3        30.0
  A(I)             7.2         7.7         8.0         9.5        15.7
  V(I)            16.08       15.16       14.41       12.24        7.40


 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          2      286     19349     45     50                         4107
497.70           286     19349     45     50  1.00     -4     40     4107


 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      55.

      WSEL     LEW     REW    AREA        K        Q    VEL
    497.70    -4.9    39.6   285.7   19349.    2320.   8.12

X STA.        -4.9         2.2         4.8         6.8         8.5        10.0
  A(I)            24.8        16.7        14.5        13.7        12.5
  V(I)             4.67        6.94        8.00        8.47        9.26

X STA.        10.0        11.5        12.9        14.2        15.6        17.0
  A(I)            12.4        12.1        11.7        11.7        11.8
  V(I)             9.39        9.55        9.94        9.95        9.87

X STA.        17.0        18.4        19.9        21.4        23.1        24.7
  A(I)            11.8        11.9        12.4        12.5        12.6
  V(I)             9.81        9.75        9.39        9.29        9.17

X STA.        24.7        26.4        28.3        30.5        33.2        39.6
  A(I)            13.2        13.5        15.0        16.5        24.5
  V(I)             8.77        8.62        7.73        7.03        4.73
```

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        U.S. Geological Survey WSPRO Input File duxb037.wsp
        Hydraulic analysis for structure DUXBTH00120037   Date: 16-MAY-97
        Town Highway 12, Ridley Brook, Duxbury, Vermont        by ECW
           *** RUN DATE & TIME: 05-29-97  14:04

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

EXITX:XS   ******     -6      303  2.41 *****  497.61  495.11    3770  495.20
       -38 ******     53    18248  1.00 ***** *******    0.98   12.44

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.80     497.19     496.28

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   494.70     523.73    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   494.70     523.73     496.28

FULLV:FV       39     -9      354  1.76  1.35  498.95  496.28    3770  497.19
         0     39     54    22522  1.00  0.00    0.00    0.80   10.65
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       55     -5      322  2.13  1.51  500.64 *******    3770  498.51
        55     55     40    23026  1.00  0.18    0.00    0.78   11.70
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                      WS3N,LSEL =   497.19     496.78

            <<<<<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       39      0      226  2.75 *****  499.72  495.86    3004  496.97
         0 ******     30    18132  1.00 ***** *******    0.86   13.31

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  496.78 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.    32.  0.34  1.09  501.59    0.00    767.  500.84

           Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    599.    89.   -73.    16.   1.3   1.0   5.8   6.8   1.7   3.0
   RT:    168.    19.    16.    35.   1.5   1.3   6.4   6.8   2.0   3.0

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

APPRO:AS       25    -78      490  1.09  0.44  501.93  497.32    3770  500.84
        55     26     42    36923  1.18  0.00    0.00    0.73    7.69

       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     -39.    -7.    53.   3770.   18248.     303.   12.44  495.20
   FULLV:FV       0.   -10.    54.   3770.   22522.     354.   10.65  497.19
   BRIDG:BR       0.     0.    30.   3004.   18132.     226.   13.31  496.97
   RDWAY:RG      11.*******   599.    767.******************    2.00  500.84
   APPRO:AS      55.   -79.    42.   3770.   36923.     490.    7.69  500.84

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    495.11    0.98  486.97  522.56************  2.41  497.61  495.20
   FULLV:FV    496.28    0.80  488.14  523.73  1.35  0.00  1.76  498.95  497.19
   BRIDG:BR    495.86    0.86  487.97  496.97************  2.75  499.72  496.97
   RDWAY:RG  ***************  499.39  522.30  0.34******  1.09  501.59  500.84
   APPRO:AS    497.32    0.73  488.89  522.30  0.44  0.00  1.09  501.93  500.84
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       U.S. Geological Survey WSPRO Input File duxb037.wsp
       Hydraulic analysis for structure DUXBTH00120037   Date: 16-MAY-97
       Town Highway 12, Ridley Brook, Duxbury, Vermont        by ECW
          *** RUN DATE & TIME: 05-29-97  14:04

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

EXITX:XS   ******    -12      401  2.93 *****  499.65  496.71    5500  496.72
       -38 ******     55    26630  1.00 ***** *******    1.00   13.73

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.85     498.84     497.88

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.22     523.73    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.22     523.73     497.88

FULLV:FV       39    -16      470  2.15  1.34  500.99  497.88    5500  498.84
         0     39     61    33115  1.01  0.00    0.00    0.85   11.71
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.00     500.02     499.18

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   498.34     522.30    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   498.34     522.30     499.18

APPRO:AS       55    -25      401  3.02  1.62  503.04  499.18    5500  500.02
        55     55     41    31052  1.03  0.44    0.00    1.00   13.72
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   498.84     496.78

            <<<<<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       39      0      226  2.95 *****  499.92  496.01    3107  496.97
         0 ******     30    18132  1.00 ***** *******    0.88   13.76

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  496.78 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.    32.  0.30  1.07  503.60    0.00   2393.  502.83

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1905.    92.   -77.    16.   3.3   2.9   8.4   7.1   3.7   2.9
   RT:    488.    23.    16.    39.   3.4   2.9   8.6   7.3   3.7   3.0

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

APPRO:AS       25    -92      745  1.07  0.47  503.90  499.18    5500  502.83
        55     26     43    57269  1.27  0.00    0.00    0.63    7.38

       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     -39.   -13.    55.   5500.   26630.     401.   13.73  496.72
   FULLV:FV       0.   -17.    61.   5500.   33115.     470.   11.71  498.84
   BRIDG:BR       0.     0.    30.   3107.   18132.     226.   13.76  496.97
   RDWAY:RG      11.******* 1905.   2393.******************    2.00  502.83
   APPRO:AS      55.   -93.    43.   5500.   57269.     745.    7.38  502.83

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

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    496.71    1.00  486.97  522.56************  2.93  499.65  496.72
   FULLV:FV    497.88    0.85  488.14  523.73  1.34  0.00  2.15  500.99  498.84
   BRIDG:BR    496.01    0.88  487.97  496.97************  2.95  499.92  496.97
   RDWAY:RG  ****************  499.39  522.30  0.30******  1.07  503.60  502.83
   APPRO:AS    499.18    0.63  488.89  522.30  0.47  0.00  1.07  503.90  502.83
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       U.S. Geological Survey WSPRO Input File duxb037.wsp
       Hydraulic analysis for structure DUXBTH00120037   Date: 16-MAY-97
       Town Highway 12, Ridley Brook, Duxbury, Vermont        by ECW
          *** RUN DATE & TIME: 05-29-97  14:04

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

EXITX:XS   ******      0      212  1.86 *****  495.43  493.41    2320  493.57
       -38 ******     51    11238  1.00 ***** *******    0.95   10.93

FULLV:FV       39     -2      247  1.37  1.35  496.76 *******    2320  495.39
         0     39     52    13798  1.00  0.00   -0.02    0.78    9.40
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       55     -3      246  1.39  1.38  498.17 *******    2320  496.78
        55     55     39    15515  1.00  0.01    0.02    0.70    9.45
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   494.73     497.26     497.70     496.78

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   499.67      2308.        20.

 ===270 REJECTED FLOW CLASS 2 (5) SOLUTION.

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                  SECID "BRIDG"     Q,CRWS =    2320.     494.73

           <<<<<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       39      0      168  2.97 *****  497.70  494.73    2320  494.73
         0     39     30    16554  1.00 ***** *******    1.00   13.81

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.78 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD      EGL      ERR       Q    WSEL
   RDWAY:RG      11.        <<<<<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       25     -4      286  1.03  0.43  498.72  495.46    2320  497.70
        55     26     40    19341  1.00  0.59    0.00    0.57    8.12

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.304  0.035   18656.     1.    31.   497.23

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW     REW       Q         K      AREA     VEL    WSEL
   EXITX:XS      -39.     0.     51.   2320.   11238.      212.   10.93  493.57
   FULLV:FV        0.    -3.     52.   2320.   13798.      247.    9.40  495.39
   BRIDG:BR        0.     0.     30.   2320.   16554.      168.   13.81  494.73
   RDWAY:RG       11.**************       0.        0.        0.    2.00********
   APPRO:AS       55.    -5.     40.   2320.   19341.      286.    8.12  497.70

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       1.    31.   18656.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    493.41    0.95  486.97  522.56************  1.86  495.43  493.57
   FULLV:FV  ********    0.78  488.14  523.73  1.35  0.00  1.37  496.76  495.39
   BRIDG:BR    494.73    1.00  487.97  496.97************  2.97  497.70  494.73
   RDWAY:RG  ****************  499.39  522.30************  0.59  500.05********
   APPRO:AS    495.46    0.57  488.89  522.30  0.43  0.59  1.03  498.72  497.70

 ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```
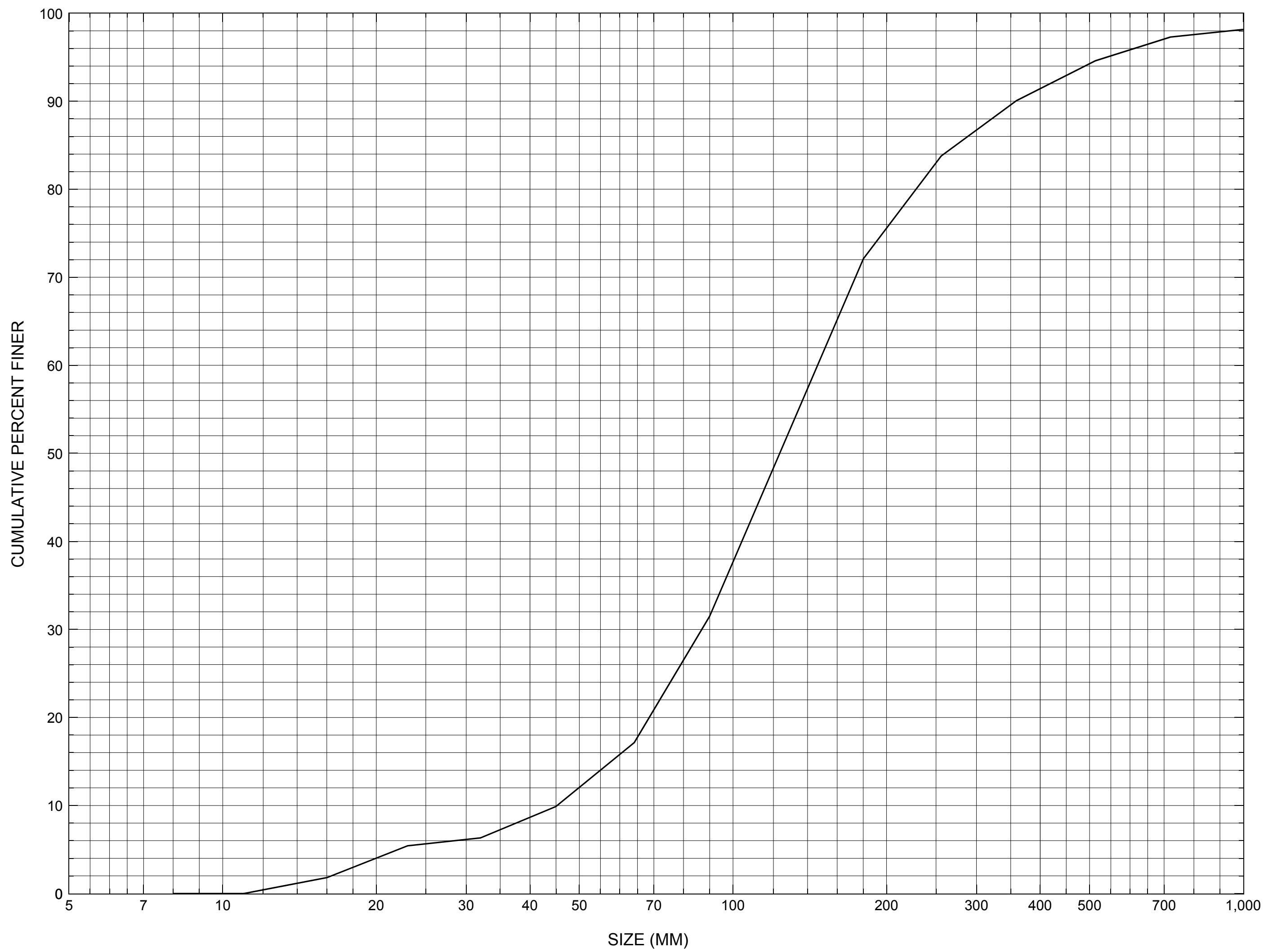

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure DUXBTH00120037, in Duxbury, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number **DUXBTH00120037**

General Location Descriptive

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

Date *(MM/DD/YY)* **10** / **13** / **95**

Highway District Number *(I - 2; nn)* **06**

County *(FIPS county code; I - 3; nnn)* **023**

Town *(FIPS place code; I - 4; nnnnn)* **18550**

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

Waterway *(I - 6)* **RIDLEY BROOK**

Road Name *(I - 7)*:

Route Number **C3012**

Vicinity *(I - 9)* **0.5 MI TO JCT W CL3 TH5**

Topographic Map **Waterbury**

Hydrologic Unit Code: **2010003**

Latitude *(I - 16; nnnn.n)* **44203**

Longitude *(i - 17; nnnnn.n)* **72501**

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* **10120600371206**

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

Maximum span length *(I - 48; nnnn)* **0030**

Year built *(I - 27; YYYY)* **1967**

Structure length *(I - 49; nnnnnn)* **000033**

Average daily traffic, ADT *(I - 29; nnnnnn)* **000200**

Deck Width *(I - 52; nn.n)* **226**

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

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

Opening skew to Roadway *(I - 34; nn)* **18**

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*) **29.75**

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

Vertical clearance from streambed (*nnn.n ft*) **8.76**

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

Waterway of full opening (*nnn.n ft*^{2}) **260.5**

Comments:

According to the structural inspection report dated 5/23/94, the deck consists of 5 reinforced concrete pre-cast panels. There is extensive rotting in the timber backwall of the RABUT. There is local scour along the RABUT footing. Both abutments have random fine cracking and have tipped towards the stream approx. 1" at the top. The streambed is lined with cobbles and large boulders. There are gravel bars at the LABUT, and stonefill at the US wings. Streamflow is skewed towards the RABUT. There is heavy scaling and spalling at the RABUT footing and wings, with loss of a section at the bottom of the stem. There is some undermining at the RABUT between the stem and footing. **(cont. on page 33)**

Bridge Hydrologic Data

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

Terrain character: ____

Stream character & type:

Streambed material: ____

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

Q_{50} ______________ Q_{100} ______________ Q_{500} ______________

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

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

Ice conditions (*Heavy, Moderate, Light*) : ___________ Debris (*Heavy, Moderate, Light*): _____________

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes:

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

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

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

Upstream distance (*miles*): ____________ Town: ____________________ Year Built: _______

Highway No. : _________________ Structure No. : _______ Structure Type: ______________________

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

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

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

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

Comments:

The LABUT US wing full-height vertical crack that is displaced approx. 0.5” at its top. The RABUT has some settlement and has tipped.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **10.15** mi^2 Lake/pond/swamp area **0** mi^2

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

Bridge site elevation **730** ft Headwater elevation **3688** ft

Main channel length **4.72** mi

10% channel length elevation **860** ft 85% channel length elevation **2540** ft

Main channel slope *(S)* **474.57** 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:

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

Foundation Type: ____ (*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? _____ *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:

Cross-sectional Data

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

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

Comments: **This cross-section is of the upstream bridge face. The low cord elevations are from the 7/1/96 USGS survey log, in which the data was also collected at the upstream bridge face. The low cord to bed length data is from the sketch (6/15/92) attached to the bridge inspection report (5/23/94).**

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: 10/2/96
Computerized by: EW Date: 10/2/96
Reviewd by: EW Date: 5/28/97

Structure Number DUXBTH00120037

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. IVANOFF Date *(MM/DD/YY)* 07 / 01 / 1996
2. Highway District Number 06 Mile marker 000000
County WASHINGTON 023 Town DUXBURY 18550
Waterway *(I - 6)* RIDLEY BROOK Road Name -
Route Number TH 12 Hydrologic Unit Code: 2010003
3. Descriptive comments:

Located 0.5 miles to junction with Town Highway 5.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 6 LBDS 6 RBDS 6 Overall 6
*(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 33 *(feet)* Span length 30 *(feet)* Bridge width 22.6 *(feet)*

Road approach to bridge:

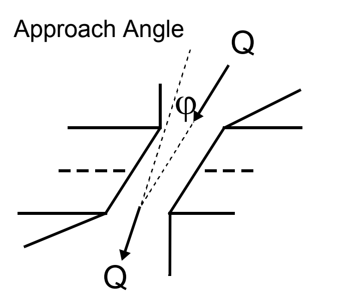
8. LB 2 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left 1.3:1 US right 4.8:1

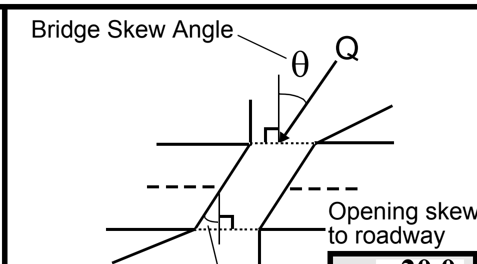
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	0	-
RBUS	0	-	0	-
RBDS	0	-	1	2
LBDS	2	1	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: 40 16. Bridge skew: 50





α= 20.0

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

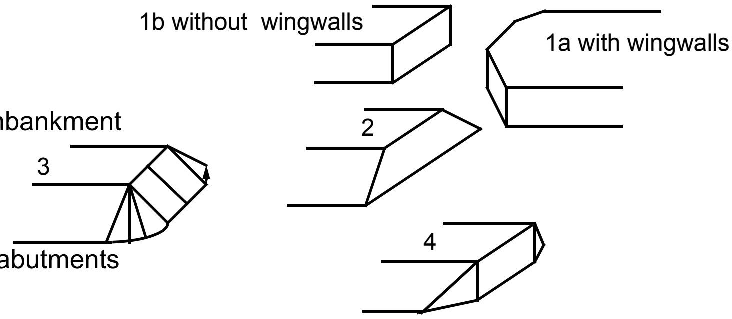
1a- Vertical abutments with wingwalls

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: The left bank upstream surface cover is forest with Town Highway 12 adjacent to bank.

#7: The values are from the Vermont AOT database. The measured span during the site visit was 30.5 feet.

#13: The right bank downstream channel erosion consists of exposed stones behind the downstream right wingwall.

#18: The ends of wingwalls are about 2 to 3 feet below low cord.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
32.5	**6.5**			**12.5**	**4**	**4**	**54**	**54**	**0**	**0**

23. Bank width **45.0** 24. Channel width **60.0** 25. Thalweg depth **51.0** 29. Bed Material **543**

30 .Bank protection type: LB **0** RB **3** 31. Bank protection condition: LB **-** RB **2**

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: Right bank protection extends 25 feet upstream of bridge.

33. Point/Side bar present? **Y** _(Y or N. if N type ctrl-n pb)_ 34. Mid-bar distance: **166** 35. Mid-bar width: **8**

36. Point bar extent: **215** feet **US** _(US, UB)_ to **135** feet **US** _(US, UB, DS)_ positioned **0** %LB to **30** %RB

37. Material: **34**

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

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

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

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

NO CHANNEL SCOUR

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
37.0		**2.0**		**2**	**7**	**7**	**-**

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

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

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

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

5

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

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

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

70. Debris and Ice Comments:

1

Some trees leaning into the channel upstream and downstream with the bridge opening skewed to flow.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		**0**	**90**	**2**	**2**	**0**	**0.1**	**90.0**
RABUT	**1**	**20**	**90**			**2**	**2**	**28.0**

Pushed: LB or RB *Toe Location (Loc.): **0**- even, **1-** set back, **2-** protrudes*
*Scour cond.: **0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**-undermined footing; **4**- piling exposed; **5**- settled; **6**- failed*
Materials: **1**- Concrete; **2**- Stone masonry or drywall; **3**- steel or metal; **4**- wood

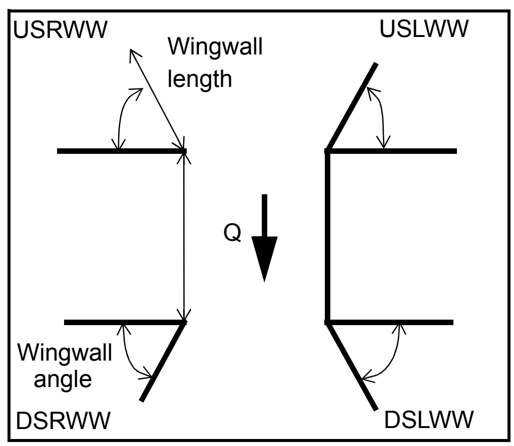
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

2.0
2.0
1
The left abutment footing is exposed at upstream end.

The right abutment footing is exposed with maximum scour at downstream end.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**28.0**	
USRWW:	**Y**		**1**		**2**	**1.0**	
DSLWW:	**0**		**0.1**		**Y**	**22.0**	
DSRWW:	**1**		**2**		**0**	**21.0**	



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

82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	**0.2**	**0**	**Y**	**2.0**	**-**	**2**	**-**	**-**
Condition	**Y**	**-**	**1**	**2.0**	**-**	**1**	**-**	**-**
Extent	**1**	**-**	**2**	**0**	**3**	**0**	**0**	**-**

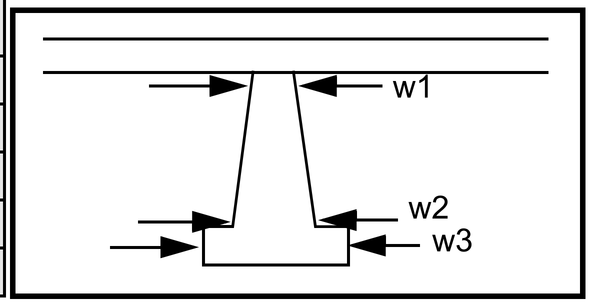
*Bank / Bridge protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*
*Bank / Bridge protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*
*Protection extent: **1**- entire base length;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

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

Piers:

84. Are there piers? _____ *(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				**25.0**	**11.5**	**85.0**
Pier 2				**11.5**	**105.0**	**10.0**
Pier 3			-	**40.0**	**10.0**	-
Pier 4	-	-	-	-	-	-



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

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
-	-			-	-	NO	PIE	RS		

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.):

4
4
546
54
1
1
543
0
0
-
-

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 **N** feet **-** *(US, UB, DS)* positioned **NO** %LB to **DR** %RB

Material: **OP**

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

STRUCTURE

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

Cut bank extent: **30** feet **20** *(US, UB, DS)* to **4.6** feet **UB** *(US, UB, DS)*

Bank damage: **55** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
0
50
34

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

Scour dimensions: Length **begi** Width **ns** Depth: **4.6** Positioned **feet** %LB to **fro** %RB

Scour comments (eg. additional scour areas, local scouring process, etc.):
m upstream bridge face.

An additional side bar extends along the right bank from 71 feet downstream to 180 feet downstream. The mid-bar distance is 120 feet downstream where it is 20 feet wide.

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

Confluence 1: Distance **100** Enters on **40** *(LB or RB)* Type **DS** *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance **160** Enters on **DS** *(LB or RB)* Type **1** *(**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)*:

Y
10 DS
25
15
2
75
100

N

109. G. Plan View Sketch - -

point bar (pb)	debris	flow (Q →)	stone wall
cut-bank (cb)	rip rap or stone fill	cross-section	other wall
scour hole		ambient channel	

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: DUXBTH00120037 Town: DUXBURY
Road Number: TOWN HIGHWAY 12 County: WASHINGTON
Stream: RIDLEY BROOK

Initials ECW Date: 5/27/97 Checked: MAI

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

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

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	3770	5500	2320
Main Channel Area, ft2	432	529	286
Left overbank area, ft2	58	217	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	48	49	45
Top width L overbank, ft	72	87	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.404	0.404	0.404
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	9.0	10.8	6.4
y1, average depth, LOB, ft	0.8	2.5	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	36920	57315	19349
Conveyance, main channel	35849	48836	19349
Conveyance, LOB	1071	8479	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	3660.6	4686.3	2320.0
Ql, discharge, LOB, cfs	109.4	813.7	0.0
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	8.5	8.9	8.1
Vl, mean velocity, LOB, ft/s	1.9	3.7	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	12.0	12.3	11.3
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	3770	5500	2320
(Q) discharge thru bridge, cfs	3004	3107	2320
Main channel conveyance	18132	18132	16537
Total conveyance	18132	18132	16537
Q2, bridge MC discharge,cfs	3004	3107	2320
Main channel area, ft2	226	226	168
Main channel width (normal), ft	28.2	28.2	28.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	28.2	28.2	28.2
y_bridge (avg. depth at br.), ft	8.01	8.01	5.96
Dm, median (1.25*D50), ft	0.505	0.505	0.505
y2, depth in contraction,ft	8.23	8.47	6.59
ys, scour depth (y2-ybridge), ft	0.21	0.45	0.63

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	3770	5500	2320
Q, thru bridge MC, cfs	3004	3107	2320
Vc, critical velocity, ft/s	11.95	12.32	11.28
Va, velocity MC approach, ft/s	8.47	8.86	8.11
Main channel width (normal), ft	28.2	28.2	28.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	28.2	28.2	28.2
qbr, unit discharge, ft2/s	106.5	110.2	82.3
Area of full opening, ft2	226.0	226.0	168.0
Hb, depth of full opening, ft	8.01	8.01	5.96
Fr, Froude number, bridge MC	0.86	0.88	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	N/A	N/A	N/A
**Hb, depth at downstream face, ft	N/A	N/A	N/A
**Fr, Froude number at DS face	ERR	ERR	ERR
**Cf, for downstream face (<=1.0)	N/A	N/A	N/A
Elevation of Low Steel, ft	496.78	496.78	496.78
Elevation of Bed, ft	488.77	488.77	490.82
Elevation of Approach, ft	500.84	502.83	0
Friction loss, approach, ft	0.44	0.47	0
Elevation of WS immediately US, ft	500.08	501.85	0.00
ya, depth immediately US, ft	11.63	13.59	-490.82
Mean elevation of deck, ft	499.54	499.54	0
w, depth of overflow, ft (>=0)	0.86	2.82	0.00
Cc, vert contrac correction (<=1.0)	0.93	0.93	ERR
**Cc, for downstream face (<=1.0)	ERR	ERR	ERR
Ys, scour w/Chang equation, ft	1.62	1.65	N/A
Ys, scour w/Umbrell equation, ft	1.93	2.66	N/A

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	3004	3107	2320
Main channel area (DS), ft2	226	226	168
Main channel width (normal), ft	28.2	28.2	28.2
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	28.2	28.2	28.2
D90, ft	1.1754	1.1754	1.1754
D95, ft	1.7679	1.7679	1.7679
Dc, critical grain size, ft	0.9113	0.9748	1.1299
Pc, Decimal percent coarser than Dc	0.147	0.135	0.107
Depth to armoring, ft	15.86	18.74	28.29

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	3770	5500	2320	3770	5500	2320
a', abut.length blocking flow, ft	79.8	93.9	5.8	12.5	13.7	10.5
Ae, area of blocked flow ft2	30.5	54.3	20.3	81.1	92.4	50.6
Qe, discharge blocked abut.,cfs	--	--	94.8	--	--	305.8
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.27	4.20	4.67	6.24	6.40	6.04
ya, depth of f/p flow, ft	0.38	0.58	3.50	6.49	6.74	4.82
--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	0.519	0.436	0.440	0.418	0.396	0.485
ys, scour depth, ft	4.97	6.18	8.25	16.14	16.68	13.10

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)	79.8	93.9	5.8	12.5	13.7	10.5
y1 (depth f/p flow, ft)	0.38	0.58	3.50	6.49	6.74	4.82
a'/y1	208.79	162.38	1.66	1.93	2.03	2.18
Skew correction (p. 49, fig. 16)	0.93	0.93	0.93	1.04	1.04	1.04
Froude no. f/p flow	0.52	0.44	0.44	0.42	0.40	0.49
Ys w/ corr. factor K1/0.55:						
vertical	2.09	2.98	ERR	ERR	ERR	ERR
vertical w/ ww's	1.71	2.45	ERR	ERR	ERR	ERR
spill-through	1.15	1.64	ERR	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship

D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)

(Richardson and others, 1995, p112, eq. 81,82)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.86	0.88	1	0.86	0.88	1
y, depth of flow in bridge, ft	8.01	8.01	5.96	8.01	8.01	5.96
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	3.21	3.23	2.49	3.21	3.23	2.49
Fr<=0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (spillthrough abut.)	2.84	2.86	2.20	2.84	2.86	2.20