LEVEL II SCOUR ANALYSIS FOR BRIDGE 50 (STARTH00250050) on TOWN HIGHWAY 25, crossing LEWIS CREEK, STARKSBORO, VERMONT

Open-File Report 97-798

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

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

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LEVEL II SCOUR ANALYSIS FOR BRIDGE 50 (STARTH00250050) on TOWN HIGHWAY 25, crossing LEWIS CREEK, STARKSBORO, VERMONT

By RONDA L. BURNS and ERICK M. BOEHMLER

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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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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 50 (STARTH00250050) ON TOWN HIGHWAY 25, CROSSING LEWIS CREEK, STARKSBORO, VERMONT

By **Ronda L. Burns and Erick M. Boehmler**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure STARTH00250050 on Town Highway 25 crossing Lewis Creek, Starksboro, 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 west-central Vermont. The 10.9-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture on the left bank downstream and upstream of the bridge. On the right bank upstream and downstream of the bridge the surface cover is forest.

In the study area, Lewis Creek has an incised, straight channel with a slope of approximately 0.007 ft/ft, an average channel top width of 64 ft and an average bank height of 7 ft. The channel bed material ranges from sand to boulder with a median grain size (D_{50}) of 35.4 mm (0.116 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 12, 1996, indicated that the reach was stable.

The Town Highway 25 crossing of Lewis Creek is a 28-ft-long, one-lane bridge consisting of one 25-foot steel-beam span (Vermont Agency of Transportation, written communication, December 15, 1995). The opening length of the structure parallel to the bridge face is 23.8 ft. The bridge is supported by vertical, concrete abutments with wingwalls on all corners except the downstream left. The channel is skewed approximately zero degrees to the opening and the opening-skew-to-roadway is also zero degrees.

A scour hole 1.0 ft deeper than the mean thalweg depth was observed along the right abutment during the Level I assessment. Also, the footing is exposed along the left and right abutments and all three wingwalls. The scour countermeasures at the site included type-1 stone fill (less than 12 inches diameter) along the left abutment and type-2 stone fill (less than 36 inches diameter) along the right abutment and the upstream and downstream right wingwalls. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 5.2 to 9.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 13.1 to 18.2 ft. The worst-case abutment scour 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.

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 STARTH00250050 ***Stream*** Lewis Creek

County Addison ***Road*** TH 25 ***District*** 5

Description of Bridge

Bridge length 28 ***ft*** ***Bridge width*** 14.6 ***ft*** ***Max span length*** 25 ***ft***

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

Abutment type Vertical, concrete ***Embankment type*** None

Stone fill on abutment? Yes ***Date of inspection*** 6/12/96

Description of stone fill Type-1, along the left abutment. Type-2, along the upstream right wingwall, the right abutment, and the downstream right wingwall.

Abutments and wingwalls are concrete. There is a one foot deep scour hole along the right abutment.

No 0

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

There is a moderate channel bend in the downstream reach and a mild bend in the upstream reach.

6/12/96

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*
	0	0	6/12/
Level I	96	0	0
Level II			

Potential for debris Moderate. There is some debris caught on the upstream banks and trees leaning over the channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) None as of 11/08/94.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley.

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

Date of inspection 6/12/96

DS left: Steep channel bank to a mildly sloped overbank

DS right: Steep channel bank to a moderately sloped overbank

US left: Low channel bank to a moderately sloped overbank

US right: Steep valley wall

Description of the Channel

Average top width 64 *ft* ***Average depth*** 7 *ft*

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

Straight and stable

with semi-alluvial channel boundaries.

6/12/96

Vegetative co A few trees with grass on the overbank

DS left: Trees

DS right: A few trees with grass on the overbank

US left: Trees

US right: Yes

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

None as of 6/12/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 10.9 ***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***: None.

Is there a USGS gage on the stream of interest? Yes

USGS gage description Lewis Creek near North Ferrisburg, VT

USGS gage number 04282780

Gage drainage area 77.2 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 2,950 ***ft³/s*** ***Q500*** 3,700 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(10.9/8.9)exp 0.67] with bridge number 49 in Starksboro. Bridge number 49 crosses Lewis Creek upstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 49 is 8.9 square miles. The values used were within a range defined by flood frequency curves developed 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 None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream left corner of the bridge deck (elev. 498.51 ft, arbitrary survey datum). RM2 is a nail five feet from the ground in a tree on the right bank 15 ft upstream and 15 ft from the stream (elev. 498.33 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	-25	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPRO	38	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 0.050 to 0.060, and overbank "n" values ranged from 0.035 to 0.080.

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 0.0067 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1963).

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

Bridge Hydraulics Summary

Average bridge embankment elevation 498.7 ***ft***
Average low steel elevation 496.0 ***ft***

100-year discharge 2,590 ***ft³/s***
Water-surface elevation in bridge opening 496.1 ***ft***
Road overtopping? Yes ***Discharge over road*** 2 ***ft³/s***
Area of flow in bridge opening 246 ***ft²***
Average velocity in bridge opening 10.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.3 ***ft/s***

Water-surface elevation at Approach section with bridge 498.7
Water-surface elevation at Approach section without bridge 494.5
Amount of backwater caused by bridge 4.2 ***ft***

500-year discharge 3,700 ***ft³/s***
Water-surface elevation in bridge opening 496.0 ***ft***
Road overtopping? Yes ***Discharge over road*** 452 ***ft³/s***
Area of flow in bridge opening 245 ***ft²***
Average velocity in bridge opening 13.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 18.5 ***ft/s***

Water-surface elevation at Approach section with bridge 500.1
Water-surface elevation at Approach section without bridge 496.3
Amount of backwater caused by bridge 3.8 ***ft***

Incipient overtopping discharge 2,570 ***ft³/s***
Water-surface elevation in bridge opening 496.1 ***ft***
Area of flow in bridge opening 246 ***ft²***
Average velocity in bridge opening 10.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.2 ***ft/s***

Water-surface elevation at Approach section with bridge 498.6
Water-surface elevation at Approach section without bridge 494.5
Amount of backwater caused by bridge 4.1 ***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 for the 100-year and 500-year discharges are presented in tables 1 and 2 and a graph of the scour depths is presented in figure 8.

At this site, the 100-year and incipient roadway-overtopping discharges resulted in unsubmerged orifice flow and 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). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and the results are presented in Appendix F. Furthermore, for the 100-year and incipient roadway-overtopping discharges, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions are provided in Appendix F.

Abutment scour was computed by use of the 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	5.3	9.1	5.2
Depth to armoring	N/A	N/A	N/A
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	17.1	18.2	17.0
Right abutment	13.1	14.4	13.1
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	3.0	3.4	3.0
Right abutment	3.0	3.4	3.0
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

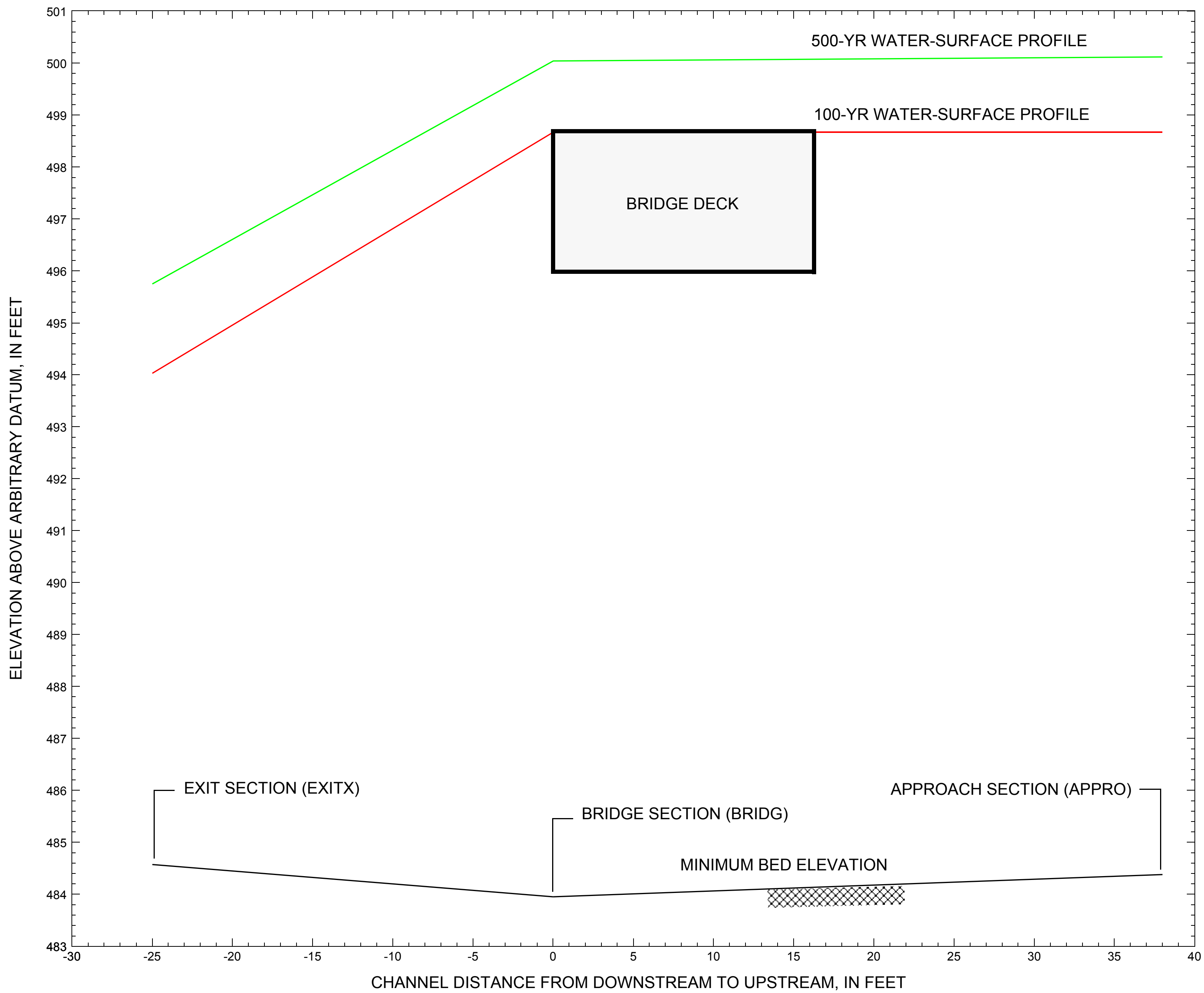

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure STARTH00250050 on Town Highway 25, crossing Lewis Creek, Starksboro, Vermont.

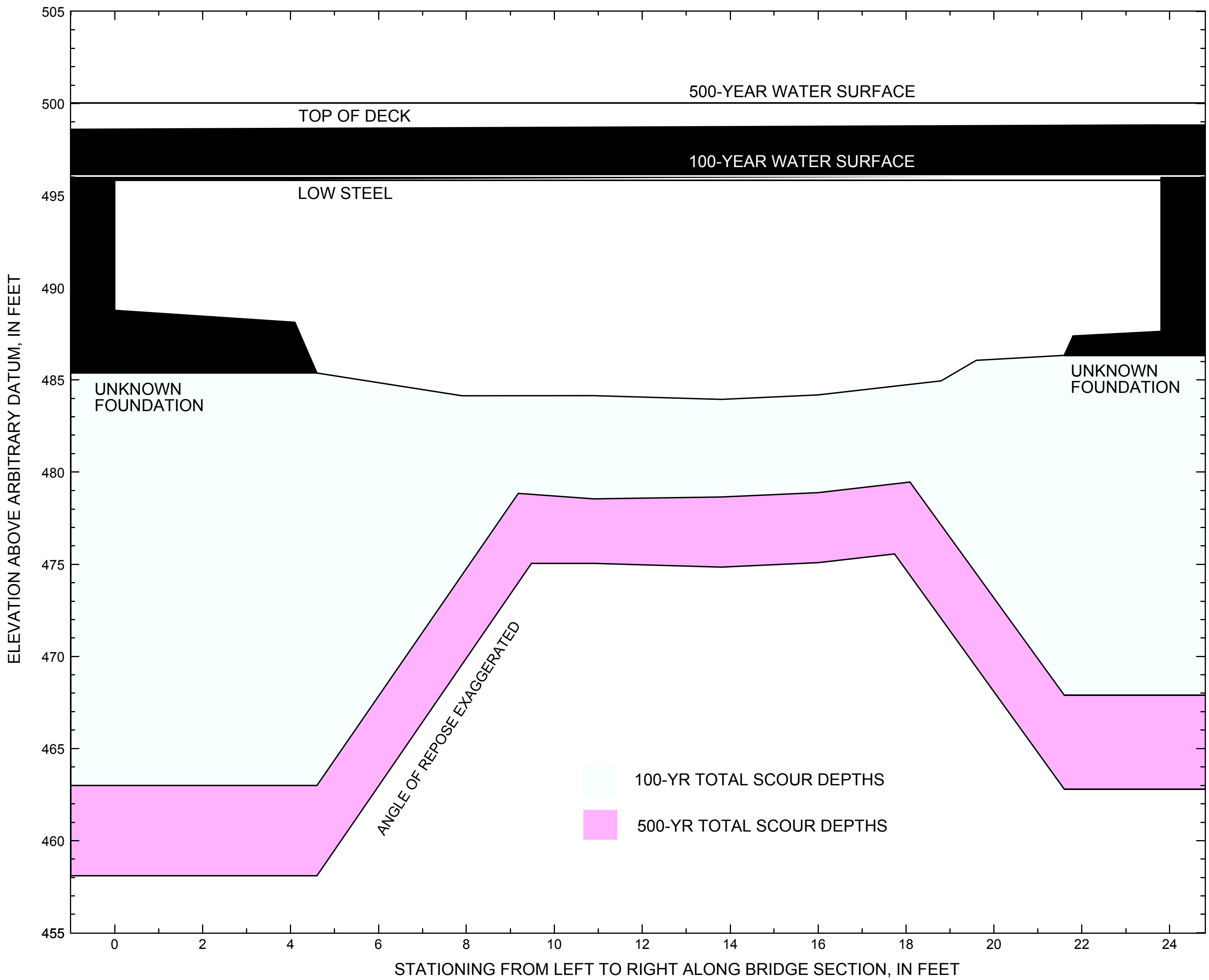

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure STARTH00250050 on Town Highway 25, crossing Lewis Creek, Starksboro, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure STARTH00250050 on Town Highway 25, crossing Lewis Creek, Starksboro, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 2,590 cubic-feet per second											
Left abutment	0.0	--	495.8	--	485.4	5.3	17.1	--	22.4	463.0	--
Right abutment	23.8	--	496.1	--	486.3	5.3	13.1	--	18.4	467.9	--

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 STARTH00250050 on Town Highway 25, crossing Lewis Creek, Starksboro, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 3,700 cubic-feet per second											
Left abutment	0.0	--	495.8	--	485.4	9.1	18.2	--	27.3	458.1	--
Right abutment	23.8	--	496.1	--	486.3	9.1	14.4	--	23.5	462.8	--

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, 1963, Bristol, 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 star050.wsp
T2        Hydraulic analysis for structure STARTH00250050   Date: 27-JUN-97
T3        TH 25 CROSSING LEWIS CREEK IN STARKSBORO, VT                 RLB
*
J1         * * .005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2590.0   3700.0   2570.0
SK          0.0067   0.0067   0.0067
*
XS   EXITX    -25           0.
GR          -93.2, 500.66    -47.9, 498.91    -19.3, 495.08     -7.9, 488.51
GR           -4.6, 488.13      0.0, 485.92      3.9, 484.71     12.2, 484.61
GR           17.6, 484.57     23.6, 485.18     24.4, 485.85     37.8, 492.08
GR           46.7, 492.80    100.0, 497.12    121.8, 511.17
*
N           0.035       0.060      0.080
SA                -47.9       37.8
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    495.95       0.0
GR            0.0, 495.83      0.2, 488.78      4.1, 488.13      4.3, 486.06
GR            4.6, 485.38      7.9, 484.14     10.9, 484.15     13.8, 483.95
GR           16.0, 484.19     18.8, 484.95     19.6, 486.07     21.6, 486.34
GR           21.8, 487.39     23.7, 487.64     23.8, 496.07      0.0, 495.83
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      24.2 * *     73.0      2.4
N           0.050
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      8      14.6     2
GR        -120.9, 503.82    -81.1, 500.95    -40.7, 499.18      0.0, 498.60
GR          23.9, 498.84     55.5, 500.05     80.5, 501.35    105.4, 510.50
*
AS   APPRO     38           0.
GR          -83.0, 501.02    -54.1, 497.74    -21.7, 490.94     -4.9, 488.92
GR            0.0, 486.23      4.6, 486.05      6.6, 485.07     11.9, 484.70
GR           19.1, 484.38     21.7, 484.55     23.1, 486.11     31.3, 489.54
GR           36.7, 493.04     47.3, 494.34     50.6, 496.81     61.9, 501.10
GR           78.8, 505.10
*
N           0.035       0.050      0.080
SA                 -4.9       36.7
*
HP 1 BRIDG  496.07 1 496.07
HP 2 BRIDG  496.07 * * 2589
HP 1 BRIDG  494.26 1 494.26
HP 1 APPRO  498.67 1 498.67
HP 2 APPRO  498.67 * * 2590
*
HP 1 BRIDG  495.99 1 495.99
HP 2 BRIDG  495.99 * * 3261
HP 2 RDWAY  500.04 * * 452
HP 1 APPRO  500.12 1 500.12
HP 2 APPRO  500.12 * * 3700
*
HP 1 BRIDG  496.07 1 496.07
HP 2 BRIDG  496.07 * * 2570
HP 1 BRIDG  494.22 1 494.22
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File star050.wsp
        Hydraulic analysis for structure STARTH00250050   Date: 27-JUN-97
        TH 25 CROSSING LEWIS CREEK IN STARKSBORO, VT                 RLB
           *** RUN DATE & TIME: 10-07-97  09:43

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      246     17419      0     67                            0
   496.07           246     17419      0     67  1.00      0     24        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.07     0.0    23.8   245.7   17419.    2589.  10.54

X STA.         0.0         3.1         5.0         6.2         7.2         8.1
  A(I)            21.9        16.5        12.9        11.5        10.9
  V(I)            5.92        7.84       10.05       11.24       11.89

X STA.         8.1         9.0         9.9        10.7        11.5        12.4
  A(I)            10.4        10.3         9.9         9.8         9.9
  V(I)           12.47       12.62       13.04       13.17       13.10

X STA.        12.4        13.2        14.0        14.8        15.7        16.6
  A(I)             9.7         9.8         9.9        10.1        10.4
  V(I)           13.30       13.23       13.13       12.78       12.45

X STA.        16.6        17.5        18.5        19.7        21.2        23.8
  A(I)            10.9        11.4        12.8        14.2        22.7
  V(I)           11.91       11.39       10.14        9.11        5.70

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      206     18304     24     40                         3433
   494.26           206     18304     24     40  1.00      0     24     3433

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      38.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      291     36180     57     58                         3717
             2      497     73590     42     45                         9760
             3       68      2829     19     20                          727
   498.67           856    112598    118    123  1.12    -61     55    12392

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      38.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.67   -62.3    55.5   855.9  112598.    2590.   3.03

X STA.       -62.3       -31.7       -24.1       -18.6       -14.0       -10.0
  A(I)            77.2        48.8        42.3        39.3        35.3
  V(I)            1.68        2.66        3.06        3.29        3.66

X STA.       -10.0        -6.3        -2.5         0.8         3.6         6.4
  A(I)            34.1        39.3        38.7        35.0        36.1
  V(I)            3.80        3.30        3.34        3.70        3.59

X STA.         6.4         8.9        11.3        13.7        16.1        18.5
  A(I)            34.2        33.6        33.7        33.8        34.4
  V(I)            3.78        3.86        3.84        3.83        3.76

X STA.        18.5        20.9        24.0        27.6        32.5        55.5
  A(I)            34.0        41.1        40.7        47.1        97.1
  V(I)            3.81        3.15        3.18        2.75        1.33
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File star050.wsp
        Hydraulic analysis for structure STARTH00250050   Date: 27-JUN-97
        TH 25 CROSSING LEWIS CREEK IN STARKSBORO, VT                RLB
           *** RUN DATE & TIME: 10-07-97  09:43

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      245     18923      8     59                          7746
   495.99           245     18923      8     59  1.00      0     24      7746

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.99     0.0    23.8   245.4   18923.    3261.  13.29

X STA.         0.0        3.3        5.3        6.5        7.6        8.6
  A(I)            23.4       18.4       13.5       12.5       11.7
  V(I)            6.98       8.85      12.05      13.07      13.91

X STA.         8.6        9.6       10.5       11.4       12.3       13.2
  A(I)            11.3       10.9       10.8       10.4       10.4
  V(I)           14.42      14.94      15.08      15.71      15.62

X STA.        13.2       14.0       14.9       15.7       16.5       17.2
  A(I)            10.2       10.1       10.2        8.8        8.8
  V(I)           16.02      16.08      16.01      18.52      18.49

X STA.        17.2       18.0       18.9       20.0       21.2       23.8
  A(I)             9.1        9.7       11.2       12.0       22.0
  V(I)           18.00      16.77      14.58      13.58       7.42

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.04   -60.3    55.2   105.6    2701.     452.   4.28

X STA.       -60.3      -42.0      -35.2      -29.4      -24.4      -19.7
  A(I)             7.4        6.0        5.7        5.3        5.2
  V(I)            3.06       3.75       3.99       4.27       4.33

X STA.       -19.7      -15.6      -11.7       -8.1       -4.7       -1.5
  A(I)             4.9        4.9        4.6        4.6        4.5
  V(I)            4.61       4.65       4.86       4.93       5.07

X STA.        -1.5        1.6        4.7        7.9       11.4       14.8
  A(I)             4.4        4.4        4.5        4.6        4.5
  V(I)            5.08       5.16       5.04       4.91       5.01

X STA.        14.8       18.6       22.6       26.8       32.6       55.2
  A(I)             4.8        4.9        4.9        5.7        9.8
  V(I)            4.71       4.64       4.62       3.94       2.31

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      38.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      383     50180     70     71                          5086
             2      558     89057     42     45                         11588
             3       98      4614     23     24                          1150
   500.12          1039    143851    134    140  1.14    -74     59     15359

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      38.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.12   -75.1    59.3  1038.7  143851.    3700.   3.56

X STA.       -75.1      -36.7      -27.9      -21.6      -16.6      -12.3
  A(I)            97.9       61.7       53.2       48.0       43.1
  V(I)            1.89       3.00       3.48       3.85       4.30

X STA.       -12.3       -8.4       -4.8       -0.8        2.3        5.3
  A(I)            41.4       38.9       50.1       43.1       42.4
  V(I)            4.47       4.76       3.69       4.29       4.36

X STA.         5.3        8.1       10.7       13.4       15.9       18.5
  A(I)            41.5       39.8       40.6       39.9       40.2
  V(I)            4.45       4.65       4.56       4.64       4.60

X STA.        18.5       21.2       24.5       28.3       33.6       59.3
  A(I)            41.7       48.8       47.5       56.2      122.7
  V(I)            4.44       3.79       3.89       3.29       1.51
```

```
        U.S. Geological Survey WSPRO Input File star050.wsp
        Hydraulic analysis for structure STARTH00250050   Date: 27-JUN-97
        TH 25 CROSSING LEWIS CREEK IN STARKSBORO, VT                 RLB
           *** RUN DATE & TIME: 10-07-97  09:43

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      246     17419      0     67                            0
   496.07           246     17419      0     67  1.00      0     24        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.07     0.0    23.8   245.7   17419.    2570.  10.46

X STA.         0.0         3.1         5.0         6.2         7.2         8.1
  A(I)            21.9        16.5        12.9        11.5        10.9
  V(I)            5.88        7.78        9.98       11.16       11.81

X STA.         8.1         9.0         9.9        10.7        11.5        12.4
  A(I)            10.4        10.3         9.9         9.8         9.9
  V(I)           12.37       12.53       12.95       13.07       13.00

X STA.        12.4        13.2        14.0        14.8        15.7        16.6
  A(I)             9.7         9.8         9.9        10.1        10.4
  V(I)           13.20       13.14       13.03       12.69       12.36

X STA.        16.6        17.5        18.5        19.7        21.2        23.8
  A(I)            10.9        11.4        12.8        14.2        22.7
  V(I)           11.82       11.31       10.06        9.04        5.66

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      205     18188     24     40                         3410
   494.22           205     18188     24     40  1.00      0     24     3410

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      38.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      286     35527     57     58                         3652
             2      494     72771     42     45                         9662
             3       66      2746     19     20                          707
   498.59           847    111044    117    122  1.11    -61     55    12244

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      38.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.59   -61.6    55.3   846.5  111044.    2570.   3.04

X STA.       -61.6       -31.8       -24.1       -18.5       -13.9        -9.9
  A(I)            74.2        49.3        42.9        38.0        35.0
  V(I)            1.73        2.61        3.00        3.38        3.67

X STA.        -9.9        -6.2        -2.4         0.9         3.7         6.4
  A(I)            34.4        38.9        38.4        34.6        35.7
  V(I)            3.73        3.30        3.35        3.71        3.60

X STA.         6.4         8.9        11.3        13.7        16.1        18.5
  A(I)            33.7        33.0        33.1        33.9        34.0
  V(I)            3.82        3.89        3.88        3.79        3.78

X STA.        18.5        20.9        24.0        27.5        32.4        55.3
  A(I)            33.6        40.7        40.3        46.6        96.0
  V(I)            3.82        3.16        3.19        2.76        1.34
```

```
        U.S. Geological Survey WSPRO Input File star050.wsp
        Hydraulic analysis for structure STARTH00250050   Date: 27-JUN-97
        TH 25 CROSSING LEWIS CREEK IN STARKSBORO, VT                 RLB
           *** RUN DATE & TIME: 10-07-97  09:43

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

EXITX:XS   ******    -16      394  0.73 *****  494.76  491.08    2590  494.03
       -24 ******     62    31639  1.09 ***** *******    0.54    6.58

FULLV:FV       25    -17      412  0.68  0.16  494.93 *******    2590  494.26
         0     25     65    33385  1.10  0.00    0.01    0.52    6.29
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       38    -38      443  0.56  0.16  495.10 *******    2590  494.54
        38     38     48    46376  1.05  0.00    0.00    0.47    5.85
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   492.76     496.94     497.03     495.95

 ===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       25      0      246  1.73 *****  497.80  492.76    2589  496.07
         0 ******     24    17419  1.00 ***** *******    0.58   10.54

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.465  0.000  495.95 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    23.  0.01  0.16  498.81    0.00      2.  498.67

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      2.    11.    -5.     7.   0.1   0.0   1.6   5.9   0.2   2.6
   RT:      0.     8.    12.    21.   0.1   0.0   1.7   4.8   0.2   2.6

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

APPRO:AS       14    -61      855  0.16  0.05  498.83  491.64    2590  498.67
        38     16     55   112528  1.12  0.82    0.00    0.21    3.03

       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     -25.   -17.    62.   2590.   31639.     394.    6.58  494.03
   FULLV:FV       0.   -18.    65.   2590.   33385.     412.    6.29  494.26
   BRIDG:BR       0.     0.    24.   2589.   17419.     246.   10.54  496.07
   RDWAY:RG       8.*******     2.      2.*********       0.    2.00  498.67
   APPRO:AS      38.   -62.    55.   2590.  112528.     855.    3.03  498.67

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    491.08    0.54  484.57  511.17************  0.73  494.76  494.03
   FULLV:FV   ********    0.52  484.57  511.17  0.16  0.00  0.68  494.93  494.26
   BRIDG:BR    492.76    0.58  483.95  496.07************  1.73  497.80  496.07
   RDWAY:RG   ****************  498.60  510.50  0.01******  0.16  498.81  498.67
   APPRO:AS    491.64    0.21  484.38  505.10  0.05  0.82  0.16  498.83  498.67
```

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        U.S. Geological Survey WSPRO Input File star050.wsp
        Hydraulic analysis for structure STARTH00250050   Date: 27-JUN-97
        TH 25 CROSSING LEWIS CREEK IN STARKSBORO, VT                 RLB
           *** RUN DATE & TIME: 10-07-97  09:43

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

EXITX:XS   ******    -23      551  0.83 *****  496.58  492.40    3700  495.75
       -24 ******     83    45181  1.19 ***** *******    0.57    6.71

FULLV:FV       25    -25      578  0.77  0.16  496.75 *******    3700  495.99
         0     25     86    47133  1.20  0.00    0.01    0.54    6.40
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  1.50

APPRO:AS       38    -46      602  0.64  0.16  496.91 *******    3700  496.27
        38     38     50    70487  1.08  0.00    0.00    0.45    6.15
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =    495.99     495.95

            <<<<<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       25      0      245  2.75 *****  498.73  493.98    3261  495.99
         0 ******     24    19012  1.00 ***** *******    0.73   13.29

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  495.95 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    23.  0.02  0.22  500.32    0.00    452.  500.04

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    319.    73.   -60.    13.   1.4   1.0   5.1   4.4   1.3   3.0
   RT:    133.    42.    13.    55.   1.3   0.8   4.5   4.1   1.1   2.9

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

APPRO:AS       14    -74     1038  0.22  0.07  500.34  492.83    3700  500.12
        38     16     59   143747  1.14  0.82    0.00    0.24    3.56

       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     -25.   -24.    83.  3700.   45181.     551.    6.71  495.75
   FULLV:FV       0.   -26.    86.  3700.   47133.     578.    6.40  495.99
   BRIDG:BR       0.     0.    24.  3261.   19012.     245.   13.29  495.99
   RDWAY:RG       8.*******   319.   452.*****************    2.00  500.04
   APPRO:AS      38.   -75.    59.  3700.  143747.    1038.    3.56  500.12

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    492.40    0.57  484.57  511.17************  0.83  496.58  495.75
   FULLV:FV  ********    0.54  484.57  511.17  0.16  0.00  0.77  496.75  495.99
   BRIDG:BR    493.98    0.73  483.95  496.07************  2.75  498.73  495.99
   RDWAY:RG  ****************  498.60  510.50  0.02******  0.22  500.32  500.04
   APPRO:AS    492.83    0.24  484.38  505.10  0.07  0.82  0.22  500.34  500.12
```

WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File star050.wsp
        Hydraulic analysis for structure STARTH00250050   Date: 27-JUN-97
        TH 25 CROSSING LEWIS CREEK IN STARKSBORO, VT                 RLB
           *** RUN DATE & TIME: 10-07-97  09:43

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

EXITX:XS   ******    -16      391  0.73 *****  494.73  491.08    2570  494.00
       -24 ******     62    31394  1.08 ***** *******    0.54    6.57

FULLV:FV       25    -17      409  0.67  0.16  494.90 *******    2570  494.22
         0     25     64    33129  1.10  0.00    0.01    0.52    6.28
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       38    -38      440  0.56  0.16  495.07 *******    2570  494.51
        38     38     48    45971  1.05  0.00    0.00    0.47    5.84
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   492.74     496.88     496.97     495.95

 ===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       25      0      246  1.70 *****  497.77  492.74    2568  496.07
         0 ******     24    17419  1.00 ***** *******    0.57   10.45

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.463  0.000  495.95 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.        <<<<<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       14    -61      847  0.16  0.05  498.75  491.62    2570  498.59
        38     16     55   111139  1.11  0.82    0.00    0.21    3.03

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   498.58

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K      AREA     VEL    WSEL
   EXITX:XS     -25.   -17.    62.   2570.   31394.     391.    6.57  494.00
   FULLV:FV       0.   -18.    64.   2570.   33129.     409.    6.28  494.22
   BRIDG:BR       0.     0.    24.   2568.   17419.     246.   10.45  496.07
   RDWAY:RG       8.**************      0.*********       0.    2.00********
   APPRO:AS      38.   -62.    55.   2570.  111139.     847.    3.03  498.59

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    491.08    0.54  484.57  511.17************  0.73  494.73  494.00
   FULLV:FV  ********    0.52  484.57  511.17  0.16  0.00  0.67  494.90  494.22
   BRIDG:BR    492.74    0.57  483.95  496.07************  1.70  497.77  496.07
   RDWAY:RG  ****************  498.60  510.50************  0.16  498.81********
   APPRO:AS    491.62    0.21  484.38  505.10  0.05  0.82  0.16  498.75  498.59
```
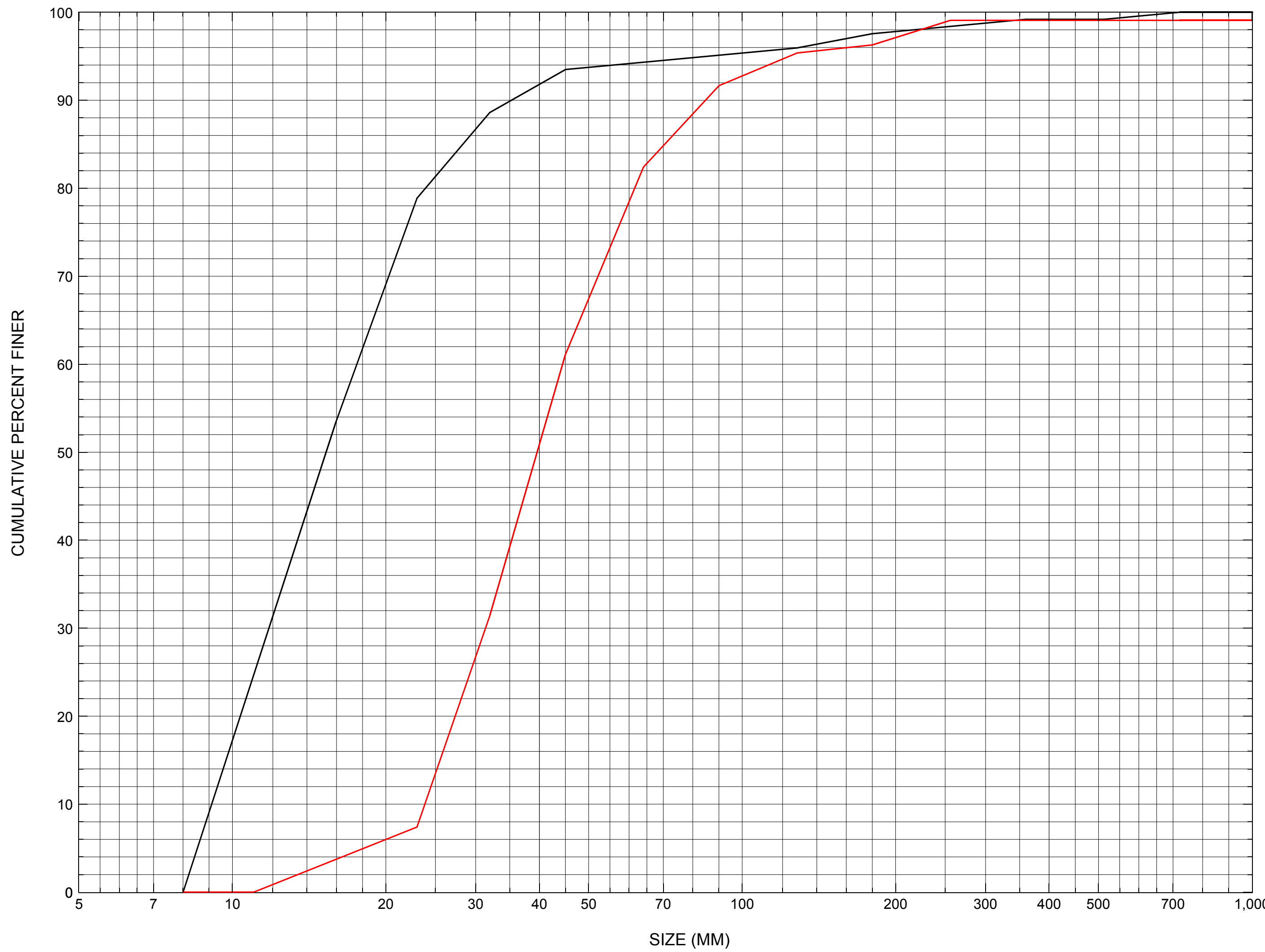

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for two pebble counts in the channel approach of structure STARTH00250050, in Starksboro, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number STARTH00250050

General Location Descriptive

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

Date *(MM/DD/YY)* 12 / 15 / 95

Highway District Number *(I - 2; nn)* 05

County *(FIPS county code; I - 3; nnn)* 001

Town *(FIPS place code; I - 4; nnnnn)* 70075

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

Waterway *(I - 6)* LEWIS CREEK

Road Name *(I - 7):* -

Route Number C3025

Vicinity *(I - 9)* 0.3 MI TO JCT W VT116

Topographic Map Bristol

Hydrologic Unit Code: 2010002

Latitude *(I - 16; nnnn.n)* 44129

Longitude *(i - 17; nnnnn.n)* 73037

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10011900500119

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

Maximum span length *(I - 48; nnnn)* 0025

Year built *(I - 27; YYYY)* 1952

Structure length *(I - 49; nnnnnn)* 000028

Average daily traffic, ADT *(I - 29; nnnnnn)* 000010

Deck Width *(I - 52; nn.n)* 146

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

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

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

Waterway adequacy *(I - 71; n)* 7

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

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

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

Year Reconstructed *(I - 106)* 1975

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

Clear span (*nnn.n ft*) 21.58

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

Vertical clearance from streambed (*nnn.n ft*) 10.32

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

Waterway of full opening (*nnn.n* ft^2) 222.8

Comments:

According to the structural inspection report dated 11/4/94, the abutments and a portion of the wingwalls are concrete. The upper parts of the abutments, between the beams, form a backwall. There are some cracks and areas of fine map cracking in the abutments. There is some horizontal cracking at the inter-

Bridge Hydrologic Data

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

Terrain character: of the backwall and the bridge seat. The upstream right wingwall has extensive

Stream character & type: map cracking with leak-
age and efflorescence. The upstream left wingwall has a large spall at the

Streambed material: end. The downstream right

Discharge Data *(cfs)*: $Q_{2.33}$ wing- Q_{10} wall Q_{25} con-
Q_{50} sists of Q_{100} irregu- Q_{500} lar

Record flood date *(MM / DD / YY)*: lai / d / u Water surface elevation *(ft)*: p

Estimated Discharge *(cfs)*: stone Velocity at Q wit *(ft/s)*: h a

Ice conditions *(Heavy, Moderate, Light)* : short sec- Debris *(Heavy, Moderate, Light)*: tion of con-

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

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

Describe any significant site conditions upstream or downstream that may influence the stream's stage: fine map
cracks and the laid up stone has voids and displacement. Both abutments have (continued page

Watershed storage area (*in percent*): 33 %

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*)	N	-	-	-	
Velocity (*ft / sec*)	Gravel	, cob-	bles,	and	some

Long term stream bed changes: boulders
-

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

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

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

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

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

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

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

Highway No. : ____ Structure No. : ____ Structure Type: ____

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

Comments:

-
-
-
-
-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 10.89 mi^2

Lake/pond/swamp area 0 mi^2

Watershed storage *(ST)* 0 %

Bridge site elevation 580 ft

Headwater elevation 2510 ft

Main channel length 7.05 mi

10% channel length elevation 600 ft

85% channel length elevation 1740 ft

Main channel slope *(S)* 215.6 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? -____ *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:

U

-

-

-

Reference Point (*MSL, Arbitrary, Other*): U_____________ 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:

-

-

an exposed concrete footing. There is a small amount of stone fill in front of each footing. The channel bed is made up of gravel, cobbles, and some boulders. There is a small amount of scour just US from the bridge. There is some small tree debris and brush along the channel length.

Cross-sectional Data

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

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

Comments: -
-
-

Station	-	NO	INF		4	-	DRI	OR			Y
Feature	-	BEN	OR		-	N	LL	MA			VTA
Low chord elevation	-	CK	MA		-	-	BOR	TIO			OT
Bed elevation	-	MA	TIO	-	-	3	ING	N			This
Low chord-bed	-	RK	N	-	-	NO	INF		-		is a

Station	cross	dow	low	from	done	06/	cord	data	h	ge	date
Feature	-sec-	nstre	cord	the	for	12/	to	is	attac	inspe	d 11/
Low chord elevation	tion	am	ele-	sur-	this	96.	bed	from	hed	ction	04/
Bed elevation	of	face.	vatio	vey	repo	The	lengt	the	to a	repo	93.
Low chord-bed	the	The	n is	log	rt on	low	h	sketc	brid	rt	The

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

Comments: itself is dated 09/23/92.
0

Station	RAB	-	-	-	LAB	-	-	-	-	-	-
Feature	496.1	496.0	496.0	495.9	495.8	-	-	-	-	-	-
Low chord elevation	487.5	486.0	485.2	486.0	489.0	-	-	-	-	-	-
Bed elevation	8.6	10	10.8	9.9	6.8	-	-	-	-	-	-
Low chord-bed	5.5	10.2	15.6	21.6	-	-	-	-	-	-	-

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: MS Date: 6/23/97

Computerized by: MS Date: 6/24/97

Reviewd by: RB Date: 10/9/97

Structure Number STARTH00250050

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* E. BOEHMLER Date *(MM/DD/YY)* 06 / 12 / 1996
2. Highway District Number 05 Mile marker 000000

County 001 ADDISON Town 70075 STARKSBORO

Waterway *(I - 6)* LEWIS CREEK Road Name TATRO RD

Route Number C3025 Hydrologic Unit Code: 2010002

3. Descriptive comments:

This bridge is located 0.3 miles from the junction with VT 116.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 6 LBDS 4 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 1 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 28 *(feet)* Span length 25 *(feet)* Bridge width 14.6 *(feet)*

Road approach to bridge:

8. LB 2 RB 2 *(**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 -- US right --

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

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

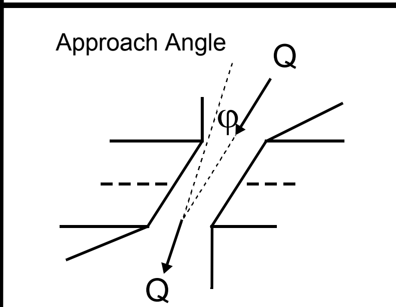
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

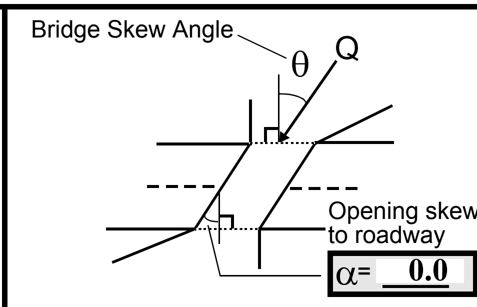
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

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

Channel approach to bridge (BF):

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





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

Where? RB *(LB, RB)* Severity 11

Range? 24 feet US *(US, UB, DS)* to 50 feet US

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

Where? LB *(LB, RB)* Severity 2

Range? 55 feet DS *(US, UB, DS)* to 90 feet DS

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

18. Bridge Type: **1a**

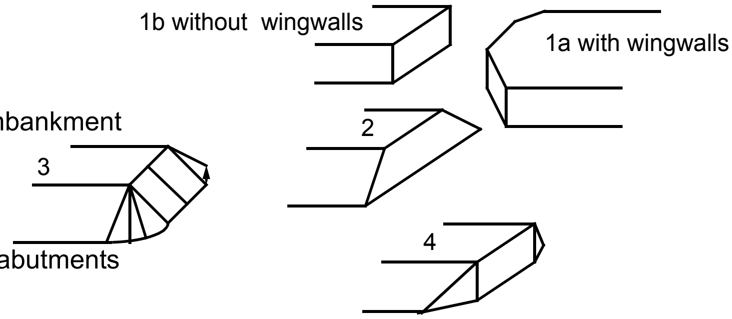
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

4. The surface cover is as indicated on the previous page. The only variation is on the US left bank where there is a barn and house a considerable distance from the channel.
7. The measured values for the bridge length, span length, and the bridge width are 28 ft, 26 ft, and 14.7 ft respectively.
18. The wingwalls are only 4 ft high. There is no DS left wingwall.

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
24.5	**2.5**			**7.0**	**2**	**3**	**235**	**235**	**2**	**2**

23. Bank width **25.0** 24. Channel width **25.0** 25. Thalweg depth **41.5** 29. Bed Material **325**

30 .Bank protection type: LB **0** RB **0** 31. 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*

32. Comments (bank material variation, minor inflows, protection extent, etc.):
The US reach to the bridge is moderately steep. There is a slight bend in the channel causing the flow to impact the right bank. The right bank and left bank are slightly scalloped. The flow is eroding the bank material from between the boulders and trees on the bank line.

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

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

37. Material: -

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

NO POINT BARS

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

41. Mid-bank distance: 70 42. Cut bank extent: 50 feet US *(US, UB)* to 125 feet US *(US, UB, DS)*

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

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

The cut bank features a downed tree in the stream and other trees with heavy root exposure. The bank material is also being slightly undermined in places.

45. **Is channel scour present?** Y *(Y or if N type ctrl-n cs)* 46. Mid-scour distance: 0

47. Scour dimensions: Length 43 Width 5 Depth : 1 Position 60 %LB to 90 %RB

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

This scour hole extends under the bridge from 16 ft US to 12 ft DS.

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
23.0		1.5		2	7	7	-

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

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

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

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

325

The channel narrows through the bridge by approximately 10% of its width at the approach section. The channel under the bridge is 1 ft. deeper than US and DS.

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 Y____ (1- Low; 2- Moderate; 3- High)

70. Debris and Ice Comments:

2

Debris US is caught in the trees along the bank. Some of the trees are leaning in toward the channel, especially at the cut bank. There is some ice scarring of trees located on the US right bank.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	90	2	2	0	2	90.0
RABUT	1	5	90			2	2	23.5

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.):

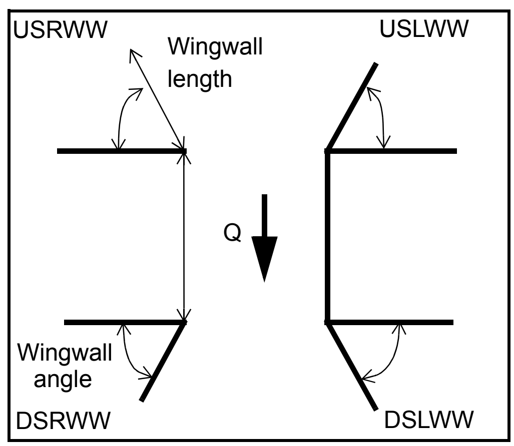
0
1
1

The left abutment footing exposure ranges from 2 ft to 2.5 ft. The right abutment footing exposure ranges from 0.5 ft to 1.5 ft.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						23.5	
USRWW:	Y		1		2	2.0	
DSLWW:	0		0.5		Y	15.5	
DSRWW:	1		2		0	15.5	

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	0.5	-	Y	0	-	1	2	1
Condition	N	-	1	1	-	1	1	1
Extent	-	-	2	0	2	1	2	-

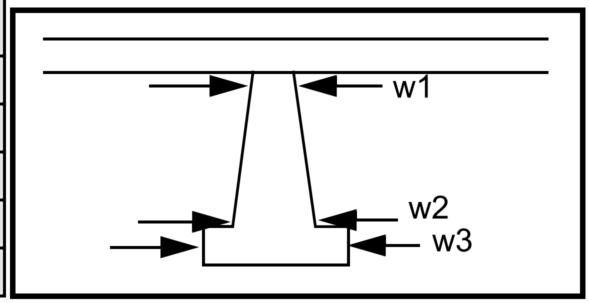
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
-
-
-
2
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		7.5		65.0	80.0	11.0
Pier 2	-		6.0	-	65.0	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e US	to 1 ft.	from 1	ranges	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	right	The	ft to	from	1- Solid pier, 2- column, 3- bent
88. Material	wing	US	2 ft.	0.5 ft	1- Wood; 2- concrete; 3- metal; 4- stone
89. Shape	wall	left	The	to 1	1- Round; 2- Square; 3- Pointed
90. Inclined?	foot-	wing	DS	ft.	Y- yes; N- no
91. Attack ∠ (BF)	ing	wall	right		
92. Pushed	expo	foot-	wing		LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	sure	ing	wall		
95. Cross-members	rang	expo	foot-		0- none; 1- laterals; 2- diagonals; 3- both
96. Scour Condition	es	sure	ing		0- not evident; 1- evident (comment); 2- footing exposed; 3- piling exposed; 4- undermined footing; 5- settled; 6- failed
97. Scour depth	from	rang	expo		
98. Exposure depth	0 ft	es	sure		

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

N
-
-
-
-
-
-
-

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

Point bar extent: - feet - (US, UB, DS) to - feet - (US, UB, DS) positioned NO %LB to PI %RB

Material: ER

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

S

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

Cut bank extent: _____ feet ____ (US, UB, DS) to _____ feet 1 (US, UB, DS)

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

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

235
235
2
1

Is channel scour present? 325 (Y or if N type ctrl-n cs) Mid-scour distance: 0

Scour dimensions: Length 0 Width - Depth: - Positioned - %LB to ____ %RB

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

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

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

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

Confluence comments (eg. confluence name):

N

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 DROP STRUCTURE

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: STARTH00250050 Town: STARKSBORO
Road Number: TH 25 County: ADDISON
Stream: LEWIS CREEK

Initials RLB Date: 10/2/97 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	2590	3700	2570
Main Channel Area, ft2	497	558	494
Left overbank area, ft2	291	383	286
Right overbank area, ft2	68	98	66
Top width main channel, ft	42	42	42
Top width L overbank, ft	57	70	57
Top width R overbank, ft	19	23	19
D50 of channel, ft	0.0827	0.0827	0.0827
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	11.8	13.3	11.8
y1, average depth, LOB, ft	5.1	5.5	5.0
y1, average depth, ROB, ft	3.6	4.3	3.5
Total conveyance, approach	112598	143851	111044
Conveyance, main channel	73590	89057	72771
Conveyance, LOB	36180	50180	35527
Conveyance, ROB	2829	4614	2746
Percent discrepancy, conveyance	-0.0009	0.0000	0.0000
Qm, discharge, MC, cfs	1692.7	2290.6	1684.2
Ql, discharge, LOB, cfs	832.2	1290.7	822.2
Qr, discharge, ROB, cfs	65.1	118.7	63.6
Vm, mean velocity MC, ft/s	3.4	4.1	3.4
Vl, mean velocity, LOB, ft/s	2.9	3.4	2.9
Vr, mean velocity, ROB, ft/s	1.0	1.2	1.0
Vc-m, crit. velocity, MC, ft/s	7.4	7.5	7.4
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	2590	3700	2570
(Q) discharge thru bridge, cfs	2589	3261	2570
Main channel conveyance	17419	18923	17419
Total conveyance	17419	18923	17419
Q2, bridge MC discharge,cfs	2589	3261	2570
Main channel area, ft2	246	245	246
Main channel width (normal), ft	23.8	23.8	23.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	23.8	23.8	23.8
y_bridge (avg. depth at br.), ft	10.34	10.29	10.34
Dm, median (1.25*D50), ft	0.103375	0.103375	0.103375
y2, depth in contraction,ft	13.18	16.06	13.09
ys, scour depth (y2-ybridge), ft	2.84	5.76	2.76

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	2589	3261	2570
Main channel area (DS), ft2	206	245	205
Main channel width (normal), ft	23.8	23.8	23.8
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	23.8	23.8	23.8
D90, ft	0.2297	0.2297	0.2297
D95, ft	0.3765	0.3765	0.3765
Dc, critical grain size, ft	0.4240	0.4498	0.4225
Pc, Decimal percent coarser than Dc	0.043	0.041	0.043
Depth to armoring, ft	N/A	N/A	N/A

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	2590	3700	2570
Q, thru bridge MC, cfs	2589	3261	2570
Vc, critical velocity, ft/s	7.37	7.52	7.37
Va, velocity MC approach, ft/s	3.41	4.11	3.41
Main channel width (normal), ft	23.8	23.8	23.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	23.8	23.8	23.8
qbr, unit discharge, ft2/s	108.8	137.0	108.0
Area of full opening, ft2	246.0	245.0	246.0
Hb, depth of full opening, ft	10.34	10.29	10.34
Fr, Froude number, bridge MC	0.58	0.73	0.57
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	206	N/A	205
**Hb, depth at downstream face, ft	8.66	N/A	8.61
**Fr, Froude number at DS face	0.75	ERR	0.75
**Cf, for downstream face (<=1.0)	1.00	N/A	1.00
Elevation of Low Steel, ft	495.95	495.95	495.95
Elevation of Bed, ft	485.61	485.66	485.61
Elevation of Approach, ft	498.67	500.12	498.59
Friction loss, approach, ft	0.05	0.07	0.05
Elevation of WS immediately US, ft	498.62	500.05	498.54
ya, depth immediately US, ft	13.01	14.39	12.93
Mean elevation of deck, ft	498.72	498.72	498.72
w, depth of overflow, ft (>=0)	0.00	1.33	0.00
Cc, vert contrac correction (<=1.0)	0.94	0.94	0.94
**Cc, for downstream face (<=1.0)	0.892709	ERR	0.89313
Ys, scour w/Chang equation, ft	5.31	9.08	5.18
Ys, scour w/Umbrell equation, ft	-1.34	0.10	-1.38

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

**Ys, scour w/Chang equation, ft	7.87	N/A	7.80

**Ys, scour w/Umbrell equation, ft	0.34	N/A	0.34

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

y2, from Laursen's equation, ft	13.18	16.06	13.09
WSEL at downstream face, ft	494.26	--	494.22
Depth at downstream face, ft	8.66	N/A	8.61
Ys, depth of scour (Laursen), ft	4.52	N/A	4.48

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	2590	3700	2570	2590	3700	2570
a', abut.length blocking flow, ft	62.3	75.1	61.6	31.7	35.5	31.5
Ae, area of blocked flow ft2	345.44	390.19	340.63	187.55	217.75	185.53
Qe, discharge blocked abut.,cfs	--	--	992.95	396.85	--	393.79
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.91	3.43	2.92	2.12	2.51	2.12
ya, depth of f/p flow, ft	5.54	5.20	5.53	5.92	6.13	5.89
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.217	0.248	0.218	0.153	0.171	0.154
ys, scour depth, ft	17.05	18.22	17.00	13.14	14.41	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)	62.3	75.1	61.6	31.7	35.5	31.5
y1 (depth f/p flow, ft)	5.54	5.20	5.53	5.92	6.13	5.89
a'/y1	11.24	14.45	11.14	5.36	5.79	5.35
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.22	0.25	0.22	0.15	0.17	0.15
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship

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

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.75	0.73	0.75	0.75	0.73	0.75
y, depth of flow in bridge, ft	8.66	10.29	8.61	8.66	10.29	8.61
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	3.01	3.39	2.99	3.01	3.39	2.99
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR