LEVEL II SCOUR ANALYSIS FOR BRIDGE 16 (GROTTH00170016) on TOWN HIGHWAY 17, crossing WELLS RIVER, GROTON, VERMONT

U.S. Geological Survey
Open-File Report 97-805

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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By LORA K. STRIKER AND MICHAEL A. IVANOFF

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Pembroke, New Hampshire

1997

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

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Slope	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Velocity and Flow	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]

OTHER ABBREVIATIONS

BF	bank full	LWW	left wingwall
cfs	cubic feet per second	MC	main channel
D_{50}	median diameter of bed material	RAB	right abutment
DS	downstream	RABUT	face of right abutment
elev.	elevation	RB	right bank
f/p	flood plain	ROB	right overbank
ft^2	square feet	RWW	right wingwall
ft/ft	feet per foot	TH	town highway
JCT	junction	UB	under bridge
LAB	left abutment	US	upstream
LABUT	face of left abutment	USGS	United States Geological Survey
LB	left bank	VTAOT	Vermont Agency of Transportation
LOB	left overbank	WSPRO	water-surface profile model

In this report, the words “right” and “left” refer to directions that would be reported by an observer facing downstream.

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929-- a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

In the appendices, the above abbreviations may be combined. For example, USLB would represent upstream left bank.

LEVEL II SCOUR ANALYSIS FOR BRIDGE 16 (GROTTH00170016) ON TOWN HIGHWAY 17 CROSSING WELLS RIVER, GROTON, VERMONT

By **Lora K. Striker and Michael A. Ivanoff**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure GROTTH00170016 on Town Highway 17 crossing the Wells River, Groton, 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 New England Upland section of the New England physiographic province in eastern Vermont. The 43.4-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is predominantly shrub and brushland, while the left bank downstream is forested.

In the study area, the Wells River has an incised, straight channel with a slope of approximately 0.003 ft/ft, an average channel top width of 57 ft and an average bank height of 4 ft. The channel bed material ranges from sand to boulder with a median grain size (D_{50}) of 77.8 mm (0.255 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 29, 1995, indicated that the reach was stable.

The Town Highway 17 crossing of the Wells River is a 43-ft-long, one-lane bridge consisting of one 41-foot steel-beam span with a concrete deck (Vermont Agency of Transportation, written communication, March 24, 1995). The opening length of the structure parallel to the bridge face is 39.4 ft. The bridge is supported by vertical, concrete abutments. The channel is skewed approximately 0 degrees and the opening-skew-to-roadway is also zero degrees.

A scour hole 1.7 ft deeper than the mean thalweg depth was observed from 30 ft upstream to 70 ft downstream in mid-channel during the Level I assessment. Scour protection measures at the site included: type-3 stone fill (less than 48 inches diameter) along the left and right bank upstream, and along the left and right bank downstream. The protection along the banks begins in the road embankment areas where the wingwalls would be located. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows was 0 ft. Abutment scour ranged from 7.6 to 8.4 ft at the left abutment and from 9.9 to 14.8 ft at the right abutment. 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.

Groton, VT. Quadrangle, 1:24,000, 1973

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 GROTTH00170016 ***Stream*** Wells River

County Windsor ***Road*** TH 17 ***District*** 7

Description of Bridge

Bridge length 43 ***ft*** ***Bridge width*** 18.2 ***ft*** ***Max span length*** 41 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 08/29/95

Description of stone fill Type-3, stone fill is in road embankment areas where wingwalls would be located.

Brief description of piers/abutments Abutments and are concrete.

No 0

Is bridge skewed to flood flow according to No ***survey?*** ***Angle***

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***
	08/29/95	0	0
Level I	08/29/95	0	0
Level II			

Potential for debris Low. There was no debris noted at the time of the assessment, 08/29/95.

Describe any features near or at the bridge that may affect flow (include observation date) None as of 08/29/95.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with a narrow flood plain and steep valley walls on both sides.

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

Date of inspection 08/29/95

DS left: Steep channel bank to moderately sloped overbank and steep valley wall

DS right: Steep channel bank to narrow flood plain, terrace, and valley wall

US left: Steep channel bank to moderately sloped overbank and steep valley wall

US right: Steep channel bank to narrow flood plain, terrace, and valley wall

Description of the Channel

Average top width 57 ft ***Average depth*** 4 ft

Predominant bed material Cobble/Boulder ***Bank material*** Cobble/Boulder

Straight and stable with semi-alluvial to alluvial channel boundaries and a narrow flood plain.

08/29/95

Vegetative co

DS left: Trees

DS right: Trees and brush

US left: Trees and brush

US right: Trees and brush with a pasture overbank subarea

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

There were no obstructions noted in the channel during the assessment on 08/29/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 43.4 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/New England Upland	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 Wells River at Wells River, VT

USGS gage number 01139000

Gage drainage area 98.4 ***mi²***

Is there a lake/p Yes

There are discharge records available from August 1940 to the current year. The flow of Wells River is partly regulated by Groton and Ricker Ponds. Ricker Pond is located 1.6 miles upstream of the bridge site.

Calculated Discharges

Q100 2,600 ***ft³/s*** ***Q500*** 3,500 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(43.4/99.7)exp 0.67] with bridge number 47 in Newbury. Bridge number 47 crosses the Wells River downstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 47 is 99.7 square miles. The VTAOT discharges compare well with gage data and fall within the range of 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 a boulder 20 ft downstream of the bridge on the left bank shoreward side of the road in a narrow ditch (elev. 898.94 ft, arbitrary survey datum). RM2 is the center of a chiseled square on the downstream right corner of the concrete deck (elev. 899.58 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	-55	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	9	1	Road Grade section
APPRO	54	1	Approach section as surveyed

[1] For location of cross-sections see plan-view sketch included with Level I field form, Appendix E.
For more detail on how cross-sections were developed see WSPRO input file.

Data and Assumptions Used in WSPRO Model

Hydraulic analyses of the reach were done by use of the Federal Highway Administration's WSPRO step-backwater computer program (Shearman and others, 1986, and Shearman, 1990). The analyses reported herein reflect conditions existing at the site at the time of the study. Furthermore, in the development of the model it was necessary to assume no accumulation of debris or ice at the site. Results of the hydraulic model are presented in the Bridge Hydraulic Summary, Appendix B, and figure 7.

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.055 and overbank "n" values ranged from 0.040 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 0.0029 ft/ft, which was estimated from water surface elevations taken from sections M and N downstream of the bridge in the Flood Insurance Study (FIS) for the Town of Groton, VT (Federal Emergency Management Agency, 1991).

The surveyed 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 899.7 ***ft***
Average low steel elevation 896.9 ***ft***

100-year discharge 2,600 ***ft³/s***
Water-surface elevation in bridge opening 896.9 ***ft***
Road overtopping? Yes ***Discharge over road*** 54 ***ft³/s***
Area of flow in bridge opening 310 ***ft²***
Average velocity in bridge opening 8.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.8 ***ft/s***

Water-surface elevation at Approach section with bridge 898.5
Water-surface elevation at Approach section without bridge 896.8
Amount of backwater caused by bridge 1.7 ***ft***

500-year discharge 3,500 ***ft³/s***
Water-surface elevation in bridge opening 896.9 ***ft***
Road overtopping? Yes ***Discharge over road*** 687 ***ft³/s***
Area of flow in bridge opening 310 ***ft²***
Average velocity in bridge opening 9.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.8 ***/s***

Water-surface elevation at Approach section with bridge 899.7
Water-surface elevation at Approach section without bridge 897.9
Amount of backwater caused by bridge 1.8 ***ft***

Incipient overtopping discharge 2,210 ***ft³/s***
Water-surface elevation in bridge opening 895.7 ***ft***
Area of flow in bridge opening 262 ***ft²***
Average velocity in bridge opening 8.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.4 ***ft/s***

Water-surface elevation at Approach section with bridge 897.1
Water-surface elevation at Approach section without bridge 896.3
Amount of backwater caused by bridge 0.8 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 100-year discharge resulted in unsubmerged orifice flow, while 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 results of the scour analysis are presented in Tables 1 and 2 and Figure 8. 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 and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and presented in Appendix F. Furthermore, for the discharge resulting in unsubmerged orifice flow, contraction scour was computed by substituting an estimate for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to this substitution is provided in Appendix F.

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

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	0.0
Depth to armoring	2.0	2.5	2.2
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	8.0	8.4	7.6
Right abutment	13.7	14.8	9.9
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.4	1.6	1.7
Right abutment	1.4	1.6	1.7
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

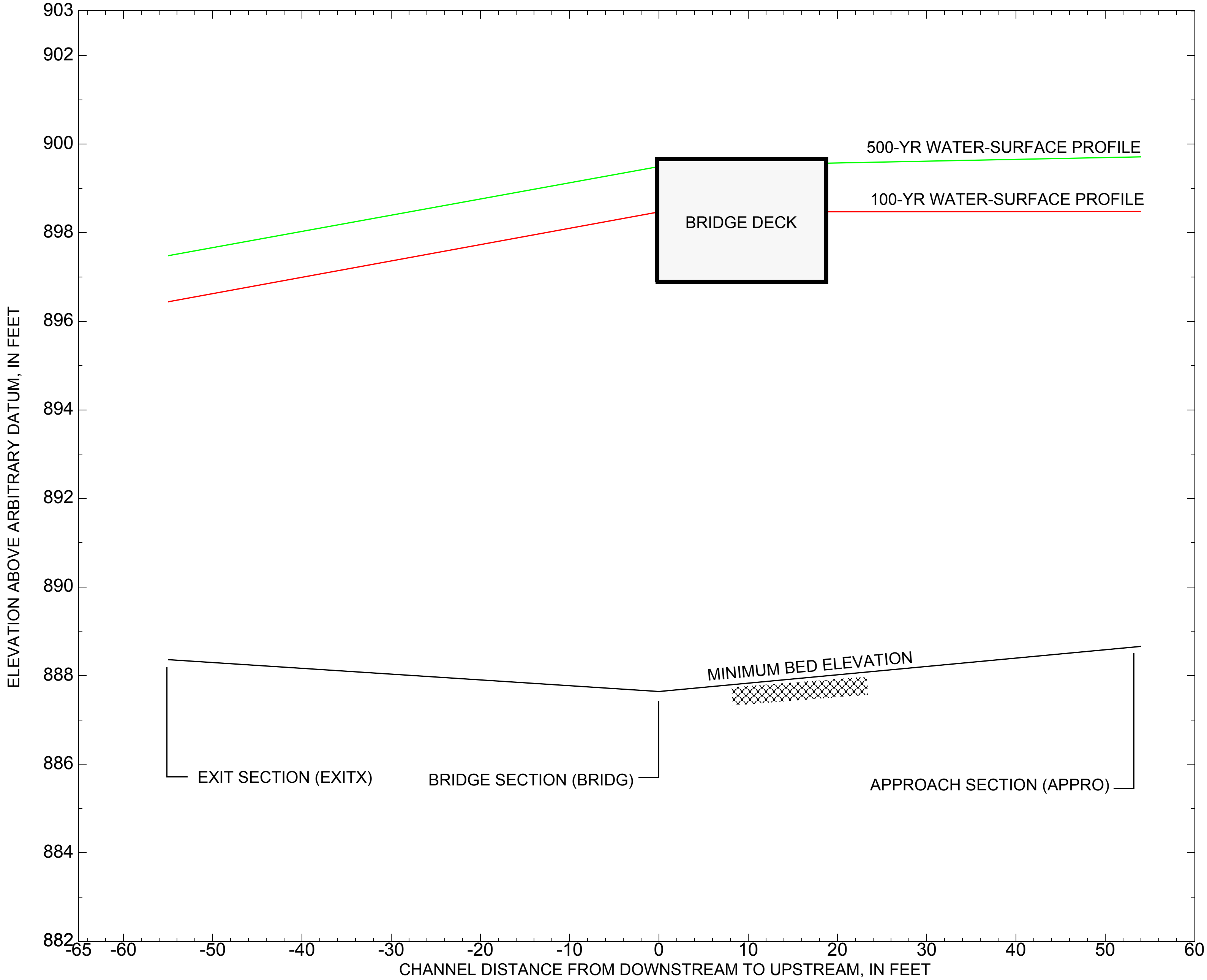

Figure 7. Water-surface profiles for the 100-year and 500-year discharges at structure GROTTH00170016 on Town Highway 17, crossing the Wells River, Groton, Vermont.

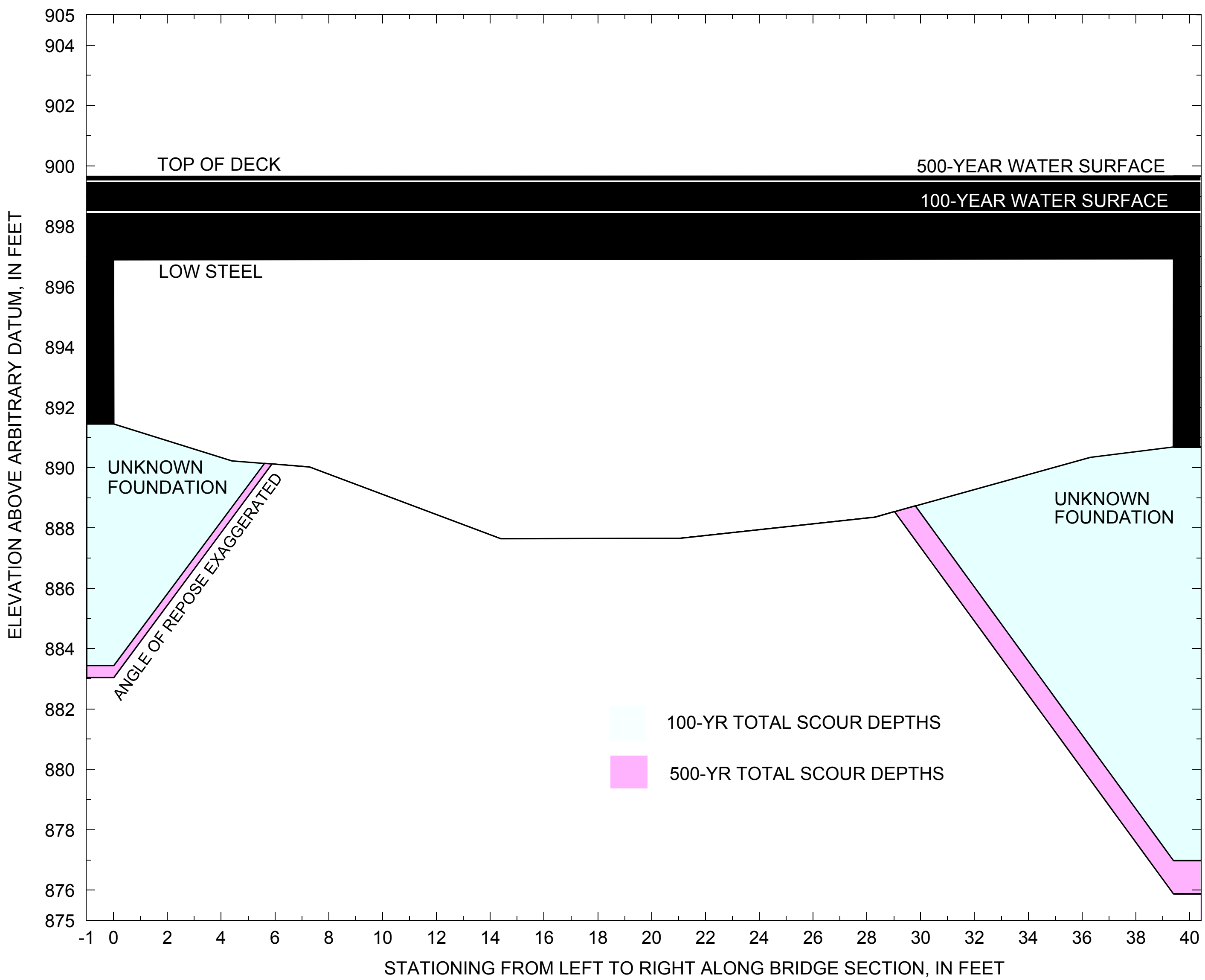

Figure 8. Scour elevations for the 100-year and 500-year discharges at structure GROTTH00170016 on Town Highway 17, crossing the Wells River, Groton, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure GROTTH00170016 on Town Highway 17, crossing Wells River, Groton, 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 2,600 cubic-feet per second											
Left abutment	0.0	--	896.9	--	891.4	0.0	8.0	--	8.0	883.4	--
Right abutment	39.4	--	896.9	--	890.7	0.0	13.7	--	13.7	877.0	--

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 GROTTH00170016 on Town Highway 17, crossing Wells River, Groton, 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 3,500 cubic-feet per second											
Left abutment	0.0	--	896.9	--	891.4	0.0	8.4	--	8.4	883.0	--
Right abutment	39.4	--	896.9	--	890.7	0.0	14.8	--	14.8	875.9	--

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, 1973, Groton, 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 grot016.wsp
T2        Hydraulic analysis for structure GROTTH00170016   Date: 25-JUL-97
T3        TH 17 crossing Wells River, 0.05 miles to junction with US 302, LKS
*
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           2600.0   3500.0   2210.0
SK          0.0029   0.0029   0.0029
*
XS   EXITX    -55           0.
GR         -142.9, 922.46    -70.2, 897.13    -48.1, 897.18    -42.5, 894.94
GR           -8.9, 892.55      0.0, 890.35      5.3, 888.59     16.1, 888.41
GR           25.7, 888.36     34.1, 888.99     38.5, 890.32     41.4, 891.98
GR           49.2, 894.58    132.6, 893.83    160.4, 898.23    228.3, 897.17
GR          245.6, 903.45    262.2, 906.63
*
N           0.080        0.050     0.080
SA                 -8.9       49.2
*
*
XS   FULLV      0  * * *   0.0000
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0    896.91       0.0
GR            0.0, 896.89      0.1, 891.44      4.4, 890.22      7.3, 890.02
GR           14.4, 887.64     21.0, 887.65     28.3, 888.36     36.3, 890.34
GR           39.4, 890.68     39.4, 896.92      0.0, 896.89
*
*        BRTYPE  BRWDTH
CD          1      17.9
N          0.045
*
*
*            SRD    EMBWID   IPAVE
XR   RDWAY      9      18.2     2
GR         -130.6, 921.44    -78.6, 907.22    -44.2, 898.98
GR            0.0, 899.65     39.4, 899.66     79.0, 898.94    144.2, 897.80
GR          183.2, 898.79    205.0, 899.61    225.2, 898.99
GR          267.3, 906.74    276.7, 908.20
*
*
AS   APPRO     54           0.
GR         -134.3, 918.26   -116.8, 914.03   -109.6, 913.92    -99.2, 910.12
GR          -81.6, 907.45    -70.9, 902.19    -50.7, 901.58    -41.9, 899.54
GR           -7.3, 896.95      0.0, 893.92      5.8, 890.34      9.7, 889.00
GR           15.2, 888.68     20.0, 888.66     26.2, 889.30     31.9, 889.32
GR           37.0, 889.58     40.5, 890.32     47.6, 893.95     77.1, 895.35
GR          170.2, 895.38    212.4, 899.82    255.7, 900.01
GR          305.3, 907.71    314.9, 908.94
*
N           0.080        0.055        0.080     0.040
SA                   -7.3         47.6      77.1
*
HP 1 BRIDG   896.92 1 896.92
HP 2 BRIDG   896.92 * * 2544
HP 1 BRIDG   896.64 1 896.64
HP 2 RDWAY   898.47 * *   54
HP 1 APPRO   898.48 1 898.48
HP 2 APPRO   898.48 * * 2600
*
HP 1 BRIDG   896.92 1 896.92
HP 2 BRIDG   896.92 * * 2819
HP 2 RDWAY   899.49 * *  687
HP 1 APPRO   899.71 1 899.71
HP 2 APPRO   899.71 * * 3500
*
HP 1 BRIDG   895.68 1 895.68
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File grot016.wsp
        Hydraulic analysis for structure GROTTH00170016   Date: 25-JUL-97
        TH 17 crossing Wells River, 0.05 miles to junction with US 302, LKS
           *** RUN DATE & TIME: 08-22-97  15:20
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      310     23166      0     91                            0
   896.92           310     23166      0     91  1.00      0     39        0

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA         K        Q    VEL
       896.92     0.0    39.4   309.8   23166.    2544.   8.21
 X STA.         0.0         4.1         6.7         9.0        11.0        12.7
   A(I)             24.1        17.6        16.6        15.4        14.5
   V(I)             5.27        7.21        7.66        8.27        8.76

 X STA.        12.7        14.3        15.8        17.2        18.6        20.0
   A(I)             13.8        13.7        13.3        13.1        13.1
   V(I)             9.23        9.26        9.57        9.69        9.69

 X STA.        20.0        21.5        22.9        24.4        25.9        27.5
   A(I)             13.2        13.0        13.5        13.9        13.8
   V(I)             9.64        9.75        9.45        9.13        9.23

 X STA.        27.5        29.2        31.1        33.2        35.6        39.4
   A(I)             14.4        15.0        16.0        17.2        24.4
   V(I)             8.86        8.47        7.94        7.41        5.21

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      299     32112     39     51                         4682
   896.64           299     32112     39     51  1.00      0     39     4682

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       9.
         WSEL     LEW     REW    AREA         K        Q    VEL
       898.47   105.9   170.6    21.7      195.      54.   2.49
 X STA.       105.9       121.3       126.0       129.2       131.8       133.9
   A(I)              2.1         1.4         1.2         1.1         1.0
   V(I)             1.29        1.87        2.20        2.44        2.69

 X STA.       133.9       135.8       137.5       139.1       140.5       141.9
   A(I)              1.0         0.9         0.9         0.8         0.8
   V(I)             2.76        2.96        3.06        3.18        3.25

 X STA.       141.9       143.2       144.4       145.7       147.0       148.6
   A(I)              0.8         0.8         0.8         0.8         0.9
   V(I)             3.29        3.28        3.26        3.19        3.08

 X STA.       148.6       150.3       152.3       154.8       158.5       170.6
   A(I)              0.9         1.0         1.1         1.3         1.9
   V(I)             2.94        2.70        2.47        2.10        1.45

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      54.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       16       243     20     20                           78
             2      426     43676     55     58                         6725
             3      113      5147     30     30                         1255
             4      336     24455    123    123                         3152
   898.48           890     73521    227    230  1.20    -27    200     9133


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      54.

         WSEL     LEW     REW    AREA         K        Q    VEL
       898.48   -27.7   199.7   889.9   73521.    2600.   2.92

 X STA.       -27.7         5.1         9.6        13.2        16.5        19.7
   A(I)             69.0        38.7        34.8        32.6        31.2
   V(I)             1.88        3.36        3.74        3.99        4.16

 X STA.        19.7        23.0        26.4        29.8        33.3        36.9
   A(I)             31.8        31.4        31.7        31.9        32.3
   V(I)             4.08        4.14        4.10        4.08        4.02

 X STA.        36.9        40.9        48.5        68.0        86.6       101.8
   A(I)             34.0        46.1        78.2        60.3        47.5
   V(I)             3.82        2.82        1.66        2.16        2.73

 X STA.       101.8       116.8       132.0       147.6       163.4       199.7
   A(I)             46.7        47.5        48.4        49.1        66.7
   V(I)             2.78        2.74        2.68        2.65        1.95
```

```
        U.S. Geological Survey WSPRO Input File grot016.wsp
        Hydraulic analysis for structure GROTTH00170016   Date: 25-JUL-97
        TH 17 crossing Wells River, 0.05 miles to junction with US 302, LKS
           *** RUN DATE & TIME: 08-22-97  15:20
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      310     23166      0     91                            0
   896.92           310     23166      0     91  1.00      0     39        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       896.92     0.0    39.4   309.8   23166.    2819.   9.10

X STA.         0.0        4.1        6.7        9.0       11.0       12.7
  A(I)            24.1       17.6       16.6       15.4       14.5
  V(I)            5.84       7.99       8.48       9.16       9.71

X STA.        12.7       14.3       15.8       17.2       18.6       20.0
  A(I)            13.8       13.7       13.3       13.1       13.1
  V(I)           10.23      10.26      10.61      10.73      10.74

X STA.        20.0       21.5       22.9       24.4       25.9       27.5
  A(I)            13.2       13.0       13.5       13.9       13.8
  V(I)           10.68      10.80      10.48      10.12      10.23

X STA.        27.5       29.2       31.1       33.2       35.6       39.4
  A(I)            14.4       15.0       16.0       17.2       24.4
  V(I)            9.82       9.38       8.80       8.21       5.77

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       9.

         WSEL     LEW     REW    AREA        K        Q    VEL
       899.49   -46.3   227.9   148.3    2323.     687.   4.63

X STA.       -46.3       76.5       92.4      102.0      109.3      115.2
  A(I)            16.1       10.3        8.4        7.4        6.7
  V(I)            2.13       3.34       4.10       4.66       5.11

X STA.       115.2      120.3      124.8      129.0      132.9      136.5
  A(I)             6.2        6.0        5.8        5.6        5.5
  V(I)            5.53       5.76       5.93       6.14       6.26

X STA.       136.5      139.9      143.2      146.4      149.9      153.9
  A(I)             5.5        5.3        5.5        5.5        5.9
  V(I)            6.27       6.43       6.29       6.23       5.83

X STA.       153.9      158.3      163.6      170.2      180.0      227.9
  A(I)             6.2        6.7        7.3        8.9       13.6
  V(I)            5.58       5.12       4.68       3.84       2.53

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      54.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       51      1201     35     35                          345
             2      493     55825     55     58                         8388
             3      149      8188     30     30                         1905
             4      494     43753    134    134                         5371
   899.71          1187    108967    254    257  1.18    -42    211    13399

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      54.

         WSEL     LEW     REW    AREA        K        Q    VEL
       899.71   -42.6   211.4  1186.8  108967.    3500.   2.95

X STA.       -42.6        3.7        9.3       13.5       17.5       21.3
  A(I)           107.6       52.9       46.0       43.6       42.3
  V(I)            1.63       3.31       3.81       4.02       4.14

X STA.        21.3       25.4       29.5       33.7       38.0       43.3
  A(I)            43.2       43.1       43.7       43.5       48.7
  V(I)            4.05       4.06       4.01       4.02       3.59

X STA.        43.3       56.6       77.4       90.3      102.8      115.9
  A(I)            79.6      100.6       56.0       54.7       56.7
  V(I)            2.20       1.74       3.13       3.20       3.09

X STA.       115.9      128.9      142.0      155.6      170.0      211.4
  A(I)            56.7       56.9       59.0       62.2       90.0
  V(I)            3.09       3.07       2.97       2.81       1.95
```

```
      U.S. Geological Survey WSPRO Input File grot016.wsp
      Hydraulic analysis for structure GROTTH00170016   Date: 25-JUL-97
      TH 17 crossing Wells River, 0.05 miles to junction with US 302, LKS
         *** RUN DATE & TIME: 08-22-97  15:20
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1      262     26300     39     49                         3824
 895.68           262     26300     39     49  1.00      0     39     3824

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     895.68     0.0    39.4   261.5   26300.    2210.   8.45

X STA.        0.0        4.6        7.4        9.7       11.6       13.2
  A(I)           22.3       15.4       13.8       12.9       12.1
  V(I)           4.96       7.18       8.03       8.60       9.10

X STA.       13.2       14.6       16.0       17.3       18.7       20.0
  A(I)           11.3       10.8       10.9       10.7       10.7
  V(I)           9.79      10.25      10.18      10.30      10.30

X STA.       20.0       21.3       22.7       24.1       25.5       27.1
  A(I)           10.7       10.6       10.9       11.3       11.4
  V(I)          10.31      10.44      10.13       9.80       9.70

X STA.       27.1       28.7       30.5       32.5       35.0       39.4
  A(I)           12.0       12.6       13.4       14.7       23.2
  V(I)           9.23       8.76       8.23       7.52       4.77

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      54.

   WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
           1        0         0      2      2                            0
           2      349     31340     55     58                         4989
           3       72      2411     30     30                          634
           4      173      8784    109    109                         1240
 897.08           594     42536    195    198  1.28     -8    186     5203

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      54.

       WSEL     LEW     REW    AREA        K        Q    VEL
     897.08    -9.0   186.4   594.0   42536.    2210.   3.72

X STA.       -9.0        5.9        9.5       12.4       15.0       17.5
  A(I)           41.3       26.8       23.9       21.5       21.1
  V(I)           2.67       4.12       4.63       5.14       5.24

X STA.       17.5       20.0       22.4       25.0       27.7       30.3
  A(I)           21.0       20.0       20.8       20.7       20.6
  V(I)           5.26       5.52       5.32       5.35       5.37

X STA.       30.3       33.0       35.7       38.6       42.3       52.5
  A(I)           20.5       20.9       21.7       24.2       38.7
  V(I)           5.38       5.29       5.10       4.57       2.86

X STA.       52.5       80.1      103.5      126.9      150.4      186.4
  A(I)           62.1       40.5       40.2       40.1       47.5
  V(I)           1.78       2.73       2.75       2.76       2.33
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File grot016.wsp
        Hydraulic analysis for structure GROTTH00170016   Date: 25-JUL-97
        TH 17 crossing Wells River, 0.05 miles to junction with US 302, LKS
           *** RUN DATE & TIME: 08-22-97  15:20

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

EXITX:XS   ******    -45      681  0.39 *****  896.83  893.93    2600  896.44
       -54 ******    149    48278  1.71 ***** *******    0.47    3.82

FULLV:FV       55    -46      719  0.35  0.15  896.98 *******    2600  896.64
         0     55    150    51587  1.71  0.00    0.01    0.44    3.62
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       54     -6      532  0.49  0.19  897.24 *******    2600  896.76
        54     54    183    36960  1.31  0.07    0.00    0.59    4.89
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   898.00       0.00     895.96     897.80

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   895.97     897.82     897.99     896.91

 ===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       55      0      310  1.05 *****  897.97  894.10    2544  896.92
         0 ******     39    23166  1.00 ***** *******    0.52    8.21

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.437  0.000  896.91 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    36.  0.04  0.16  898.60    0.00     54.  898.47

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.    25.   -46.   -20.   0.4   0.2   2.8   5.1   0.5   2.7
   RT:     54.    64.   106.   170.   0.7   0.3   2.7   2.5   0.5   2.7

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

APPRO:AS       36    -27      891  0.16  0.16  898.64  894.66    2600  898.48
        54     42    200    73629  1.20  0.15    0.00    0.28    2.92

       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     -55.   -46.   149.   2600.   48278.     681.    3.82  896.44
   FULLV:FV       0.   -47.   150.   2600.   51587.     719.    3.62  896.64
   BRIDG:BR       0.     0.    39.   2544.   23166.     310.    8.21  896.92
   RDWAY:RG       9.*******     0.     54.       0.*********    2.00  898.47
   APPRO:AS      54.   -28.   200.   2600.   73629.     891.    2.92  898.48

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    893.93    0.47  888.36  922.46************  0.39  896.83  896.44
   FULLV:FV  ********    0.44  888.36  922.46  0.15  0.00  0.35  896.98  896.64
   BRIDG:BR    894.10    0.52  887.64  896.92************  1.05  897.97  896.92
   RDWAY:RG  ****************  897.80  921.44  0.04******  0.16  898.60  898.47
   APPRO:AS    894.66    0.28  888.66  918.26  0.16  0.15  0.16  898.64  898.48
```

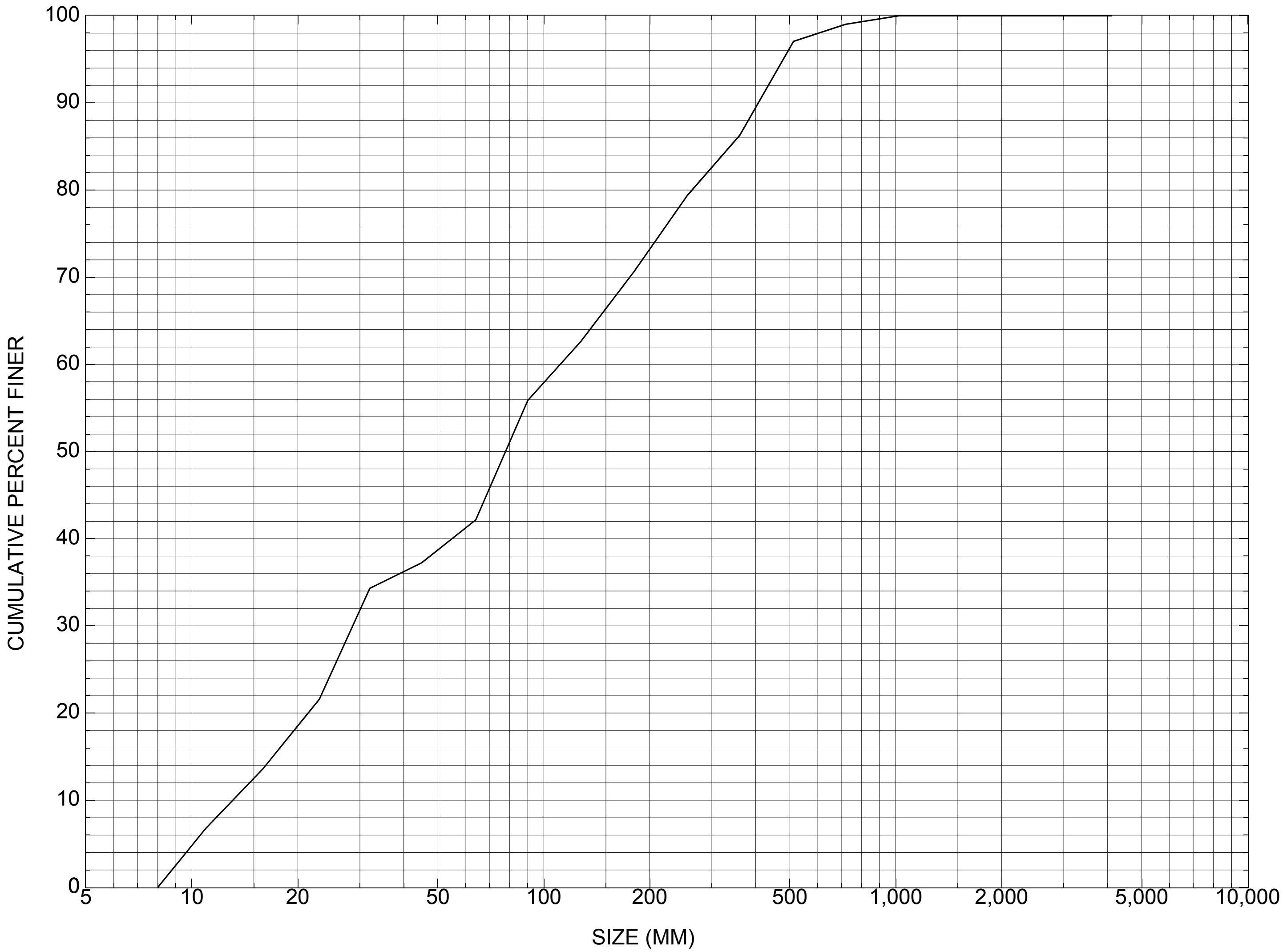
WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File grot016.wsp
       Hydraulic analysis for structure GROTTH00170016   Date: 25-JUL-97
       TH 17 crossing Wells River, 0.05 miles to junction with US 302, LKS
          *** RUN DATE & TIME: 08-22-97  15:20

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

EXITX:XS   ******    -70      898  0.45 *****  897.93  895.24    3500  897.48
       -54 ******    229    64956  1.91 ***** *******    0.50    3.90

FULLV:FV       55    -71      949  0.42  0.15  898.09 *******    3500  897.68
         0     55    230    68504  1.96  0.00    0.01    0.48    3.69
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       54    -18      753  0.41  0.16  898.27 *******    3500  897.86
        54     54    194    58571  1.22  0.00    0.01    0.48    4.65
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   897.68      896.91

            <<<<<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       55      0      310  1.29 *****  898.21  894.47    2819  896.92
         0 ******     39    23166  1.00 ***** *******    0.57    9.10

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  896.91 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.    36.  0.04  0.16  899.83    0.00    687.  899.49

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    44.    36.   -46.   -11.   0.5   0.3   3.1   4.8   0.6   2.7
   RT:   643.   172.    49.   228.   1.7   0.8   4.9   4.6   1.1   3.0

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

APPRO:AS       36    -42     1186  0.16  0.18  899.87  896.43    3500  899.71
        54     46    211   108832  1.18  0.15    0.00    0.26    2.95

       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      -55.   -71.   229.   3500.   64956.     898.    3.90  897.48
   FULLV:FV       0.    -72.   230.   3500.   68504.     949.    3.69  897.68
   BRIDG:BR       0.     0.    39.    2819.   23166.     310.    9.10  896.92
   RDWAY:RG       9.*******    44.    687.        0.*********    2.00  899.49
   APPRO:AS      54.   -43.   211.   3500.  108832.    1186.    2.95  899.71

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF    HO  VHD      EGL     WSEL
   EXITX:XS    895.24     0.50  888.36  922.46************  0.45  897.93  897.48
   FULLV:FV  ********     0.48  888.36  922.46  0.15  0.00  0.42  898.09  897.68
   BRIDG:BR    894.47     0.57  887.64  896.92************  1.29  898.21  896.92
   RDWAY:RG  ****************  897.80  921.44  0.04******  0.16  899.83  899.49
   APPRO:AS    896.43     0.26  888.66  918.26  0.18  0.15  0.16  899.87  899.71
```

```
        U.S. Geological Survey WSPRO Input File grot016.wsp
        Hydraulic analysis for structure GROTTH00170016   Date: 25-JUL-97
        TH 17 crossing Wells River, 0.05 miles to junction with US 302, LKS
           *** RUN DATE & TIME: 08-22-97  15:20

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

EXITX:XS   ******    -44      593  0.36 *****  896.35  893.41    2210  895.98
       -54 ******    146    41008  1.69 ***** *******    0.49    3.73

FULLV:FV       55    -45      630  0.32  0.15  896.50 *******    2210  896.18
         0     55    147    44039  1.70  0.00    0.01    0.45    3.51
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.68

APPRO:AS       54     -5      442  0.53  0.20  896.80 *******    2210  896.28
        54     54    179    29889  1.35  0.10    0.00    0.66    5.00
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

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

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

BRIDG:BR       55      0      262  1.37  0.25  897.05  893.65    2210  895.68
         0     55     39    26323  1.23  0.45    0.00    0.64    8.45

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  0.901 ******  896.91 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.         <<<<<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       36     -8      593  0.28  0.18  897.35  894.09    2210  897.08
        54     41    186    42470  1.28  0.13    0.01    0.43    3.72

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.786  0.281   30390.     6.    46.   896.98

   FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -55.   -45.   146.   2210.   41008.     593.    3.73  895.98
   FULLV:FV       0.   -46.   147.   2210.   44039.     630.    3.51  896.18
   BRIDG:BR       0.     0.    39.   2210.   26323.     262.    8.45  895.68
   RDWAY:RG       9.**************      0.******************    2.00********
   APPRO:AS      54.    -9.   186.   2210.   42470.     593.    3.72  897.08

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       6.    46.   30390.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    893.41    0.49  888.36  922.46************  0.36  896.35  895.98
   FULLV:FV  ********    0.45  888.36  922.46  0.15  0.00  0.32  896.50  896.18
   BRIDG:BR    893.65    0.64  887.64  896.92  0.25  0.45  1.37  897.05  895.68
   RDWAY:RG  ****************  897.80  921.44**********************************
   APPRO:AS    894.09    0.43  888.66  918.26  0.18  0.13  0.28  897.35  897.08
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure GROTTH00170016, in Groton, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number GROTTH00170016

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 24 / 95

Highway District Number *(I - 2; nn)* 07

County *(FIPS county code; I - 3; nnn)* 005

Town *(FIPS place code; I - 4; nnnnn)* 30550

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

Waterway *(I - 6)* WELLS RIVER

Road Name *(I - 7):* -

Route Number TH017

Vicinity *(I - 9)* 0.05 MI JCT TH 17 +US302

Topographic Map Groton

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44132

Longitude *(i - 17; nnnnn.n)* 72132

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10030400160304

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

Maximum span length *(I - 48; nnnn)* 0041

Year built *(I - 27; YYYY)* 1965

Structure length *(I - 49; nnnnnn)* 000043

Average daily traffic, ADT *(I - 29; nnnnnn)* 000050

Deck Width *(I - 52; nn.n)* 182

Year of ADT *(I - 30; YY)* 93

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

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)* 0000

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

Clear span (*nnn.n ft*) 025.0

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

Vertical clearance from streambed (*nnn.n ft*) 006.7

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

Waterway of full opening (*nnn.n ft^2*) 167.5

Comments:

The structural inspection report of 6/29/93 indicates that the structure is a steel stringer type bridge with a concrete deck. The abutments are concrete. The abutments have boulder fill piled on the road embankments at the ends of each abutment in the wingwall areas. There is also some stone fill reported on the upstream and downstream banks. There appears to be some erosion of the bank protection. The abutment footings are not exposed and show no signs of settlement. Point bars and debris accumulation problems are noted as minor at this bridge site.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} - Q_{25} -
Q_{50} - Q_{100} - Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

Are there other structures nearby? (*Yes, No, Unknown*): Y *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*): **0.75** Town: **Groton** Year Built: **1963**
Highway No. : **TH 48** Structure No. : **18** Structure Type: **303**
Clear span (*ft*): **-** Clear Height (*ft*): **10.0** Full Waterway (ft^2): **-**

Comments:
-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **43.45** mi^2 Lake/pond/swamp area **2.04** mi^2
Watershed storage *(ST)* **4.7** %
Bridge site elevation **890** ft Headwater elevation **2369** ft
Main channel length **10.47** mi
10% channel length elevation **950** ft 85% channel length elevation **1634** ft
Main channel slope *(S)* **87.11** ft / mi

Watershed Precipitation Data

Average site precipitation **-** in Average headwater precipitation **-** in

Maximum 2yr-24hr precipitation event *(I24,2)* **-** in

Average seasonal snowfall *(Sn)* **-** ft

Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

There is no benchmark information available.

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

Datum (*NAD27, NAD83, Other*): -

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

If 1: Footing Thickness ______ Footing bottom elevation: ______

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

If 3: Footing bottom elevation: ______

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

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

Briefly describe material at foundation bottom elevation or around piles:

There is no foundation material information available.

Comments:

There are no bridge plans available.

Cross-sectional Data

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

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

Comments: **This is a cross section of the upstream face. The low chord elevation is from the survey log done for this report on 08/29/95. The low chord to bed length data is from the sketch attached to a bridge inspection report dated 06/29/93.**

Station	0	6	12	26	35	39	-	-	-	-	-
Feature	LAB	-	-	-	-	RAB	-	-	-	-	-
Low chord elevation	896.9	896.9	896.9	896.9	896.9	896.9	-	-	-	-	-
Bed elevation	890.8	888.9	887.7	887.9	899.0	890.1	-	-	-	-	-
Low chord-bed	6.1	8	9.2	9	7.9	6.8	-	-	-	-	-

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

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

Comments:

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

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: EW Date: 02/29/96
Computerized by: EW Date: 03/01/96
Reviewd by: LKS Date: 09/29/97

Structure Number GROTTH00170016

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. Ivanoff Date *(MM/DD/YY)* 08 / 29 / 1995
2. Highway District Number 07 Mile marker 0
County Caledonia (005) Town Groton (30550)
Waterway *(I - 6)* The Wells River Road Name Cochran Road
Route Number TH017 Hydrologic Unit Code: 01080102
3. Descriptive comments:
The bridge is located 0.05 miles from the junction with US Route 302.

B. Bridge Deck Observations

4. Surface cover... LBUS 5 RBUS 5 LBDS 6 RBDS 5 Overall 5
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 1 UB 1 DS 1 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 43 *(feet)* Span length 41 *(feet)* Bridge width 18.2 *(feet)*

Road approach to bridge:

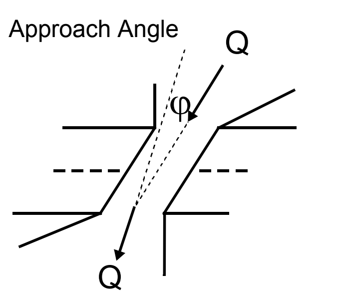
8. LB 2 RB 0 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

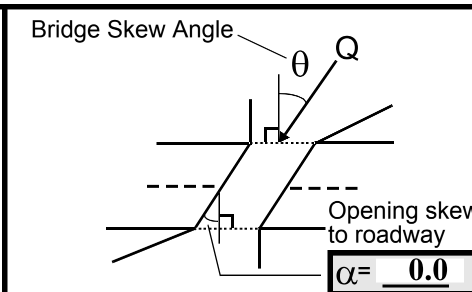
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	3	1	0	0
RBUS	3	1	0	0
RBDS	3	1	2	1
LBDS	3	1	0	0

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

Channel approach to bridge (BF):

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





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

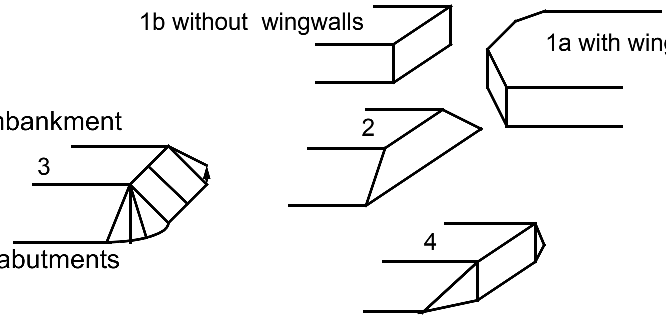
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

#7: The values are from VTAOT; the measured values include: the span length= 40 ft, the bridge length= 43 ft, and the bridge width= 18.2 ft.

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
36.5	**6.5**			**3.5**	**3**	**4**	**543**	**435**	**0**	**0**

23. Bank width **25.0** 24. Channel width **25.0** 25. Thalweg depth **55.0** 29. Bed Material **452**

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

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

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

The right bank protection extends 25 ft from the bridge. The left bank protection extends 210 ft from the bridge.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **145** 35. Mid-bar width: **24**

36. Point bar extent: **75** feet **US** (US, UB) to **162** feet **US** (US, UB, DS) positioned **20** %LB to **100** %RB

37. Material: **453**

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

The point bar has formed at the bend. At the upstream end of the bar is the confluence with the South Branch of the Wells River which overtops the bar.

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

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

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

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

There are no cut-banks upstream at this site.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **15 DS**

47. Scour dimensions: Length **118** Width **33** Depth : **1.7** Position **10** %LB to **90** %RB

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

A scour hole extends from 30 ft upstream to 70 ft downstream.

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

51. Confluence 1: Distance **210** 52. Enters on **RB** (LB or RB) 53. Type **1** (**1**- perennial; **2**- ephemeral)

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

54. Confluence comments (eg. confluence name):

-

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
35.0		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.):

452

-

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 1____ *(1- Low; 2- Moderate; 3- High)*

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

70. Debris and Ice Comments:

1

#67: The banks are lined with small trees and brush. There are no cut-banks.

#68: The capture efficiency of the bridge is low since the bridge opening is 80% of bank-full width upstream.

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	0	0	0	90.0
RABUT	1	0	90			2	0	39.5

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

0

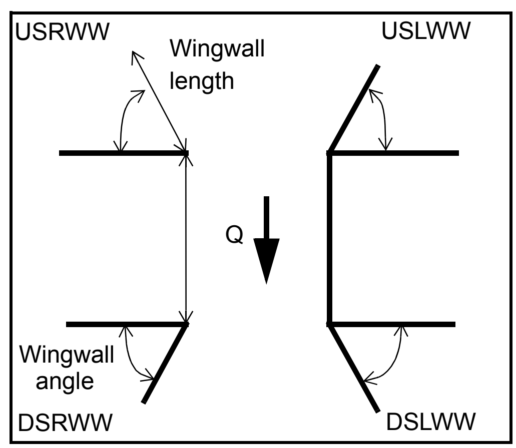
1

Some boulders exist at base of abutment walls. The extensive protection in the road embankment areas is described in the upstream and downstream assessment under bank protection.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						39.5	
USRWW:	N		-		-	2.5	
DSLWW:	-		-		N	18.0	
DSRWW:	-		-		-	18.0	

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	-	-	N	-	-	-	-	-
Condition	N	-	-	-	-	-	-	-
Extent	-	-	-	-	-	-	-	-

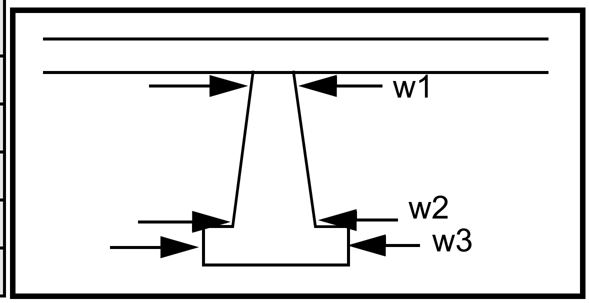
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

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	-	-	-	-	-	-
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e abut-	nding	tec-	and	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	ment	unde	tion.	dow	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	pro-	r	The	nstre	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	tec-	brid	pro-	am	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	tion	ge	tec-	ends	*Y- yes; N- no*
91. Attack ∠ (BF)	con-	from	tion	in	
92. Pushed	sists	bank	is	the	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	of a	/	most	road	
95. Cross-members	few	road	ly at	emb	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	boul-	appr	the	ank-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	ders	oach	upst	ment	
98. Exposure depth	exte	pro-	ream	area	

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

E. Downstream Channel Assessment

100.

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

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

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

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

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

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

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

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

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

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

Material: -

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

-
-
-
-

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

Cut bank extent: are feet no (US, UB, DS) to piers feet . (US, UB, DS)

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

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

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

Scour dimensions: Length ____ Width ____ Depth: 4 Positioned 3 %LB to 453 %RB

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

453
0
0
452

Are there major confluences? 3 (Y or if N type ctrl-n mc) How many? 3

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

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

Confluence comments (eg. confluence name):

protection extends 25 ft from the bridge, while the right bank protection extends 60 ft from the bridge.

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

1- Constructed
2- Stable
3- Aggraded
4- Degraded
5- Laterally unstable
6- Vertically and laterally unstable

108. Evolution comments *(Channel evolution not considering bridge effects; See HEC-20, Figure 1 for geomorphic descriptors)*:

N

-

109. G. Plan View Sketch

T

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number:	GROTTH00170016	Town:	GROTON
Road Number:	TH 17	County:	CALEDONIA
Stream:	WELLS RIVER		

Initials LKS   Date: 08/07/97 Checked: SAO

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	2600	3500	2210
Main Channel Area, ft2	426	493	349
Left overbank area, ft2	16	51	0
Right overbank area, ft2	449	643	245
Top width main channel, ft	55	55	55
Top width L overbank, ft	20	35	2
Top width R overbank, ft	153	164	139
D50 of channel, ft	0.2551	0.2551	0.2551
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.7	9.0	6.3
y1, average depth, LOB, ft	0.8	1.5	0.0
y1, average depth, ROB, ft	2.9	3.9	1.8
Total conveyance, approach	73521	108967	42536
Conveyance, main channel	43676	55825	31340
Conveyance, LOB	243	1201	0
Conveyance, ROB	29602	51941	11195
Percent discrepancy, conveyance	0.0000	0.0000	0.0024
Qm, discharge, MC, cfs	1544.6	1793.1	1628.3
Ql, discharge, LOB, cfs	8.6	38.6	0.0
Qr, discharge, ROB, cfs	1046.8	1668.3	581.6
Vm, mean velocity MC, ft/s	3.6	3.6	4.7
Vl, mean velocity, LOB, ft/s	0.5	0.8	ERR
Vr, mean velocity, ROB, ft/s	2.3	2.6	2.4
Vc-m, crit. velocity, MC, ft/s	10.0	10.2	9.7
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	2600	3500	2210
(Q) discharge thru bridge, cfs	2544	2819	2210
Main channel conveyance	23166	23166	26300
Total conveyance	23166	23166	26300
Q2, bridge MC discharge,cfs	2544	2819	2210
Main channel area, ft2	310	310	262
Main channel width (normal), ft	39.4	39.4	39.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	39.4	39.4	39.4
y_bridge (avg. depth at br.), ft	7.86	7.86	6.64
Dm, median (1.25*D50), ft	0.318875	0.318875	0.318875
y2, depth in contraction,ft	6.11	6.67	5.41
ys, scour depth (y2-ybridge), ft	-1.76	-1.19	**-1.22**

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	2544	2819	2210
Main channel area (DS), ft2	299	309.8	261.5
Main channel width (normal), ft	39.4	39.4	39.4
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	39.4	39.4	39.4
D90, ft	1.3339	1.3339	1.3339
D95, ft	1.5706	1.5706	1.5706
Dc, critical grain size, ft	0.4059	0.4566	0.4270
Pc, Decimal percent coarser than Dc	0.379	0.353	0.369
Depth to armoring, ft	**1.99**	**2.51**	**2.19**

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	2600	3500	2210
Q, thru bridge MC, cfs	2544	2819	2210
Vc, critical velocity, ft/s	10.00	10.25	9.67
Va, velocity MC approach, ft/s	3.63	3.64	4.67
Main channel width (normal), ft	39.4	39.4	39.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	39.4	39.4	39.4
qbr, unit discharge, ft2/s	64.6	71.5	56.1
Area of full opening, ft2	309.8	309.8	261.5
Hb, depth of full opening, ft	7.86	7.86	6.64
Fr, Froude number, bridge MC	0.52	0.57	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	299	N/A	N/A
**Hb, depth at downstream face, ft	7.59	N/A	N/A
**Fr, Froude number at DS face	0.54	ERR	ERR
**Cf, for downstream face (<=1.0)	1.00	N/A	N/A
Elevation of Low Steel, ft	896.61	896.91	0
Elevation of Bed, ft	888.75	889.05	-6.64
Elevation of Approach, ft	898.48	899.71	0
Friction loss, approach, ft	0.16	0.18	0
Elevation of WS immediately US, ft	898.32	899.53	0.00
ya, depth immediately US, ft	9.57	10.48	6.64
Mean elevation of deck, ft	899.66	899.66	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.95	0.93	1.00
**Cc, for downstream face (<=1.0)	0.942557	ERR	ERR
Ys, scour w/Chang equation, ft	**-1.08**	**-0.34**	N/A
Ys, scour w/Umbrell equation, ft	-2.14	-1.68	N/A

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

**Ys, scour w/Chang equation, ft	-0.74	ERR	N/A

**Ys, scour w/Umbrell equation, ft	-1.87	ERR	ERR

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

y2, from Laursen's equation, ft	6.11	6.67	5.41
WSEL at downstream face, ft	896.64	--	--
Depth at downstream face, ft	7.59	N/A	N/A
Ys, depth of scour (Laursen), ft	-1.48	ERR	N/A

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and others, 1995, p. 48, eq. 28)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	2600	3500	2210	2600	3500	2210
a', abut.length blocking flow, ft	27.7	42.6	9	160.3	172	147
Ae, area of blocked flow ft2	58.27	90	24.95	481.55	568.9	288.07
Qe, discharge blocked abut.,cfs	109.79	--	66.74	--	--	749.61
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.88	1.63	2.67	2.42	2.65	2.60
ya, depth of f/p flow, ft	2.10	2.11	2.77	3.00	3.31	1.96
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	1	1	1
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	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	0.229	0.188	0.283	0.241	0.230	0.328
ys, scour depth, ft	**7.99**	**8.41**	**7.61**	18.83	20.06	16.38

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)	27.7	42.6	9	160.3	172	147
y1 (depth f/p flow, ft)	2.10	2.11	2.77	3.00	3.31	1.96
a'/y1	13.17	20.16	3.25	53.36	52.00	75.01
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.23	0.19	0.28	0.24	0.23	0.33
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	**13.66**	**14.81**	**9.86**
vertical w/ ww's	ERR	ERR	ERR	11.20	12.14	8.09
spill-through	ERR	ERR	ERR	7.51	8.15	5.42

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	0.54	0.57	0.64	0.54	0.57	0.64
y, depth of flow in bridge, ft	7.59	7.86	6.64	7.59	7.86	6.64
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	**1.37**	**1.58**	**1.68**	**1.37**	**1.58**	**1.68**
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR