LEVEL II SCOUR ANALYSIS FOR BRIDGE 18 (GROTTH00480018) on TOWN HIGHWAY 48, crossing the WELLS RIVER, GROTON, VERMONT

U.S. Geological Survey
Open-File Report 97-626

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

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By LORA K. STRIKER AND LAURA MEDALIE

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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 18 (GROTTH00480018) ON TOWN HIGHWAY 48, CROSSING WELLS RIVER, GROTON, VERMONT

By Lora K. Striker and Laura Medalie

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure GROTTH00480018 on Town Highway 48 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 53.6-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 right bank upstream and the left bank downstream while the surface cover is shrub and brushland along the left bank upstream and the right bank downstream. The immediate banks are vegetated with brush and scattered trees.

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 69 ft and an average bank height of 7 ft. The channel bed material ranges from sand to cobble with a median grain size (D_{50}) of 66.7 mm (0.219 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 28, 1995, indicated that the reach was stable.

The Town Highway 48 crossing of the Wells River is a 38-ft-long, one-lane bridge consisting of one 36-foot steel-beam span (Vermont Agency of Transportation, written communication, March 24, 1995). The opening length of the structure parallel to the bridge face is 33.7 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 0 degrees to the opening and the opening-skew-to-roadway is also 0 degrees.

Local scour 3.25 ft deeper than the mean thalweg depth was observed underneath the bridge along the left and right abutments during the Level I assessment. In addition, a scour hole extends from 90 ft US to 50 ft DS for a total length of 115 ft with an average scour depth of 2.0 ft. The only scour protection measure at the site was type-2 stone fill (less than 36 inches diameter) along the left bank upstream, along the entire base length of the downstream right wingwall, and along the left and right banks downstream; and type-1 stone fill (less than 12 inches diameter) along the entire base length of the upstream left wingwall. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995) 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 0.0 ft. Abutment scour ranged from 2.0 to 2.3 ft at the left abutment and 8.8 to 14.6 ft at the right abutment. The worst-case abutment scour occurred at the 500-year discharge at the right abutment. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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 GROTTH00480018 ***Stream*** Wells River

County Caledonia ***Road*** TH 48 ***District*** 7

Description of Bridge

Bridge length 38 ***ft*** ***Bridge width*** 13.1 ***ft*** ***Max span length*** 36 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 08/28/95

Description of stone fill Type-1, along the entire base length of the upstream left wingwall, and type-2 along the entire base length of the downstream right wingwall.

Brief description of piers/abutments Abutments and wingwalls are concrete. The upstream right wingwall is concrete for the first 10 feet and then piled granite blocks for another 10 feet. The LABUT and RABUT are undermined slightly.

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

Is bridge located on a bend in channel? If so, describe (mild, moderate, severe)

Debris accumulation on bridge at time of Level I or Level II site visit:

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	08/28/95	0	0
Level II	08/28/95	0	0

Potential for debris Low. There are some trees leaning into the channel upstream.

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

None, 08/28/95

.

Description of the Geomorphic Setting

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

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

Date of inspection 08/28/95

DS left: Steep channel bank to a narrow floodplain

DS right: Steep channel bank to a narrow floodplain

US left: Steep channel bank with natural levee to irregular overbank

US right: Steep channel bank with natural levee to a narrow flood plain

Description of the Channel

Average top width 69 *ft* ***Average depth*** 7 *ft*

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

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

08/28/95

Vegetative co Brush on the immediate banks with a pasture overbank

DS left: Brush

DS right: Brush

US left: Brush with a few trees with a pasture overbank

US right:

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

None, 08/28/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 53.6 ***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 current year. The flow of Wells River is partly regulated by Groton and Ricker Ponds. Ricker Pond is located 2.5 miles upstream of this site.

Calculated Discharges

Q100 3,700 ***ft³/s*** ***Q500*** 5,100 ***ft³/s***

The 100- and 500-year discharges were taken directly from FEMA discharge estimates below the confluence of the North Branch of the Wells River. A drainage area estimate from FEMA for this location, located 0.3 miles upstream of the bridge site, is not available. Therefore, the discharges were used directly since there is no significant contribution to the flow within this distance. The discharges used are within range of several empirical methods. (Benson, 1962; Johnson and Tasker, 1974; FEMA, 1991; FHWA, 1983; Potter, 1957a&b; Talbot, 1887)

Description of the Water-Surface Profile Model (WSPRO) Analysis

Datum for WSPRO analysis (USGS survey, sea level, VTAOT plans) USGS survey

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the right abutment (elev. 499.42 ft, arbitrary survey datum). RM2 is a chiseled square on top of the downstream end of the left abutment (elev. 498.62ft, arbitrary survey datum). RM2 is RM30 from FEMA (elev. 805.71 ft, NGVD of 1929).

Cross-Sections Used in WSPRO Analysis

[1]Cross-section	*Section Reference Distance (SRD) in feet*	*[2]Cross-section development*	*Comments*
EXITX	-41	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	50	2	Approach section as surveyed

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.055, and overbank "n" values ranged from 0.040 to 0.070.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0028 ft/ft, which was estimated from the 500-year water surface elevation downstream of the bridge site (Federal Emergency Management Agency, 1991).

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

Bridge Hydraulics Summary

Average bridge embankment elevation 500.4 *ft*
Average low steel elevation 497.4 *ft*

100-year discharge 3,700 *ft³/s*
Water-surface elevation in bridge opening 497.5 *ft*
Road overtopping? Y *Discharge over road* 1,100 *ft³/s*
Area of flow in bridge opening 343 *ft²*
Average velocity in bridge opening 7.6 *ft/s*
Maximum WSPRO tube velocity at bridge 9.0 *ft/s*

Water-surface elevation at Approach section with bridge 498.6
Water-surface elevation at Approach section without bridge 496.9
Amount of backwater caused by bridge 1.7 *ft*

500-year discharge 5,100 *ft³/s*
Water-surface elevation in bridge opening 497.5 *ft*
Road overtopping? Y *Discharge over road* 2200 */s*
Area of flow in bridge opening 343 *ft²*
Average velocity in bridge opening 8.4 *ft/s*
Maximum WSPRO tube velocity at bridge 10.0 */s*

Water-surface elevation at Approach section with bridge 499.3
Water-surface elevation at Approach section without bridge 497.6
Amount of backwater caused by bridge 1.7 *ft*

Incipient overtopping discharge 2,630 *ft³/s*
Water-surface elevation in bridge opening 495.8 *ft*
Area of flow in bridge opening 288 *ft²*
Average velocity in bridge opening 9.1 *ft/s*
Maximum WSPRO tube velocity at bridge 11.5 *ft/s*

Water-surface elevation at Approach section with bridge 496.9
Water-surface elevation at Approach section without bridge 496.3
Amount of backwater caused by bridge 0.6 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

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 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 100-year discharge which resulted in unsubmerged orifice flow, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions are provided in Appendix F.

Scour at the abutments was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. Variables for the Hire equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	0.0
Depth to armoring	0.4	0.6	1.4
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	2.3	2.0	2.2
Right abutment	13.1	14.6	8.8
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(D_{50} in feet)		
Abutments:			
Left abutment	1.2	1.4	1.6
Right abutment	1.2	1.4	1.6
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

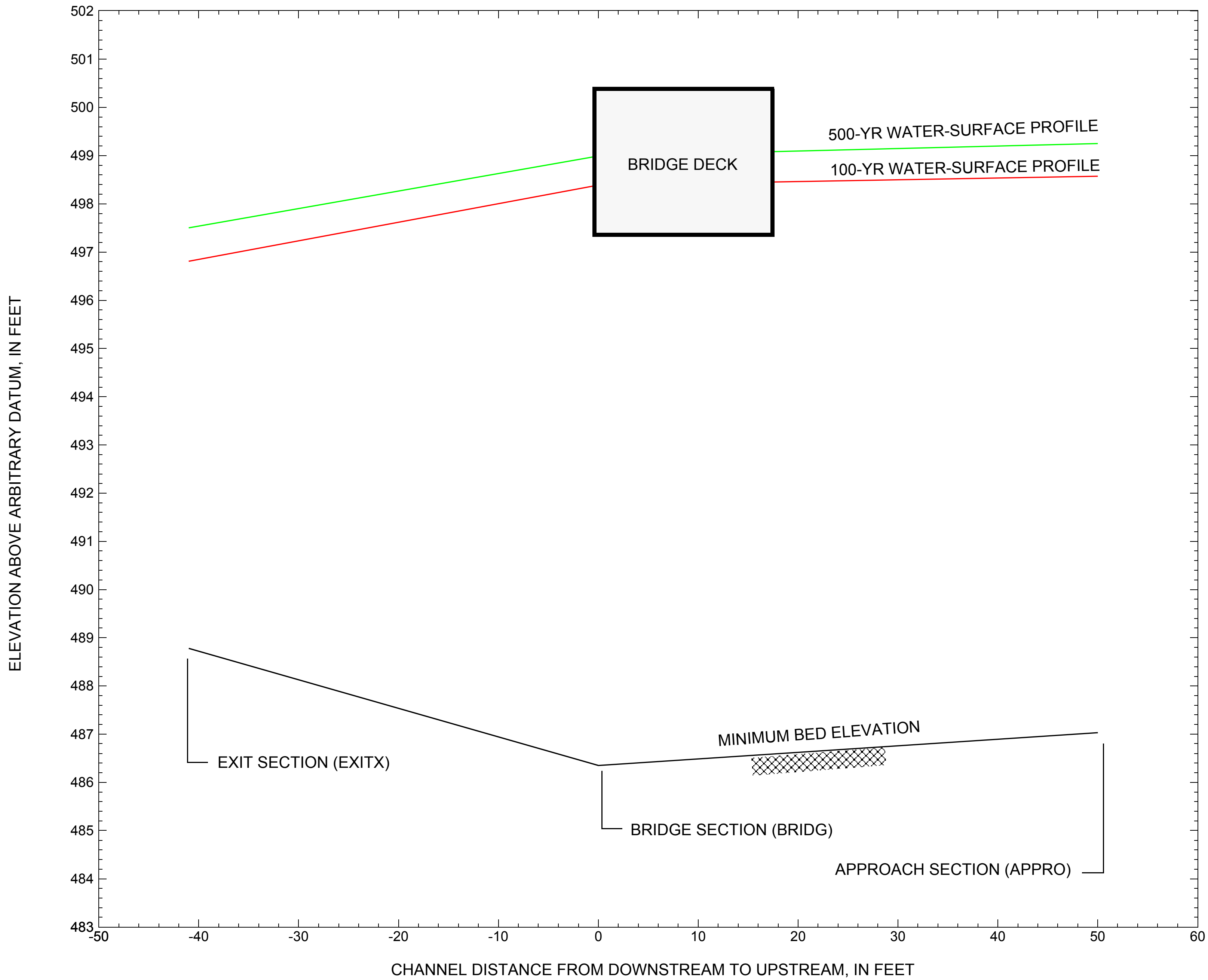

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure GROTTH00480018 on Town Highway 48, crossing Wells River, Groton, Vermont.

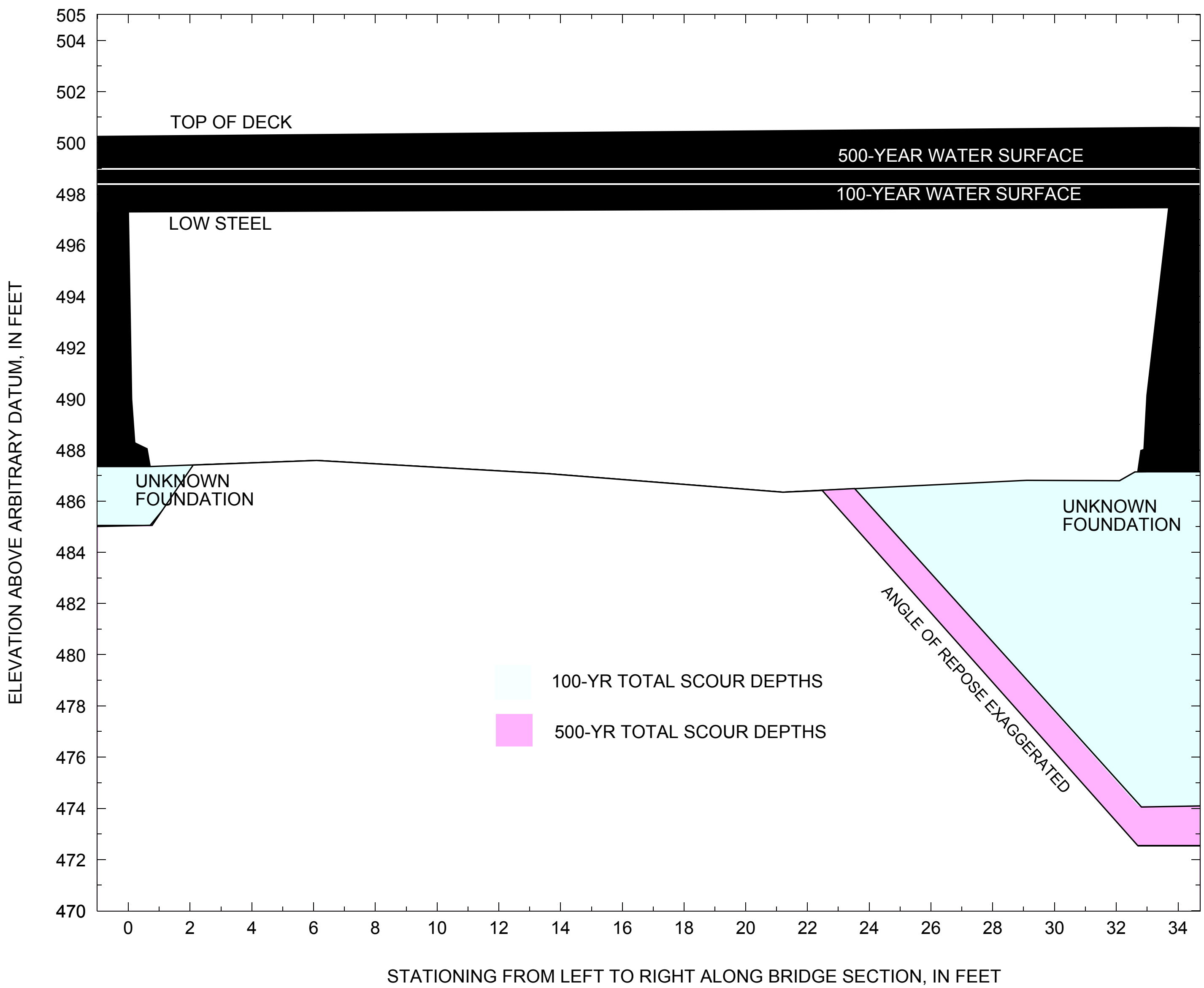

Figure 8. Scour elevations for the 100-year and 500-year discharges at structure GROTTH00480018 on Town Highway 48, crossing Wells River, Groton, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure GROTTH00480018 on Town Highway 48, 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 3,700 cubic-feet per second											
Left abutment	0.0	--	497.3	--	487.3	0.0	2.3	--	2.3	485.0	--
Right abutment	33.7	--	497.5	--	487.2	0.0	13.1	--	13.1	474.1	--

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 GROTTH00480018 on Town Highway 48, 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 5,100 cubic-feet per second											
Left abutment	0.0	--	497.3	--	487.3	0.0	2.0	--	2.0	485.3	--
Right abutment	33.7	--	497.5	--	487.2	0.0	14.6	--	14.6	472.6	--

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

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T1        U.S. Geological Survey WSPRO Input File grot018.wsp
T2        Hydraulic analysis for structure GROTTH00480018   Date: 25-JUL-97
T3        TH 48 over the Wells River 0.1 miles to junction with US Route 302, LK
*
J1          *  *  0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3700.0   5100.0  2630.0
SK          0.0028   0.0028  0.0028
*
XS   EXITX    -41           0.
GR         -279.7, 501.02   -199.5, 497.04   -158.6, 496.29
GR         -152.3, 494.79   -102.2, 494.49     -8.3, 495.69      0.0, 492.69
GR            2.3, 490.01      4.2, 489.30     12.3, 489.19     17.4, 488.78
GR           38.1, 489.31     54.9, 489.90     57.5, 490.48     58.8, 492.04
GR           67.5, 495.66    210.2, 494.80    267.7, 506.83    371.2, 510.35
*
N           0.040        0.050        0.060
SA                  -8.3         67.5
*
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    497.39       0.0
GR            0.0, 497.30      0.1, 489.99      0.2, 488.28      0.6, 487.34
GR            0.7, 488.05      6.1, 487.59     13.6, 487.07     21.2, 486.35
GR           29.1, 486.81     32.1, 486.80     32.6, 487.14     32.7, 487.15
GR           32.8, 487.98     32.9, 488.02     33.0, 490.14     33.7, 497.47
GR            0.0, 497.30
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD          1      25.6 * *     55.5      7.6
N           0.040
*
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      8      13.1     2
GR         -282.8, 501.12
GR         -216.0, 497.51   -149.2, 496.65    -81.3, 497.02     -1.9, 499.79
GR           -1.8, 500.26     34.6, 500.60
GR           34.7, 500.04     94.4, 498.52    145.6, 498.33    185.9, 499.39
GR          250.1, 503.28    331.4, 509.38    401.6, 513.33    458.3, 514.78
GR          479.7, 518.38
*
*
AS   APPRO     50           0.
GR          -265.5, 501.16   -253.8, 499.34  -126.0, 495.63
GR          -61.9, 497.20     -7.8, 499.18      0.0, 494.11      3.2, 490.53
GR            7.6, 490.06      8.5, 487.10     13.2, 487.03     17.5, 487.88
GR           29.1, 487.96     40.3, 488.04     42.3, 488.52     44.5, 490.04
GR           49.9, 493.46     50.1, 495.75     53.1, 496.60     67.7, 495.92
GR          150.2, 495.27    186.9, 498.40    405.0, 513.73
*
N           0.070        0.055        0.040
SA                  -7.8         53.1
*
HP 1 BRIDG   497.47 1 497.47
HP 2 BRIDG   497.47 * * 2602
HP 1 BRIDG   496.96 1 496.96
HP 2 RDWAY   498.39 * * 1104
HP 1 APPRO   498.57 1 498.57
HP 2 APPRO   498.57 * * 3700
*
HP 1 BRIDG   497.47 1 497.47
HP 2 BRIDG   497.47 * * 2890
HP 2 RDWAY   498.99 * * 2200
HP 2 RDWAY   499.25 * * 2200
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File grot018.wsp
        Hydraulic analysis for structure GROTTH00480018   Date: 25-JUL-97
        TH 48 over the Wells River 0.1 miles to junction with US Route 302, LK
           *** RUN DATE & TIME: 08-05-97  09:40
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1     343     31832     0     87                             0
   497.47          343     31832     0     87  1.00      0     34         0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.47     0.0    33.7   342.8   31832.    2602.   7.59
X STA.         0.0         3.3         5.3         7.0         8.7        10.3
  A(I)            30.3        19.2        16.8        16.7        15.9
  V(I)            4.30        6.76        7.74        7.80        8.18

X STA.        10.3        11.8        13.3        14.8        16.2        17.6
  A(I)            15.5        15.1        15.1        14.9        14.6
  V(I)            8.40        8.61        8.60        8.75        8.91

X STA.        17.6        18.9        20.3        21.6        22.9        24.3
  A(I)            14.5        14.6        14.5        14.7        14.9
  V(I)            9.00        8.89        9.00        8.87        8.76

X STA.        24.3        25.7        27.1        28.7        30.4        33.7
  A(I)            15.1        15.7        16.7        18.7        29.5
  V(I)            8.63        8.31        7.79        6.96        4.41

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1     328     41529    34     53                          5824
   496.96          328     41529    34     53  1.00      0     34      5824

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.39  -232.3   147.9   227.7    9523.    1104.   4.85
X STA.      -232.3      -205.2      -193.2      -183.4      -175.2      -167.9
  A(I)            17.4        13.1        12.1        11.1        10.6
  V(I)            3.17        4.20        4.54        4.96        5.21

X STA.      -167.9      -161.2      -155.2      -149.6      -144.1      -138.5
  A(I)            10.2         9.8         9.5         9.5         9.4
  V(I)            5.39        5.64        5.81        5.78        5.88

X STA.      -138.5      -132.8      -126.8      -120.7      -114.4      -107.7
  A(I)             9.6         9.7         9.8         9.7        10.3
  V(I)            5.74        5.67        5.61        5.67        5.34

X STA.      -107.7      -100.6       -93.1       -85.0       -75.0       147.9
  A(I)            10.6        10.8        11.5        12.9        19.6
  V(I)            5.19        5.09        4.79        4.26        2.82

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      50.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1     313      8879   203    203                          2203
             2     510     52517    60     69                          8448
             3     343     23635   136    136                          3089
   498.57         1166     85030   399    408  1.49   -226    189      9254

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      50.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.57  -227.3   189.3  1166.0   85030.    3700.   3.17

X STA.      -227.3      -124.5       -68.7         6.6        11.1        14.3
  A(I)           153.2       123.8        98.7        47.4        36.9
  V(I)            1.21        1.49        1.87        3.90        5.02

X STA.        14.3        17.6        20.9        24.2        27.4        30.7
  A(I)            36.5        35.3        34.8        34.3        34.2
  V(I)            5.07        5.24        5.32        5.39        5.40

X STA.        30.7        34.0        37.3        40.8        45.3        68.6
  A(I)            35.1        35.0        36.6        43.2        74.1
  V(I)            5.28        5.29        5.06        4.28        2.50

X STA.        68.6        89.9       109.7       127.9       145.9       189.3
  A(I)            58.4        57.4        55.7        57.6        77.9
  V(I)            3.17        3.23        3.32        3.21        2.38
```

```
        U.S. Geological Survey WSPRO Input File grot018.wsp
        Hydraulic analysis for structure GROTTH00480018   Date: 25-JUL-97
        TH 48 over the Wells River 0.1 miles to junction with US Route 302, LK
           *** RUN DATE & TIME: 08-05-97  09:40
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      343     31832      0     87                            0
  497.47            343     31832      0     87  1.00      0     34        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.47     0.0    33.7   342.8   31832.    2890.   8.43
X STA.         0.0         3.3         5.3         7.0         8.7        10.3
  A(I)            30.3        19.2        16.8        16.7        15.9
  V(I)            4.78        7.51        8.59        8.67        9.08

X STA.        10.3        11.8        13.3        14.8        16.2        17.6
  A(I)            15.5        15.1        15.1        14.9        14.6
  V(I)            9.33        9.56        9.55        9.72        9.89

X STA.        17.6        18.9        20.3        21.6        22.9        24.3
  A(I)            14.5        14.6        14.5        14.7        14.9
  V(I)            9.99        9.87        9.99        9.85        9.73

X STA.        24.3        25.7        27.1        28.7        30.4        33.7
  A(I)            15.1        15.7        16.7        18.7        29.5
  V(I)            9.58        9.23        8.66        7.73        4.90

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.99  -243.4   170.7   391.3   18419.    2200.   5.62
X STA.      -243.4      -210.9      -198.7      -188.3      -179.0      -170.9
  A(I)            28.0        19.8        18.4        17.6        16.3
  V(I)            3.92        5.56        5.96        6.25        6.76

X STA.      -170.9      -163.4      -156.3      -149.7      -143.3      -136.6
  A(I)            15.8        15.7        15.1        14.9        15.2
  V(I)            6.96        7.03        7.27        7.37        7.25

X STA.      -136.6      -129.9      -123.0      -115.8      -108.4      -100.5
  A(I)            15.2        15.4        15.6        15.8        16.6
  V(I)            7.25        7.15        7.05        6.96        6.64

X STA.      -100.5       -92.2       -83.2       -72.4       -54.4       170.7
  A(I)            17.1        18.0        19.9        24.2        56.8
  V(I)            6.43        6.11        5.53        4.55        1.94

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      50.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      465     15243    243    243                         3648
             2      551     59120     61     70                         9416
             3      439     34050    146    146                         4321
  499.25           1455    108413    450    459  1.50   -250    199    12141

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      50.

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.25  -250.7   199.0  1455.2  108413.    5100.   3.50
X STA.      -250.7      -138.2       -99.7         1.3         8.9        12.8
  A(I)           183.7       128.7       180.7        68.3        47.6
  V(I)            1.39        1.98        1.41        3.73        5.36

X STA.        12.8        16.6        20.4        24.2        27.9        31.6
  A(I)            45.5        42.6        42.8        42.2        42.1
  V(I)            5.60        5.98        5.96        6.04        6.06

X STA.        31.6        35.4        39.2        43.6        60.4        80.7
  A(I)            42.1        43.3        47.7        79.4        67.0
  V(I)            6.06        5.88        5.35        3.21        3.80

X STA.        80.7        98.4       116.2       132.9       150.0       199.0
  A(I)            62.1        65.0        62.7        66.9        94.7
  V(I)            4.11        3.92        4.06        3.81        2.69
```

```
        U.S. Geological Survey WSPRO Input File grot018.wsp
        Hydraulic analysis for structure GROTTH00480018   Date: 25-JUL-97
        TH 48 over the Wells River 0.1 miles to junction with US Route 302, LK
           *** RUN DATE & TIME: 08-05-97  09:40
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      288     34392     34     50                         4787
   495.75           288     34392     34     50  1.00      0     34     4787

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.75     0.0    33.5   287.8   34392.    2630.   9.14
X STA.         0.0         3.7         5.7         7.6         9.2        10.8
  A(I)            28.1        16.7        14.8        13.8        13.0
  V(I)            4.68        7.89        8.86        9.56       10.09

X STA.        10.8        12.2        13.6        15.0        16.3        17.6
  A(I)            12.6        12.0        12.1        11.9        11.7
  V(I)           10.43       10.94       10.91       11.09       11.29

X STA.        17.6        18.9        20.1        21.4        22.6        23.9
  A(I)            11.4        11.5        11.8        11.7        11.9
  V(I)           11.54       11.39       11.12       11.21       11.08

X STA.        23.9        25.3        26.7        28.3        30.1        33.5
  A(I)            12.4        12.9        14.3        16.1        27.3
  V(I)           10.64       10.19        9.22        8.18        4.82

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      50.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       64      1016     98     98                          291
             2      414     38186     57     66                         6308
             3      136      5617    117    117                          834
   496.93           614     44819    272    280  1.40   -170    170     4422

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      50.

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.93  -170.8   169.7   613.7   44819.    2630.   4.29
X STA.      -170.8         4.1         8.8        11.2        13.4        15.6
  A(I)            90.5        33.2        23.8        21.9        21.4
  V(I)            1.45        3.96        5.54        6.01        6.14

X STA.        15.6        17.9        20.2        22.4        24.7        26.9
  A(I)            21.1        20.4        20.5        20.2        20.2
  V(I)            6.22        6.46        6.42        6.50        6.52

X STA.        26.9        29.2        31.5        33.8        36.2        38.6
  A(I)            20.5        20.4        20.6        21.3        22.0
  V(I)            6.43        6.44        6.38        6.18        5.97

X STA.        38.6        41.3        44.9        89.6       127.3       169.7
  A(I)            23.3        28.5        61.7        50.1        52.1
  V(I)            5.64        4.61        2.13        2.62        2.52
```

```
        U.S. Geological Survey WSPRO Input File grot018.wsp
        Hydraulic analysis for structure GROTTH00480018   Date: 25-JUL-97
        TH 48 over the Wells River 0.1 miles to junction with US Route 302, LK
           *** RUN DATE & TIME: 08-05-97  09:40

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******   -186     1000  0.32 *****  497.13  495.57    3700  496.81
       -40 ******    220    69918  1.51 ***** *******    0.51    3.70

FULLV:FV       41   -194     1062  0.28  0.11  497.24 *******    3700  496.96
         0     41    221    75000  1.49  0.00    0.01    0.47    3.48
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.85    496.90     494.36

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   496.46     513.73    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   496.46     513.73     494.36

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.59

APPRO:AS       50   -169      605  0.81  0.21  497.71  494.36    3700  496.90
        50     50    169    44229  1.39  0.26    0.00    0.85    6.12
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   498.66       0.00     496.10     496.65

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   496.64     497.89     498.03     497.39

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

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

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
BRIDG:BR       41      0      343  0.90 *****  498.37  492.85    2602  497.47
         0 ******     34    31832  1.00 ***** *******    0.42    7.59

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.375  0.000  497.39 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    37.  0.07  0.23  498.73    0.00   1104.  498.39

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1093.   190.  -232.   -42.   1.7   1.2   5.6   4.8   1.5   3.0
   RT:     11.    18.   130.   148.   0.1   0.0   2.4  21.2   0.4   2.6

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
APPRO:AS       24   -226     1166  0.23  0.12  498.80  494.36    3700  498.57
        50     33    189    85055  1.49  0.15    0.00    0.40    3.17

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL   WSEL
   EXITX:XS     -41.  -187.   220.   3700.   69918.    1000.    3.70  496.81
   FULLV:FV       0.  -195.   221.   3700.   75000.    1062.    3.48  496.96
   BRIDG:BR       0.     0.    34.   2602.   31832.     343.    7.59  497.47
   RDWAY:RG       8.******* 1093.    1104.*********       0.    2.00  498.39
   APPRO:AS      50.  -227.   189.   3700.   85055.    1166.    3.17  498.57

  SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    495.57    0.51  488.78  510.35************  0.32  497.13  496.81
   FULLV:FV  ********    0.47  488.78  510.35  0.11  0.00  0.28  497.24  496.96
   BRIDG:BR    492.85    0.42  486.35  497.47************  0.90  498.37  497.47
   RDWAY:RG  ****************  496.65  518.38  0.07******  0.23  498.73  498.39
   APPRO:AS    494.36    0.40  487.03  513.73  0.12  0.15  0.23  498.80  498.57
```

```
        U.S. Geological Survey WSPRO Input File grot018.wsp
        Hydraulic analysis for structure GROTTH00480018   Date: 25-JUL-97
        TH 48 over the Wells River 0.1 miles to junction with US Route 302, LK
           *** RUN DATE & TIME: 08-05-97  09:40

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
EXITX:XS   ******   -208     1293  0.34 *****  497.84  496.27    5100  497.50
       -40 ******    223    96339  1.42 ***** *******    0.48    3.95

FULLV:FV       41   -211     1357  0.31  0.11  497.95 *******    5100  497.65
         0     41    224   102746  1.40  0.00    0.00    0.44    3.76
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.86    497.55     497.13

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   497.15     513.73    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   497.15     513.73     497.13

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.56

APPRO:AS       50   -191      799  0.93  0.22  498.48  497.13    5100  497.55
        50     50    177    57486  1.46  0.31    0.00    0.86    6.38
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   497.65     497.39

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

 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL
BRIDG:BR       41      0      343  1.11 *****  498.58  493.28    2890  497.47
         0 ******     34    31832  1.00 ***** *******    0.47    8.43

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  497.39 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    37.  0.08  0.29  499.45    0.00   2200.  498.99

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1970.   218.  -243.   -25.   2.3   1.6   6.6   5.6   2.1   3.0
   RT:    230.    94.    76.   171.   0.7   0.4   4.0   5.6   0.9   2.8
 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

APPRO:AS       24   -250     1455  0.29  0.16  499.54  497.13    5100  499.25
        50     35    199   108374  1.50  0.15    0.00    0.42    3.51


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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -41.  -209.   223.   5100.    96339.    1293.    3.95  497.50
   FULLV:FV       0.  -212.   224.   5100.  102746.    1357.    3.76  497.65
   BRIDG:BR       0.     0.    34.   2890.    31832.     343.    8.43  497.47
   RDWAY:RG       8.*******  1970.   2200.******************    2.00  498.99
   APPRO:AS      50.  -251.   199.   5100.  108374.    1455.    3.51  499.25

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    496.27    0.48  488.78  510.35************  0.34  497.84  497.50
   FULLV:FV  ********    0.44  488.78  510.35  0.11  0.00  0.31  497.95  497.65
   BRIDG:BR    493.28    0.47  486.35  497.47************  1.11  498.58  497.47
   RDWAY:RG ****************  496.65  518.38  0.08******  0.29  499.45  498.99
   APPRO:AS    497.13    0.42  487.03  513.73  0.16  0.15  0.29  499.54  499.25
```

1

WSPRO OUTPUT FILE (continued)

```
       U.S. Geological Survey WSPRO Input File grot018.wsp
       Hydraulic analysis for structure GROTTH00480018   Date: 25-JUL-97
       TH 48 over the Wells River 0.1 miles to junction with US Route 302, LK
          *** RUN DATE & TIME: 08-05-97  09:40

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

 EXITX:XS   ******   -157      736  0.30 *****  496.43  493.47    2630  496.12
        -40 ******    217    49682  1.53 ***** *******    0.56    3.57

 FULLV:FV       41   -158      791  0.26  0.11  496.53 *******    2630  496.27
          0     41    217    53851  1.52  0.00    0.00    0.50    3.32
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  0.65

 APPRO:AS       50   -146      452  0.66  0.18  496.91 *******    2630  496.25
         50     50    162    35109  1.24  0.20    0.00    0.77    5.82
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
            WS1,WSSD,WS3,RGMIN =   496.93       0.00     495.75     496.65

  ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

  ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                    WS,QBO,QRD =   496.91      2630.         0.

  ===280 REJECTED FLOW CLASS 4 SOLUTION.

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

  ===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                         YU/Z,WSIU,WS = 1.07     498.06     498.12

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

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

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

 BRIDG:BR       41      0      288  1.30  0.17  497.05  492.91    2630  495.75
          0     41     34    34374  1.00  0.45    0.00    0.55    9.14

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        1. ****   1.  1.000 ******  497.39 ****** ****** ******

     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       24   -170      615  0.40  0.14  497.33  493.19    2630  496.93
         50     30    170    44870  1.40  0.15    0.00    0.59    4.28

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.891  0.213   35273.     8.    41.   496.81

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

   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXITX:XS     -41.  -158.   217.   2630.   49682.     736.    3.57  496.12
    FULLV:FV       0.  -159.   217.   2630.   53851.     791.    3.32  496.27
    BRIDG:BR       0.     0.    34.   2630.   34374.     288.    9.14  495.75
    RDWAY:RG       8.**************      0.       0.       0.    2.00********
    APPRO:AS      50.  -171.   170.   2630.   44870.     615.    4.28  496.93

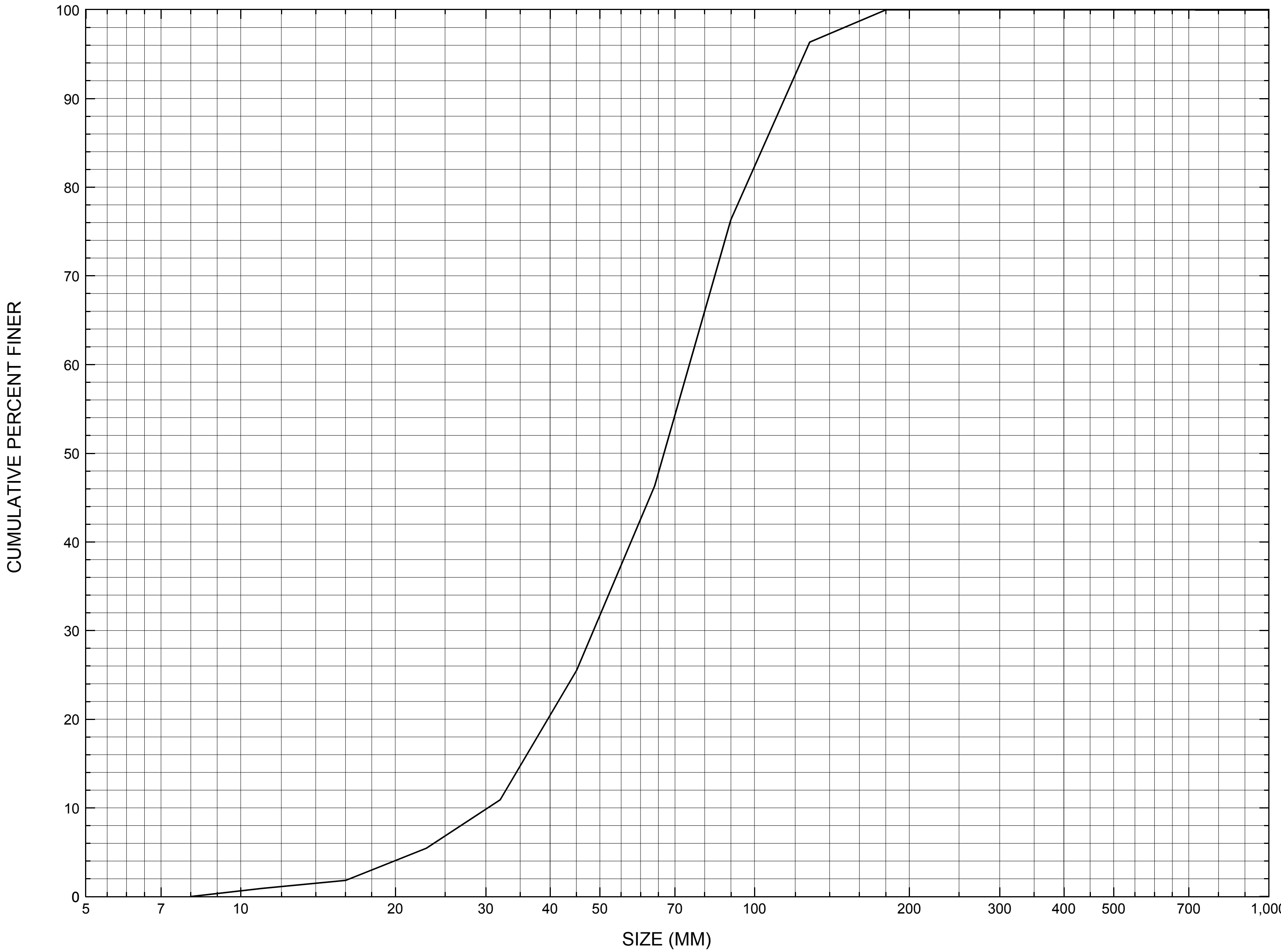
     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS       8.    41.   35273.

  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
    EXITX:XS    493.47    0.56  488.78  510.35************  0.30  496.43  496.12
    FULLV:FV  ********    0.50  488.78  510.35  0.11  0.00  0.26  496.53  496.27
    BRIDG:BR    492.91    0.55  486.35  497.47  0.17  0.45  1.30  497.05  495.75
    RDWAY:RG  ***************  496.65  518.38************  0.16  498.24********
    APPRO:AS    493.19    0.59  487.03  513.73  0.14  0.15  0.40  497.33  496.93
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure GROTTH00480018, in Groton, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number GROTTH00480018

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 TH048

Vicinity *(I - 9)* 0.1 MI JCT TH 48 + US302

Topographic Map Groton

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44128

Longitude *(i - 17; nnnnn.n)* 72126

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10030400180304

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

Maximum span length *(I - 48; nnnn)* 0036

Year built *(I - 27; YYYY)* 1963

Structure length *(I - 49; nnnnnn)* 000038

Average daily traffic, ADT *(I - 29; nnnnnn)* 000020

Deck Width *(I - 52; nn.n)* 131

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

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

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

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

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

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

Structure type *(I - 43; nnn)* 303

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 010.0

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

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

Comments:

The structural inspection report of 6/29/93 indicates that the structure is a steel girder and floor beam system type bridge with a concrete deck and an asphalt roadway surface. The abutment walls and wingwalls are concrete. The wingwalls are extended with “laid-up” stone block walls. The report indicates the channel is scoured 2 to 3.5 feet below the water surface at each abutment footing. Both footings are exposed, but not undermined and no settlement is reported. The channel banks are reported as showing evidence of erosion from previous flooding. Point bars and debris accumulation are reported as minor at this bridge site.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **53.65** mi^2

Lake/pond/swamp area **2.08** mi^2

Watershed storage *(ST)* **3.9** %

Bridge site elevation **800** ft

Headwater elevation **2369** ft

Main channel length **11.34** mi

10% channel length elevation **900** ft

85% channel length elevation **1595** ft

Main channel slope *(S)* **81.72** 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 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 08/28/95. The low chord to bed length data is from the sketch attached to a bridge inspection report dated 06/29/93.**

Station	0	2	19	30.6	32.6	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	497.3	497.3	497.4	497.5	497.5	-	-	-	-	-	-
Bed elevation	-	486.4	486.3	488.0	-	-	-	-	-	-	-
Low chord-bed	-	10.9	11.1	9.5	-	-	-	-	-	-	-

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: 02/29/96
Reviewd by: LKS Date: 08/05/97

Structure Number GROTTH00480018

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* L. MEDALIE Date *(MM/DD/YY)* 08 / 28 / 1996
2. Highway District Number 07 Mile marker 0
County CALENDONIA 005 Town GROTON
Waterway *(I - 6)* WELLS RIVER Road Name WELTON ROAD
Route Number TH048 Hydrologic Unit Code: 01080102
3. Descriptive comments:
The bridge is located 0.1 miles from the junction with US Route 302.

B. Bridge Deck Observations

4. Surface cover... LBUS 5 RBUS 4 LBDS 4 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 38.0 *(feet)* Span length 36.0 *(feet)* Bridge width 13.1 *(feet)*

Road approach to bridge:

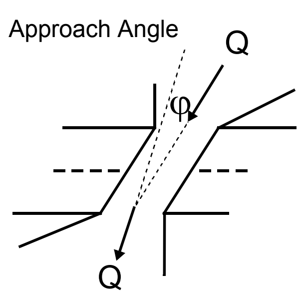
8. LB 1 RB 1 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

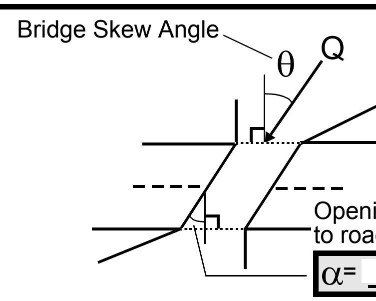
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	2	-

*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



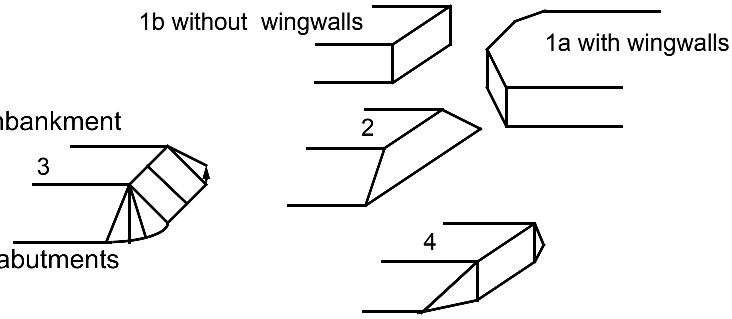


Opening skew to roadway
α= 0.0

17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 65 feet US *(US, UB, DS)* to 0 feet DS
Channel impact zone 2: Exist? N *(Y or N)*
Where? ____ *(LB, RB)* Severity ____
Range? ____ feet ____ *(US, UB, DS)* to ____ feet ____
*Impact Severity: **0**- none to very slight; **1**- Slight; **2**- Moderate; **3**- Severe*

18. Bridge Type: **1a**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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: Field measurements of bridge; measured span= 34.5 feet; bridge length= 38.5; bridge width= 15 feet; bridge width= 13 feet (between the curbs).

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
34.5	**8.5**			**8.0**	**4**	**2**	**54**	**34**	**1**	**1**

23. Bank width **35.0** 24. Channel width **35.0** 25. Thalweg depth **61.0** 29. Bed Material **3**

30 .Bank protection type: LB **2** RB **0** 31. Bank protection condition: LB **1** 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.):

#26: RB two large trees between US bridge face and 90 feet US
#30: LB protection extends from US bridge face to 95 feet US

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

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

37. Material: -

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

There are no pointbars upstream at this site.
US from where channel scour begins (US 90 feet), the series of alternating cobble/gravel side bars between LB and RB terminates. The bridge deck photo looking US clearly shows this feature.

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.
Note: There are some leaning trees US in the bridge deck photo of US.

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

47. Scour dimensions: Length **90** Width **34.5** Depth : **2** Position **15** %LB to **20** %RB

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

Scour begins 90 feet US and continues under bridge to 50 feet DS. The total length of the scour hole is 155 feet. The mid-scour distance is located at the US bridge face.

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

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

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

54. Confluence comments (eg. confluence name):

There are no major confluences upstream at this site.

D. Under Bridge Channel Assessment

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

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
39.0		**2.0**		**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.):

3

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

Although the debris potential is noted as low, there are some trees US leaning into the stream.

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	3	3.25	1.25	90.0
RABUT	1	0	90			2	3	32.5

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

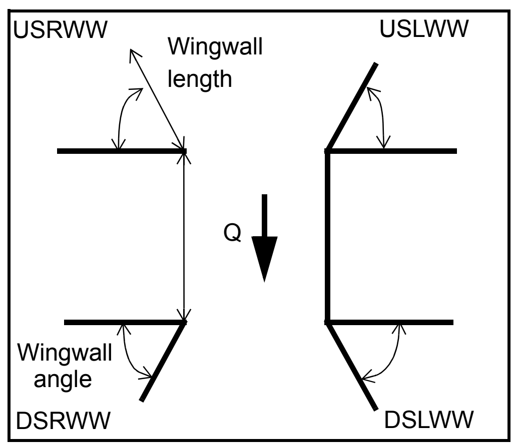
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

3.25
1.25
1
RABUT: the footing is undermined at the US end (at the suture between WW and abutment).
LABUT: the footing is undermined at the US end (at the suture between WW and abutment).
The undermining of both abutments is minimal. The bottom of the footing is exposed about 2 feet on the left and right abutment.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						32.5	
USRWW:	Y		1		2	3.5	
DSLWW:	2		0.75		Y	17.0	
DSRWW:	1/2		3		3.25	17.0	

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	1.25	2	Y	0	1	-	-	-
Condition	Y	2	1/2	0	1	-	-	-
Extent	1/2	0.75	1	1	0	0	0	0

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

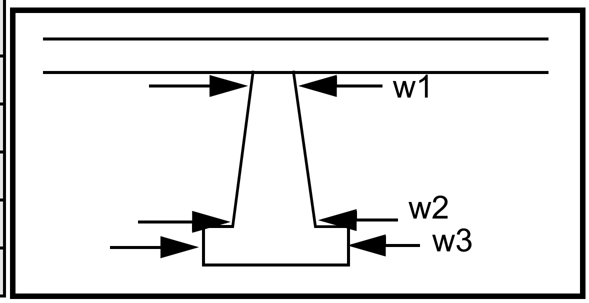
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
0
-
-
0
-
-
2
1
1

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1		8.0		55.0	55.0	18.5
Pier 2				60.0	14.0	60.0
Pier 3		-	-	11.0	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	RWW:	for	5 feet	expose	LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP
87. Type	con-	anot	of	d.	**1**- Solid pier, **2**- column, **3**- bent
88. Material	crete	her	wing	DSR	**1**- Wood; **2**- concrete; **3**- metal; **4**- stone
89. Shape	first	10	wall.	WW	**1**- Round; **2**- Square; **3**- Pointed
90. Inclined?	10	feet.	The	and	Y- yes; N- no
91. Attack ∠ (BF)	feet,	The	entir	DSL	
92. Pushed	then	foot-	e	WW	LB or RB
93. Length (feet)	-	-	-	-	
94. # of piles	piled	ing	lengt	:	
95. Cross-members	gran	exist	h of	con-	**0**- none; **1**- laterals; **2**- diagonals; **3**- both
96. Scour Condition	ite	s for	the	crete	**0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed
97. Scour depth	bloc	the	foot-	for	
98. Exposure depth	ks	first	ing is	first	

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

6 feet, then dry quarried granite blocks for at least 10 feet. At the stream end of both DSRWW and DSLWW - top exposed of concrete footing.

N

E. Downstream Channel Assessment

100.

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

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

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

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

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

-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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

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

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

-
-
-
-
-
-

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

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

Material: __-__

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

-
-
-
-

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

Cut bank extent: __no__ feet __pie__ *(US, UB, DS)* to __rs at__ feet __this__ *(US, UB, DS)*

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

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

dge.

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

Scour dimensions: Length ______ Width ______ Depth: _____ Positioned ____ %LB to __3__ %RB

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

3
2/4
2/4
1

Are there major confluences? __1__ *(Y or if N type ctrl-n mc)* How many? __3/2/4__

Confluence 1: Distance __2__ Enters on __2__ *(LB or RB)* Type __1__ *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance __1__ Enters on __Ban__ *(LB or RB)* Type __k__ *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

material: sand layer on top of cobble layer (base).
LB protection starts at end of dry masonry end of LB DSWW to beyond 200 feet DS.

F. Geomorphic Channel Assessment

107. Stage of reach evolution __RB__

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)*:

protection starts at end of dry masonry end of RB DSWW to beyond 30 feet DS.

The protection on the left and right bank downstream consists of dumped quarried stone.

109. **G. Plan View Sketch** - N

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: GROTTH00480018 Town: GROTON
Road Number: TH 48 County: CALEDONIA
Stream: WELLS RIVER

Initials LKS Date: 08/01/97 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	3700	5100	2630
Main Channel Area, ft2	510	551	414
Left overbank area, ft2	313	465	64
Right overbank area, ft2	343	439	136
Top width main channel, ft	60	61	57
Top width L overbank, ft	203	243	98
Top width R overbank, ft	136	146	117
D50 of channel, ft	0.21883	0.21883	0.21883
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.5	9.0	7.3
y1, average depth, LOB, ft	1.5	1.9	0.7
y1, average depth, ROB, ft	2.5	3.0	1.2
Total conveyance, approach	85030	108413	44819
Conveyance, main channel	52517	59120	38186
Conveyance, LOB	8879	15243	1016
Conveyance, ROB	23635	34050	5617
Percent discrepancy, conveyance	-0.0012	0.0000	0.0000
Qm, discharge, MC, cfs	2285.2	2781.1	2240.8
Ql, discharge, LOB, cfs	386.4	717.1	59.6
Qr, discharge, ROB, cfs	1028.5	1601.8	329.6
Vm, mean velocity MC, ft/s	4.5	5.0	5.4
Vl, mean velocity, LOB, ft/s	1.2	1.5	0.9
Vr, mean velocity, ROB, ft/s	3.0	3.6	2.4
Vc-m, crit. velocity, MC, ft/s	9.7	9.7	9.4
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	3700	5100	2630
(Q) discharge thru bridge, cfs	2602	2890	2630
Main channel conveyance	31832	31832	34392
Total conveyance	31832	31832	34392
Q2, bridge MC discharge,cfs	2602	2890	2630
Main channel area, ft2	343	343	288
Main channel width (normal), ft	33.7	33.7	33.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	33.7	33.7	33.5
y_bridge (avg. depth at br.), ft	10.17	10.17	8.59
Dm, median (1.25*D50), ft	0.273538	0.273538	0.273538
y2, depth in contraction,ft	7.44	8.14	7.55
ys, scour depth (y2-ybridge), ft	-2.73	-2.03	-1.05

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	2602	2890	2630
Main channel area (DS), ft2	328	342.8	287.8
Main channel width (normal), ft	33.7	33.7	33.5
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	33.7	33.7	33.5
D90, ft	0.3754	0.3754	0.3754
D95, ft	0.4100	0.4100	0.4100
Dc, critical grain size, ft	0.1916	0.2131	0.2656
Pc, Decimal percent coarser than Dc	0.591	0.523	0.357
Depth to armoring, ft	0.40	0.58	1.43

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	3700	5100	2630
Q, thru bridge MC, cfs	2602	2890	2630
Vc, critical velocity, ft/s	9.65	9.75	9.40
Va, velocity MC approach, ft/s	4.48	5.05	5.41
Main channel width (normal), ft	33.7	33.7	33.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	33.7	33.7	33.5
qbr, unit discharge, ft2/s	77.2	85.8	78.5
Area of full opening, ft2	342.8	342.8	287.8
Hb, depth of full opening, ft	10.17	10.17	8.59
Fr, Froude number, bridge MC	0.42	0.47	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	328	N/A	N/A
**Hb, depth at downstream face, ft	9.73	N/A	N/A
**Fr, Froude number at DS face	0.45	ERR	ERR
**Cf, for downstream face (<=1.0)	1.00	N/A	N/A
Elevation of Low Steel, ft	497.39	497.39	0
Elevation of Bed, ft	487.22	487.22	-8.59
Elevation of Approach, ft	498.57	499.25	0
Friction loss, approach, ft	0.12	0.16	0
Elevation of WS immediately US, ft	498.45	499.09	0.00
ya, depth immediately US, ft	11.23	11.87	8.59
Mean elevation of deck, ft	500.43	500.43	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.98	0.96	1.00
**Cc, for downstream face (<=1.0)	0.965079	ERR	ERR
Ys, scour w/Chang equation, ft	-1.97	-1.03	N/A
Ys, scour w/Umbrell equation, ft	-2.38	-1.38	N/A

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

**Ys, scour w/Chang equation, ft	-1.44	N/A	N/A

**Ys, scour w/Umbrell equation, ft	-1.94	N/A	ERR

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

y2, from Laursen's equation, ft	7.44	8.14	7.55
WSEL at downstream face, ft	496.96	--	--
Depth at downstream face, ft	9.73	N/A	N/A
Ys, depth of scour (Laursen), ft	-2.29	N/A	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)

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	3700	5100	2630	3700	5100	2630
a', abut.length blocking flow, ft	227.3	250.7	170.8	155.6	165.3	136.2
Ae, area of blocked flow ft2	146.4	142.8	88.38	492.1	564.3	261.69
Qe, discharge blocked abut.,cfs	--	--	128.42	--	--	937.65
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.47	1.55	1.45	3.37	3.96	3.58
ya, depth of f/p flow, ft	0.64	0.57	0.52	3.16	3.41	1.92
--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	0.204	0.195	0.356	0.332	0.364	0.456
ys, scour depth, ft	6.31	5.93	6.73	19.21	21.61	15.75

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)	227.3	250.7	170.8	155.6	165.3	136.2
y1 (depth f/p flow, ft)	0.64	0.57	0.52	3.16	3.41	1.92
a'/y1	352.90	440.13	330.08	49.20	48.42	70.89
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.20	0.20	0.36	0.33	0.36	0.46
Ys w/ corr. factor K1/0.55:						
vertical	2.77	2.42	2.68	15.99	17.79	10.78
vertical w/ ww's	2.27	1.98	2.19	13.11	14.59	8.84
spill-through	1.52	1.33	1.47	8.79	9.78	5.93

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	0.45	0.47	0.55	0.45	0.47	0.55
y, depth of flow in bridge, ft	9.73	10.17	8.59	9.73	10.17	8.59
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.22	1.39	1.61	1.22	1.39	1.61
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	1.06	1.21	1.40	1.06	1.21	1.40
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR