LEVEL II SCOUR ANALYSIS FOR BRIDGE 38 (CONCTH00060038) on TOWN HIGHWAY 6, crossing the MOOSE RIVER, CONCORD, VERMONT

U.S. Geological Survey
Open-File Report 96-744

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

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By SCOTT A. OLSON

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Pembroke, New Hampshire

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U.S. DEPARTMENT OF THE INTERIOR
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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 38 (CONCTH00060038) ON TOWN HIGHWAY 6, CROSSING THE MOOSE RIVER, CONCORD, VERMONT

By **Scott A. Olson**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CONCTH00060038 on Town Highway 6 crossing the Moose River, Concord, 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.

Approximately 85 percent of the drainage above the site is in the White Mountain section and 15 percent is in the New England Upland section of the New England physiographic province in northeastern Vermont. The 98.4-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover of the banks is primarily forest and brush.

In the study area, the Moose River has an incised, sinuous channel with a slope of approximately 0.009 ft/ft, an average channel top width of 110 ft and an average channel depth of 6 ft. The channel bed material ranged from gravel to boulder and had a median grain size (D_{50}) of 74.4 mm (0.244 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 17, 1995, indicated that the reach was stable.

The Town Highway 6 crossing of the Moose River is a 59-ft-long, two-lane bridge consisting of one 55-foot steel-beam span (Vermont Agency of Transportation, written communication, March 24, 1995). The bridge is supported by a vertical, laid-up stone abutment with wingwalls on the left and a vertical, concrete abutment with wingwalls on the right. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is 0 degrees.

The footing of the left abutment is exposed as much as 2.8 feet. The footing of the right abutment is undermined vertically by as much as 0.3 feet. Type-2 stone-fill (less than 36 inches diameter) protection can be found along the left abutment. Type-3 stone-fill (less than 48 inches diameter) protection can be found along the right abutment. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.1 to 3.1 ft. The worst-case contraction scour occurred at the incipient-overtopping discharge. Abutment scour at the left abutment ranged from 10.4 to 12.5 ft with the worst-case occurring at the 500-year discharge. Abutment scour at the right abutment ranged from 25.3 to 27.3 ft with the worst-case occurring at the incipient-overtopping discharge. The worst-case total scour also occurred at the incipient-overtopping discharge. The incipient-overtopping discharge was in between the 100- and 500-year discharges. 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.

Concord, VT. Quadrangle, 1:24,000, 1967
Photoinspected 1988

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 CONCTH00060038 **_Stream_** Moose River

County Essex **_Road_** TH6 **_District_** 7

Description of Bridge

Bridge length 59 **_ft_** **_Bridge width_** 23.2 **_ft_** **_Max span length_** 55 **_ft_**

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

Abutment type Stone, lt; concrete, rt **_Embankment type_** Sloping

Stone fill on abutment? Yes **_Date of inspection_** 8/17/95

Description of stone fill Type-2 along left abutment and all four wingwalls. Type-3 along right abutment.

Brief description of piers/abutments Left abutment is constructed of laid-up stone with a concrete cap. The right abutment is concrete. The footing of both abutments are exposed. The footing of the right abutment is undermined by as much as 0.3 ft.

Is bridge skewed to flood flow according to Y **_survey?_** Y **_Angle_** 10

If so, describe (mild, moderate, severe) There are mild channel bends through the reach.

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

	Date of inspection	_Percent of channel blocked horizontally_	_Percent of channel blocked vertically_
Level I	8/17/95	0	0
Level II	8/17/95	0	0

Potential for debris Low.

Describe any features near or at the bridge that may affect flow (include observation date) No significant feature. August 17, 1995.

Description of the Geomorphic Setting

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

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

Date of inspection 8/17/95

DS left: Narrow, irregular terrace.

DS right: Narrow, irregular flood plain and high terrace.

US left: Narrow, irregular terrace.

US right: Narrow, irregular flood plain and high terrace.

Description of the Channel

Average top width 110 *ft* ***Average depth*** 6 *ft*

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

Sinuous but stable with semi-alluvial to non-alluvial channel boundaries.

8/17/95

Vegetative co Forested with a gravel roadway on the overbank.

DS left: Brush and tree with a gravel roadway and a building on the overbank.

DS right: Brush and tree covered with a gravel roadway on the overbank.

US left: Brush and tree covered with a gravel roadway on the overbank.

US right:

Do banks appear stable? Y ***If not, describe location and type of instability and date of observation.*** August 17, 1995

None, August 17, 1995.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 98.4 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/New England Upland	15
New England/White Mountain	85

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 Moose River at Victory and St. Johnsbury

USGS gage number 01134500 and 01135000

Gage drainage area 75.2/128 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 5,910 ***ft³/s*** ***Q500*** 7,530 ***ft³/s***

The 100- and 500-year discharges are interpolated from the 100- and 500-year discharges determined for the upstream (01134500, Moose River at Victory) and downstream (01135000, Moose River at St. Johnsbury) gages. The 100- and 500- year discharges at the gages were developed using a log-Pearson type-III analysis of annual peak-flow data (Interagency Advisory Committee on Water Data, 1982).

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 the center of a chiseled square on top of the upstream rail above the left abutment (elev. 901.75 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the right abutment (elev. 896.61 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	-62	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	13	1	Road Grade section
APPRO	85	2	Modelled Approach section (Templated from APTEM)
APTEM	97	1	Approach section as surveyed (Used as a template)

[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 0.035 to 0.066.

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 0.00913 ft/ft which was measured from the 100-year water-surface profile downstream of the bridge in the Flood Insurance Study for the Town of Concord (Federal Emergency Management Agency, 1992).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.00913 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

For the incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. Analyzing both the supercritical and subcritical profiles and noting that the depth in the bridge converged onto critical depth at a lower discharge than the incipient road-overflow discharge, it can be determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 897.6 ***ft***
Average low steel elevation 894.4 ***ft***

100-year discharge 5,910 ***ft³/s***
Water-surface elevation in bridge opening 889.7 ***ft***
Road overtopping? N ***Discharge over road*** 0 ***s***
Area of flow in bridge opening 399 ***ft²***
Average velocity in bridge opening 14.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 18.2 ***ft/s***

Water-surface elevation at Approach section with bridge 893.7
Water-surface elevation at Approach section without bridge 891.9
Amount of backwater caused by bridge 1.8 ***t***

500-year discharge 7,530 ***ft³/s***
Water-surface elevation in bridge opening 895.1 ***ft***
Road overtopping? Y ***Discharge over road*** 896.6 ***/s***
Area of flow in bridge opening 649 ***ft²***
Average velocity in bridge opening 10.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.7 ***/s***

Water-surface elevation at Approach section with bridge 896.7
Water-surface elevation at Approach section without bridge 893.1
Amount of backwater caused by bridge 3.6

Incipient overtopping discharge 6,730 ***ft³/s***
Water-surface elevation in bridge opening 890.1 ***ft***
Area of flow in bridge opening 420 ***ft²***
Average velocity in bridge opening 16.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 19.6 ***ft/s***

Water-surface elevation at Approach section with bridge 894.7
Water-surface elevation at Approach section without bridge 892.5
Amount of backwater caused by bridge 2.2 ***t***

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 100-year and incipient roadway overtopping discharge was computed by use of Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). The 500-year discharge resulted in unsubmerged 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 the 500-year event was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146) The results of Laursen's clear-water contraction scour for the 500-year event were also computed and can be found in appendix F.

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	2.4	0.1	3.1
Depth to armoring	N/A	2.2	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour	10.4	12.5	11.4
Left abutment	25.3	25.7	27.3
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3			

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:	3.1	2.0	3.4
Left abutment	3.1	2.0	3.4
Right abutment	--	--	--
Piers:	--	--	--
Pier 1	--	--	--
Pier 2			

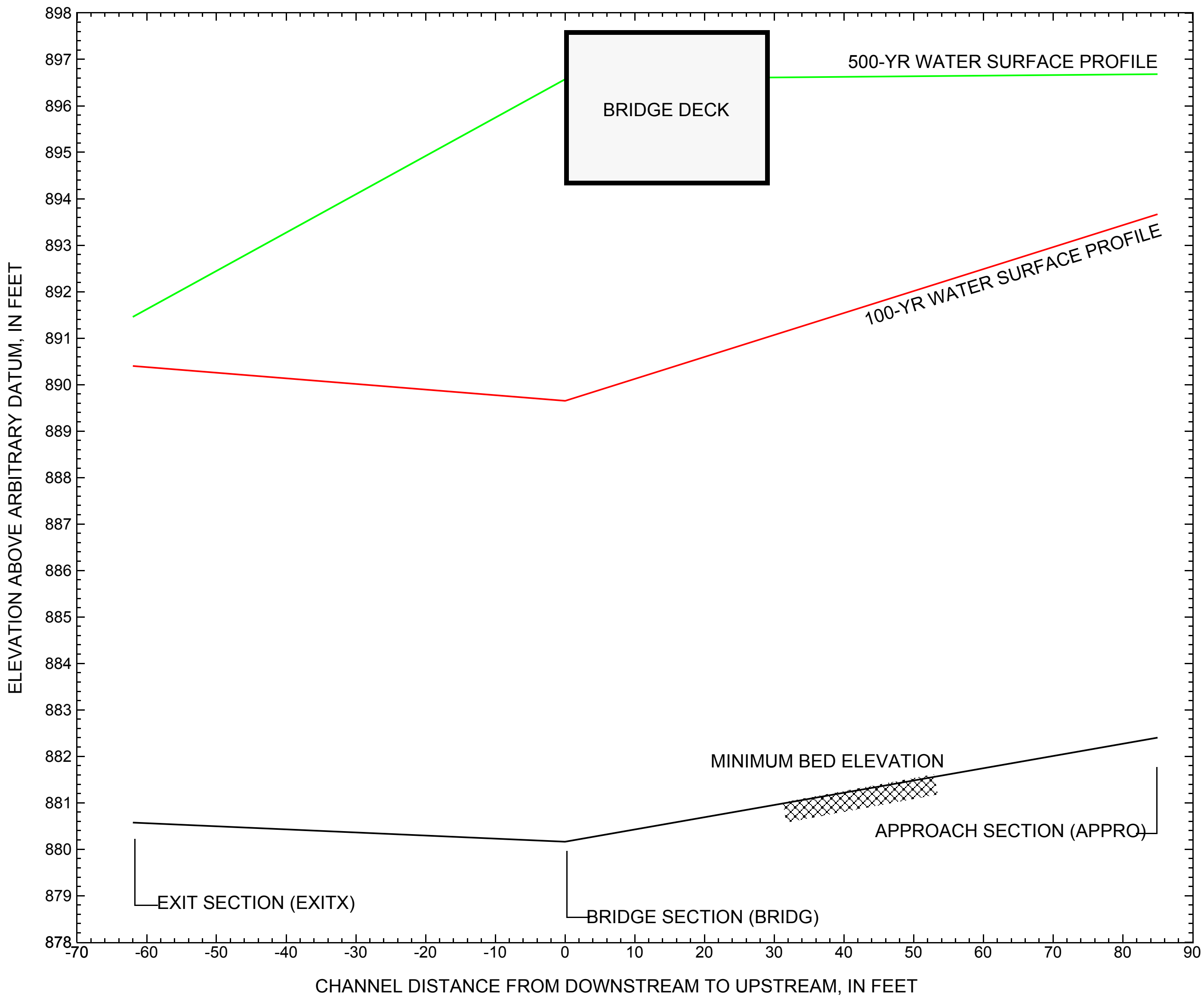

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CONCTH00060038 on Town Highway 6, crossing the Moose River, Concord, Vermont.

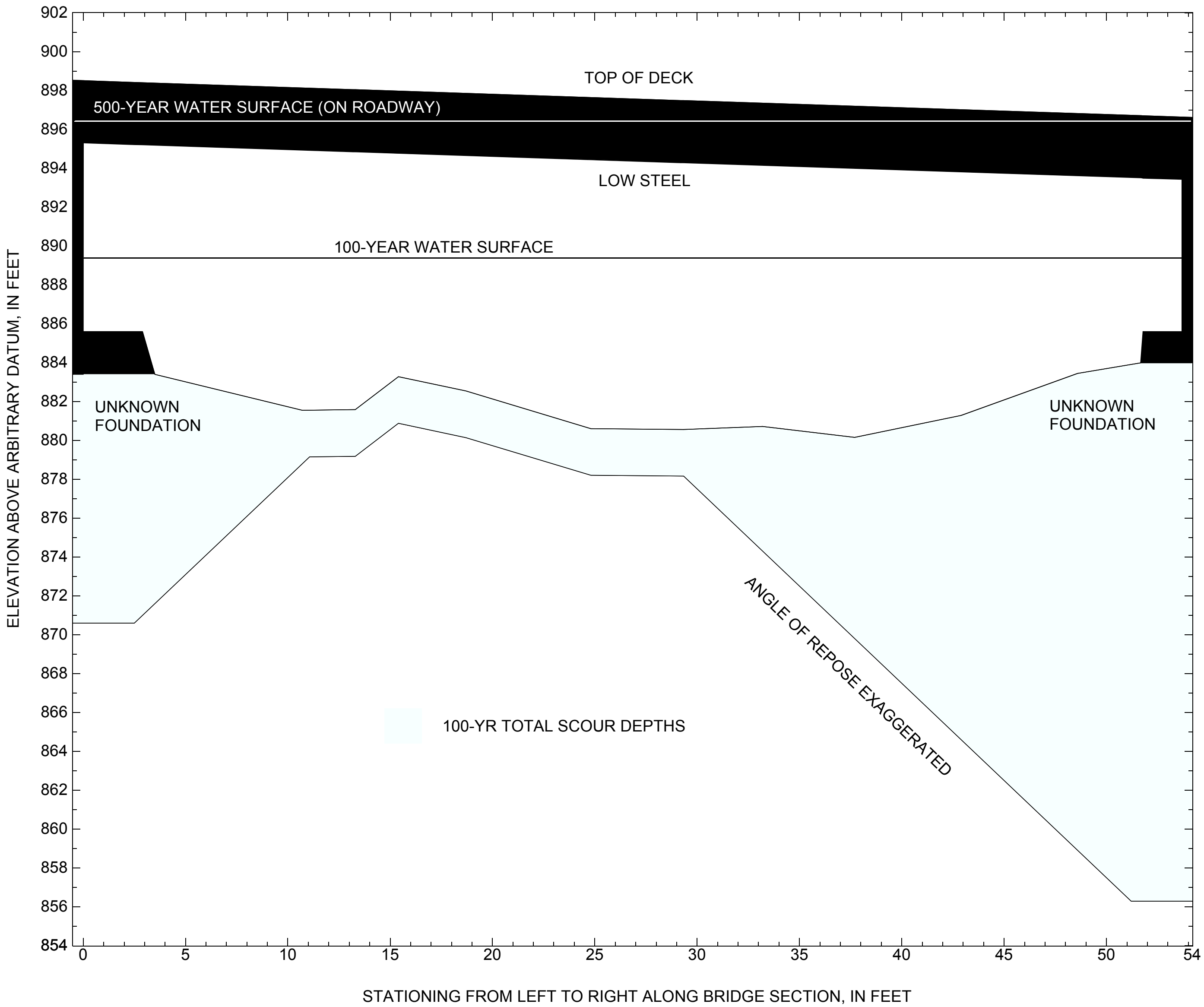

Figure 8. Scour elevations for the 100-yr discharge at structure CONCTH00060038 on Town Highway 6, crossing the Moose River, Concord, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CONCTH00060038 on Town Highway 6, crossing the Moose River, Concord, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 5,910 cubic-feet per second											
Left abutment	0.0	--	895.31	--	883.4	2.4	10.4	--	12.8	870.6	--
Right abutment	53.7	--	893.44	--	884.0	2.4	25.3	--	27.7	856.3	--

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 CONCTH00060038 on Town Highway 6, crossing the Moose River, Concord, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 7,530 cubic-feet per second											
Left abutment	0.0	--	895.31	--	883.4	0.1	12.5	--	12.6	870.8	--
Right abutment	53.7	--	893.44	--	884.0	0.1	25.7	--	25.8	858.2	--

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

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U.S. Geological Survey, 1967, Concord, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1988, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

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T1        U.S. Geological Survey WSPRO Input File conc038.wsp
T2        Hydraulic analysis for structure CONCTH00060038   Date: 24-JUN-96
T3        Hydraulic Analysis of CONC038 over the Moose River   SAO
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           5910 7530 6730
SK          0.00913 0.00913 0.00913
*
XS   EXITX    -62
GR          -79.9, 909.75    -70.8, 904.04    -28.4, 902.02     -7.2, 889.43
GR           -4.2, 886.76      1.4, 885.42      5.0, 883.30     13.2, 880.57
GR           21.2, 881.24     36.2, 881.02     49.7, 882.29     65.0, 883.41
GR           77.8, 889.24    127.8, 890.18    157.0, 895.67    226.3, 906.71
N           0.035        0.055        0.066
SA                 -28.4        77.8
*
XS   FULLV      0
*
BR   BRIDG     0 894.4
GR            0.0, 895.31      1.6, 885.60      2.9, 885.61      3.5, 883.40
GR           10.7, 881.56     13.3, 881.59     15.4, 883.28     18.7, 882.55
GR           24.8, 880.61     29.2, 880.57     33.2, 880.72     37.7, 880.16
GR           42.9, 881.29     48.6, 883.45     51.7, 884.01     51.8, 885.55
GR           53.1, 885.59     53.7, 893.44      0.0, 895.31
N            0.045
CD           1 40 * * 48 8
*
XR   RDWAY     13 23 2
GR          -91.9, 909.46    -82.2, 903.64    -63.1, 903.95    -55.9, 899.09
GR          -37.8, 899.51     -2.4, 898.19     -2.3, 901.72     -0.8, 901.81
GR           53.6, 900.12     55.5, 899.99     56.4, 896.98     56.5, 896.24
GR          109.7, 895.00    173.5, 894.72    198.9, 898.24    224.7, 913.93
*
XT   APTEM     97
GR          -85.1, 910.73    -74.5, 903.57    -57.3, 904.85    -51.8, 900.66
GR          -37.7, 900.64    -22.4, 898.68    -17.2, 896.24    -13.6, 892.74
GR           -9.3, 890.60      0.0, 890.51      0.7, 888.48      8.6, 884.33
GR           12.6, 882.92     16.8, 882.51     30.7, 883.58     41.4, 883.96
GR           56.3, 884.90     61.7, 886.17     64.8, 884.76     70.8, 884.74
GR           84.6, 887.77     91.8, 888.47    107.1, 889.32    135.4, 889.79
GR          150.3, 892.56    176.0, 900.64    208.7, 901.96    230.2, 910.54
*
AS   APPRO    85
GT           -0.11
N           0.035        0.055        0.040
SA                 -22.4         84.6
*
HP 1 BRIDG   889.65 1 889.65
HP 2 BRIDG   889.65 * * 5910
HP 1 APPRO   893.67 1 893.67
HP 2 APPRO   893.67 * * 5910
*
HP 1 BRIDG   895.09 1 895.09
HP 2 BRIDG   895.09 * * 6566
HP 2 RDWAY   896.57 * * 858
HP 1 APPRO   896.68 1 896.68
```

APPENDIX B:

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File conc038.wsp
        Hydraulic analysis for structure CONCTH00060038   Date: 24-JUN-96
        Hydraulic Analysis of CONC038 over the Moose River   SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     399.  44450.    52.    65.                        6241.
   889.65          399.  44450.    52.    65.  1.00     1.    53.   6241.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       889.65     0.9    53.4   398.9   44450.    5910.  14.81
X STA.         0.9         7.1        10.0        12.5        15.2        18.2
  A(I)             33.9        21.6        20.0        20.5        20.4
  V(I)             8.72       13.70       14.78       14.39       14.51

X STA.        18.2        20.8        23.0        25.0        26.8        28.7
  A(I)             19.2        17.9        17.4        16.5        16.5
  V(I)            15.38       16.52       17.01       17.91       17.88

X STA.        28.7        30.5        32.3        34.2        36.0        37.8
  A(I)             16.3        16.7        16.6        16.8        16.7
  V(I)            18.15       17.72       17.85       17.60       17.70

X STA.        37.8        39.7        41.7        44.1        47.2        53.4
  A(I)             17.5        18.0        20.1        22.8        33.7
  V(I)            16.86       16.41       14.73       12.96        8.77

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      85.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     812.  86682.    99.   104.                       13177.
             3     276.  25676.    70.    70.                        3123.
   893.67         1088. 112358.   169.   174.  1.01   -15.   154.  15598.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      85.
         WSEL     LEW     REW    AREA        K        Q    VEL
       893.67   -14.7   154.2  1088.2  112358.    5910.   5.43
X STA.       -14.7         7.7        13.4        18.1        22.5        26.9
  A(I)             93.0        57.6        51.7        48.8        46.7
  V(I)             3.18        5.13        5.72        6.05        6.33

X STA.        26.9        31.4        36.1        40.7        45.5        50.5
  A(I)             46.7        46.7        46.1        46.3        47.8
  V(I)             6.32        6.32        6.41        6.38        6.19

X STA.        50.5        55.8        62.2        67.9        73.5        80.6
  A(I)             48.0        52.6        49.9        49.4        55.0
  V(I)             6.16        5.61        5.93        5.99        5.38

X STA.        80.6        89.4        99.8       112.4       126.7       154.2
  A(I)             53.6        53.7        57.3        60.7        76.7
  V(I)             5.52        5.50        5.16        4.87        3.85
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File conc038.wsp
        Hydraulic analysis for structure CONCTH00060038   Date: 24-JUN-96
        Hydraulic Analysis of CONC038 over the Moose River   SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             1     649.   65682.     6.   121.                      37418.
   895.09          649.   65682.     6.   121.  1.00     0.    54.  37418.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       895.09     0.0    53.7   648.8   65682.    6566.  10.12
 X STA.         0.0         5.3         7.8        10.1        12.3        14.6
   A(I)            47.4        30.8        30.2        29.7        29.9
   V(I)            6.92       10.66       10.85       11.05       10.98

 X STA.        14.6        17.4        19.9        22.2        24.4        26.4
   A(I)            32.3        29.9        30.0        29.0        28.0
   V(I)           10.16       11.00       10.93       11.33       11.71

 X STA.        26.4        28.5        30.6        32.7        34.8        37.0
   A(I)            28.7        28.5        28.6        29.4        29.5
   V(I)           11.45       11.51       11.50       11.16       11.14

 X STA.        37.0        39.2        41.6        44.3        47.6        53.7
   A(I)            30.2        31.2        34.0        37.3        54.2
   V(I)           10.89       10.52        9.66        8.79        6.06

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      13.
         WSEL     LEW     REW    AREA        K        Q    VEL
       896.57    56.5   186.8   172.0    4874.     858.   4.99
 X STA.        56.5        78.4        89.9        98.1       104.7       110.3
   A(I)            12.9        11.1         9.9         9.0         8.5
   V(I)            3.34        3.86        4.34        4.75        5.03

 X STA.       110.3       115.4       120.4       125.3       130.0       134.6
   A(I)             8.1         8.0         8.0         7.8         7.7
   V(I)            5.27        5.39        5.37        5.47        5.58

 X STA.       134.6       139.2       143.7       148.1       152.4       156.7
   A(I)             7.7         7.6         7.6         7.5         7.6
   V(I)            5.54        5.65        5.63        5.72        5.64

 X STA.       156.7       160.9       165.2       169.4       173.8       186.8
   A(I)             7.5         7.7         7.7         8.2        11.8
   V(I)            5.72        5.54        5.60        5.26        3.63

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      85.
     WSEL  SA#     AREA        K  TOPW   WETP  ALPH    LEW    REW     QCR
             2    1116.  142801.   103.   109.                      20836.
             3     500.   63150.    79.    80.                       7133.
   896.68         1616.  205951.   182.   189.  1.00   -18.   164.  27305.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      85.
         WSEL     LEW     REW    AREA        K        Q    VEL
       896.68   -18.4   163.8  1615.6  205951.    7530.   4.66
 X STA.       -18.4         5.3        12.6        18.0        23.4        28.7
   A(I)           137.3        91.1        76.4        75.1        71.9
   V(I)            2.74        4.13        4.93        5.01        5.23

 X STA.        28.7        34.2        39.8        45.4        51.2        57.3
   A(I)            72.3        72.8        71.6        71.6        73.8
   V(I)            5.21        5.17        5.26        5.26        5.10

 X STA.        57.3        64.3        70.5        77.2        85.6        93.7
   A(I)            78.3        74.4        76.0        81.7        69.1
   V(I)            4.81        5.06        4.96        4.61        5.44

 X STA.        93.7       102.7       112.7       123.5       135.1       163.8
   A(I)            72.0        74.6        79.2        82.0       114.5
   V(I)            5.23        5.05        4.76        4.59        3.29
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File conc038.wsp
        Hydraulic analysis for structure CONCTH00060038   Date: 24-JUN-96
        Hydraulic Analysis of CONC038 over the Moose River   SAO

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     420.   48112.    53.    65.                       6747.
   890.06          420.   48112.    53.    65.  1.00     1.    53.   6747.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       890.06     0.9    53.4   420.5   48112.    6730.  16.01
X STA.         0.9        7.0       10.0       12.4       15.1       18.1
  A(I)             35.9       23.4       20.3       21.8       21.2
  V(I)             9.37      14.38      16.57      15.47      15.87

X STA.        18.1       20.7       22.9       24.9       26.7       28.6
  A(I)             20.0       18.9       18.3       17.4       17.5
  V(I)            16.86      17.82      18.38      19.32      19.28

X STA.        28.6       30.4       32.3       34.1       36.0       37.8
  A(I)             17.2       17.6       17.5       17.7       17.6
  V(I)            19.60      19.13      19.27      19.03      19.14

X STA.        37.8       39.7       41.7       44.2       47.2       53.4
  A(I)             18.4       19.0       21.2       23.6       36.2
  V(I)            18.24      17.72      15.88      14.28       9.30

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      85.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     919.  105471.   100.   105.                      15773.
             3     353.   37293.    73.    74.                       4396.
   894.74         1271.  142764.   173.   179.  1.00   -16.   158.  19498.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      85.
         WSEL     LEW     REW    AREA        K        Q    VEL
       894.74   -15.8   157.6  1271.3  142764.    6730.   5.29
X STA.       -15.8        6.6       13.1       18.0       22.8       27.5
  A(I)            106.1       71.4       59.1       58.0       55.5
  V(I)             3.17       4.72       5.70       5.80       6.06

X STA.        27.5       32.4       37.4       42.5       47.6       53.1
  A(I)             55.6       55.8       55.0       55.1       56.8
  V(I)             6.05       6.03       6.12       6.11       5.93

X STA.        53.1       59.0       65.6       71.3       77.8       86.4
  A(I)             57.6       61.7       57.2       60.9       65.6
  V(I)             5.84       5.46       5.88       5.52       5.13

X STA.        86.4       95.3      105.5      117.3      130.2      157.6
  A(I)             57.8       60.4       64.3       68.0       89.4
  V(I)             5.82       5.57       5.23       4.95       3.76
```

```
        U.S. Geological Survey WSPRO Input File conc038.wsp
        Hydraulic analysis for structure CONCTH00060038   Date: 24-JUN-96
        Hydraulic Analysis of CONC038 over the Moose River   SAO

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

EXITX:XS   ******    -9.      659.  1.36 *****  891.76  888.28   5910.  890.40
      -62. ******   129.   61830.  1.08 ***** *******    0.75    8.97

FULLV:FV      62.   -10.      768.  1.04  0.47  892.22 *******   5910.  891.18
        0.    62.   133.   74017.  1.13  0.00   -0.01    0.62    7.70
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      85.   -12.      796.  0.89  0.57  892.78 *******   5910.  891.90
       85.    85.   147.   70051.  1.03  0.00   -0.01    0.60    7.43
         <<<<<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      62.     1.      399.  3.41  0.79  893.06  889.39   5910.  889.65
        0.    62.    53.   44494.  1.00  0.52    0.00    0.95   14.81

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  894.40 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      13.       <<<<<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      45.   -15.     1088.  0.46  0.37  894.13  890.49   5910.  893.67
       85.    52.   154.  112258.  1.01  0.70    0.01    0.38    5.43

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.669  0.455   61009.    18.    71.  893.49

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -62.    -9.   129.   5910.   61830.     659.    8.97  890.40
   FULLV:FV      0.   -10.   133.   5910.   74017.     768.    7.70  891.18
   BRIDG:BR      0.     1.    53.   5910.   44494.     399.   14.81  889.65
   RDWAY:RG     13.**************      0.******************    2.00********
   APPRO:AS     85.   -15.   154.   5910.  112258.    1088.    5.43  893.67

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      18.    71.   61009.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    888.28    0.75  880.57  909.75************  1.36  891.76  890.40
   FULLV:FV  ********    0.62  880.57  909.75  0.47  0.00  1.04  892.22  891.18
   BRIDG:BR    889.39    0.95  880.16  895.31  0.79  0.52  3.41  893.06  889.65
   RDWAY:RG  ****************  894.72  913.93**********************************
   APPRO:AS    890.49    0.38  882.40  910.62  0.37  0.70  0.46  894.13  893.67
```

```
        U.S. Geological Survey WSPRO Input File conc038.wsp
        Hydraulic analysis for structure CONCTH00060038   Date: 24-JUN-96
        Hydraulic Analysis of CONC038 over the Moose River   SAO

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

EXITX:XS   ******   -11.     808.  1.54 *****  893.00  889.33   7530.  891.46
      -62. ******   135.   78792.  1.14 ***** *******    0.74    9.32

FULLV:FV      62.   -12.     929.  1.19  0.48  893.47 *******   7530.  892.28
        0.    62.   139.   93701.  1.17  0.00   -0.01    0.62    8.10
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      85.   -14.     988.  0.92  0.53  893.99 *******   7530.  893.07
       85.    85.   152.   96790.  1.02  0.00   -0.01    0.56    7.63
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   895.66       0.00     890.69     894.72

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   890.56     895.09     895.44     894.40

 ===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      62.     0.     649.  1.59 *****  896.69  889.92   6566.  895.09
        0. ******    54.   65661.  1.00 ***** *******    0.51   10.12

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.434 ******  894.40 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       13.    62.  0.08  0.34  896.94   -0.01    858.  896.57

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.    69.   -59.    28.   3.1   1.9   8.2   9.3   3.2   3.1
   RT:    858.   130.    56.   187.   1.8   1.3   5.9   5.0   1.7   3.0

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

APPRO:AS      45.   -18.    1616.  0.34  0.20  897.02  891.08   7530.  896.68
       85.    54.   164.  205983.  1.00  0.78   -0.01    0.28    4.66

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

  FIRST USER DEFINED TABLE.
    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -62.   -11.   135.   7530.   78792.     808.    9.32  891.46
   FULLV:FV       0.   -12.   139.   7530.   93701.     929.    8.10  892.28
   BRIDG:BR       0.     0.    54.   6566.   65661.     649.   10.12  895.09
   RDWAY:RG      13.*******     0.    858.       0.*********    2.00  896.57
   APPRO:AS      85.   -18.   164.   7530.  205983.    1616.    4.66  896.68

 SECOND USER DEFINED TABLE.
    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    889.33     0.74  880.57  909.75************  1.54  893.00  891.46
   FULLV:FV  ********     0.62  880.57  909.75  0.48  0.00  1.19  893.47  892.28
   BRIDG:BR    889.92     0.51  880.16  895.31************  1.59  896.69  895.09
   RDWAY:RG  ****************  894.72  913.93  0.08******  0.34  896.94  896.57
   APPRO:AS    891.08     0.28  882.40  910.62  0.20  0.78  0.34  897.02  896.68
```

```
        U.S. Geological Survey WSPRO Input File conc038.wsp
        Hydraulic analysis for structure CONCTH00060038   Date: 24-JUN-96
        Hydraulic Analysis of CONC038 over the Moose River   SAO

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

EXITX:XS   ******   -10.     736.  1.46 *****  892.41  888.83   6730.  890.96
      -62. ******   132.   70426.  1.12 ***** *******    0.75    9.14

FULLV:FV      62.   -11.     852.  1.12  0.47  892.88 *******   6730.  891.76
        0.    62.   136.   84076.  1.15  0.00   -0.01    0.62    7.90
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      85.   -13.     896.  0.90  0.55  893.41 *******   6730.  892.52
       85.    85.   151.   83496.  1.02  0.00   -0.01    0.57    7.51
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   894.74       0.00     890.06     894.72

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    6730.     890.06

            <<<<<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      62.     1.     420.  3.99 *****  894.04  890.06   6730.  890.06
        0.    62.    53.   48086.  1.00 ***** *******    1.00   16.01

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  1.000 ******  894.40 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR      Q    WSEL
   RDWAY:RG      13.        <<<<<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      45.   -16.    1271.  0.44  0.35  895.18  890.75   6730.  894.74
       85.    53.   158.  142784.  1.00  0.78    0.01    0.35    5.29

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.677  0.495   72076.    20.    73. ********

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

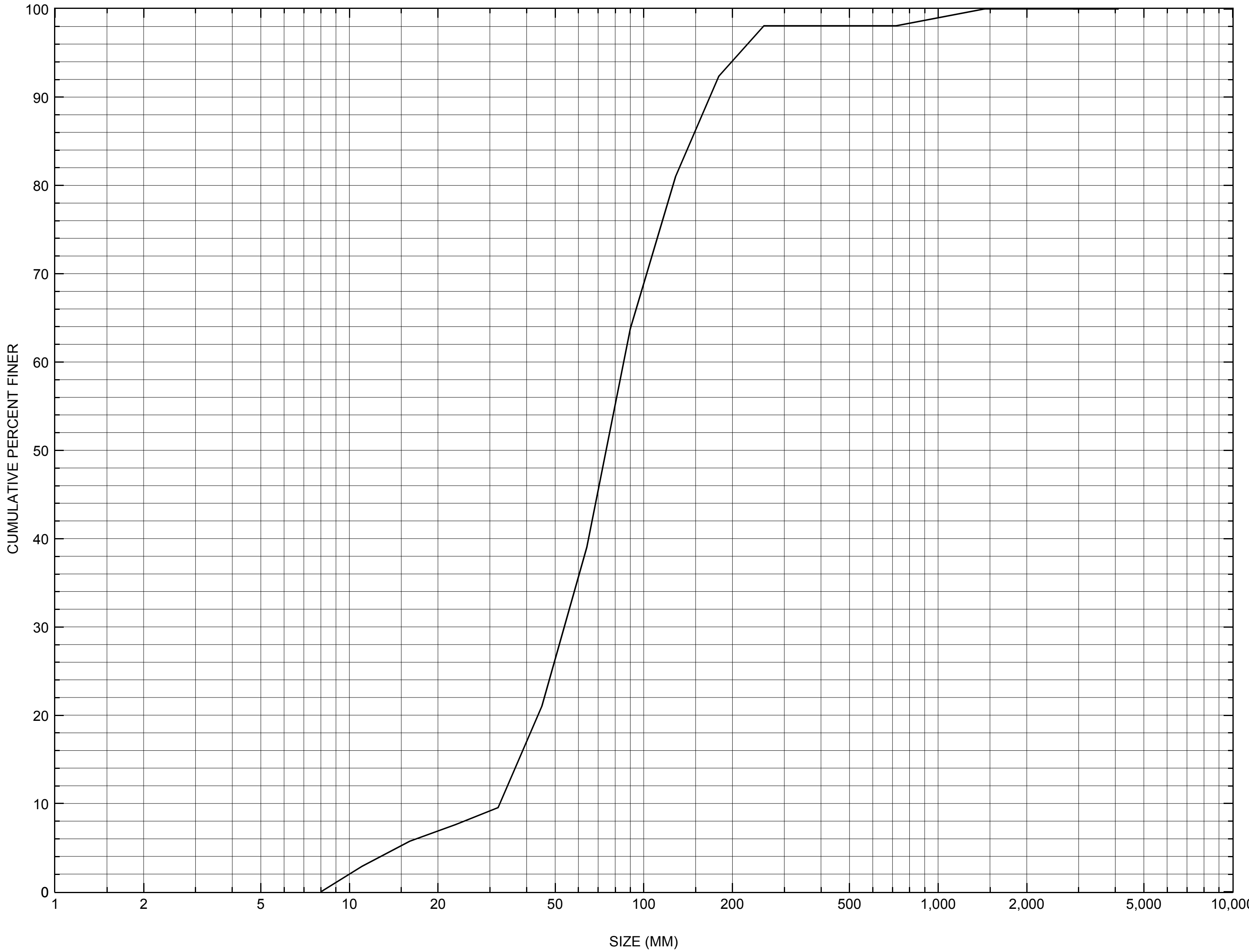
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -62.   -10.   132.   6730.   70426.     736.    9.14  890.96
   FULLV:FV       0.   -11.   136.   6730.   84076.     852.    7.90  891.76
   BRIDG:BR       0.     1.    53.   6730.   48086.     420.   16.01  890.06
   RDWAY:RG      13.**************       0.       0.       0.    2.00********
   APPRO:AS      85.   -16.   158.   6730.  142784.    1271.    5.29  894.74

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      20.    73.   72076.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    888.83    0.75  880.57  909.75************  1.46  892.41  890.96
   FULLV:FV  ********    0.62  880.57  909.75  0.47  0.00  1.12  892.88  891.76
   BRIDG:BR    890.06    1.00  880.16  895.31************  3.99  894.04  890.06
   RDWAY:RG  ****************  894.72  913.93  0.14******  0.44  895.05********
   APPRO:AS    890.75    0.35  882.40  910.62  0.35  0.78  0.44  895.18  894.74
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CONCTH00060038, in Concord, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CONCTH00060038

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)* 009

Town *(FIPS place code; I - 4; nnnnn)* 15250

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

Waterway *(I - 6)* MOOSE RIVER

Road Name *(I - 7):* -

Route Number TH006

Vicinity *(I - 9)* 0.1 MI TO JCT W US2

Topographic Map Concord

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44257

Longitude *(i - 17; nnnnn.n)* 71530

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10050700380507

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

Maximum span length *(I - 48; nnnn)* 0055

Year built *(I - 27; YYYY)* 1930

Structure length *(I - 49; nnnnnn)* 000059

Average daily traffic, ADT *(I - 29; nnnnnn)* 000500

Deck Width *(I - 52; nn.n)* 232

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

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

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 012.1

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

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

Comments:

The structural inspection report of 9/19/94 indicates the structure is a steel stringer type bridge with a concrete deck. The left abutment and its wingwalls are constructed of “laid-up” stone with a concrete cap while the right abutment and its wingwalls are concrete. The cap on the left abutment has alligator cracks and leaks with small spalls reported. The stone abutment face has a few random fine cracks. Some of the grout from between the stones is missing at the upstream end of the abutment and wingwall. The right abutment footing is exposed with a voided (undermined) area extending along the downstream half of the abutment wall. The undermining is about 0.5 foot with 2 to 3 inches of **(Continued, page 33)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

penetration. The left wingwall has a few cracks and leaks. The abutment face has some minor cracks and small leaks. Boulder fill is reported as placed in front of each abutment and wingwall. Randomly distributed boulders are reported on the banks up- and downstream. The report mentions some undermining has occurred in the past. Point bars and debris accumulation problems are noted as minor at this site.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **98.388** mi^2 Lake and pond area **3.179** mi^2

Watershed storage *(ST)* **3.23** %

Bridge site elevation **862** ft Headwater elevation **3174** ft

Main channel length **26.489** mi

10% channel length elevation **975** ft 85% channel length elevation **1965** ft

Main channel slope *(S)* **49.832** 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:

NO BENCHMARK INFORMATION

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:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS.

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 2/16/96
Computerized by: EW Date: 2/20/96
Reviewd by: SAO Date: 10/30/96

Structure Number CONCTH00060038

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* L. MEDALIE Date *(MM/DD/YY)* 08 / 17 / 1995

2. Highway District Number 7 Mile marker 0

County ESSEX 009 Town CONCORD 15250

Waterway *(I - 6)* MOOSE RIVER Road Name -

Route Number TH6 Hydrologic Unit Code: 01080102

3. Descriptive comments:

BRIDGE LOCATED 0.1 MILES FROM JUCTION WITH US 2

B. Bridge Deck Observations

4. Surface cover... LBUS 5 RBUS 6 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 2 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 59 *(feet)* Span length 55 *(feet)* Bridge width 23.2 *(feet)*

Road approach to bridge:

8. LB 2 RB 1 *(**0** even, **1**- lower, **2**- higher)*

9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*

10. Embankment slope (*run / rise in feet / foot*):
US left ________ US right ________

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

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

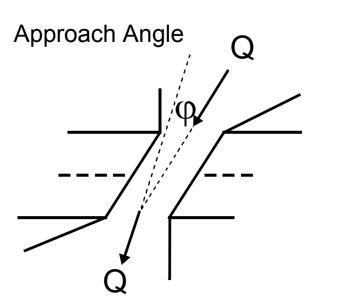
*Bank protection conditions: **1**- good; **2**- slumped; **3**- eroded; **4**- failed*

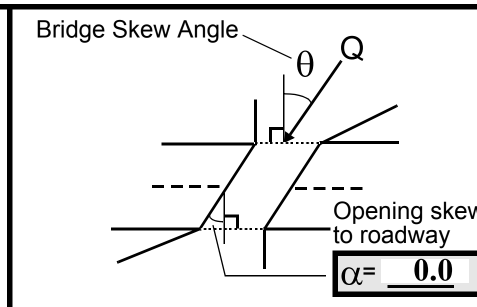
*Erosion: **0** - none; **1**- channel erosion; **2**- road wash; **3**- both; **4**- other*

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

Channel approach to bridge (BF):

15. Angle of approach: 5 16. Bridge skew: 10





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

Where? LB *(LB, RB)* Severity 0

Range? 10 feet US *(US, UB, DS)* to 120 feet US

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, 4**

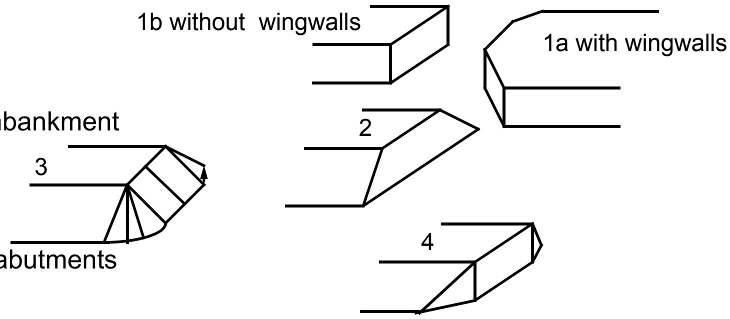
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

#4: there are trees along all four banks with some open areas for the roadways and factory on RDS
#7: values from VTOAT form; measured values: span length= 53.5 feet; bridge length= 59 feet; bridge width= 23.2 feet
#8: RB road approach width is 18 feet.
#18: type 4 bridge right side US and DS; type 1a bridge left side US and DS

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
71.0	**6.0**			**6.5**	**3**	**4**	**745**	**453**	**0**	**0**

23. Bank width **25.0**   24. Channel width **20.0**   25. Thalweg depth **112.5**   29. Bed Material **453**

30 .Bank protection type: LB **27** RB **2**   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.):

LB: consists of piled stones on slope of bank from end of wingwall to 30 feet US, then piled in a vertical wall for 20 feet then a concrete wall extends from 70 feet from the bridge face to 115 feet US; placed protection (stones) extends all the way out to 130 feet.

RB: protection begins at 75 feet US of bridge deck and extends to 108 feet US protecting gravel road embankment.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 60 35. Mid-bar width: 40

36. Point bar extent: 11 feet US (US, UB) to 120 feet US (US, UB, DS) positioned 60 %LB to 90 %RB

37. Material: 43

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

Point bar

Additional side bar on right bank begins about 190 feet US of bridge

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

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

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

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

NO CUT BANKS

Left bank is well protected by stone fill.

45. Is channel scour present? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 175

47. Scour dimensions: Length 10 Width 10 Depth : 1.5 Position 75 %LB to 90 %RB

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

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
83.5		2.0		2	7	7	-

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

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

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

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

5

#63: bed material placed stones across channel, many 0.5 to 1 meter in diameter

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

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	90	2	2	-	2.8	90.0
RABUT	2	10	90			2	3	71.0

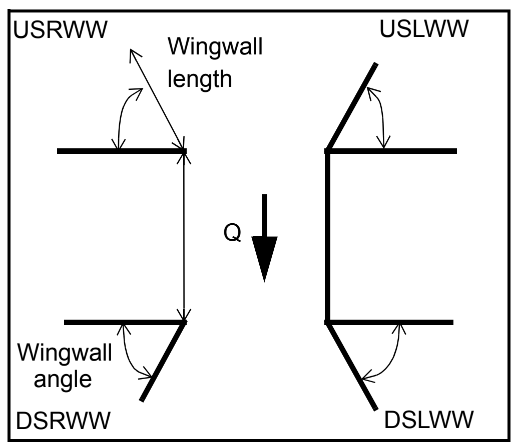
Pushed: LB or RB   *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood

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

0.4
3
1
#74: RABUT: Undermining is about 4 inches vertically in one location, 0-3 inches in a couple of other locations (DS end) in between large placed boulders
#76: LABUT: Extending 20 feet along the US end of the LABUT, the footing is exposed 1.3 feet and subfooting is exposed up to 2 feet- other areas are protected. Between 20 feet from US end to the DS end, there is no subfooting and footing is exposed up to 2.8 feet--average exposure is about 2.0 ft.
#77: LABUT material is laid-up stone with a concrete cap.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						71.0	
USRWW:	Y		2		2	2.5	
DSLWW:	-		1.3		Y	33.0	
DSRWW:	1		2		-	29.5	



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

82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	0.75	2	Y	-	1	1	1	1
Condition	Y	-	1	-	1	3	1	1
Extent	2	2	0	2	2	2	3	-

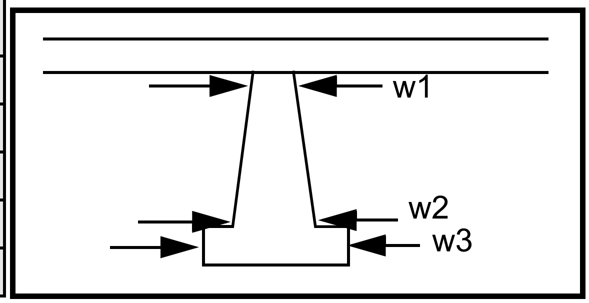
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
1
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				35.0	11.0	60.0
Pier 2				13.5	180.0	13.0
Pier 3		7.0	-	70.0	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	RW	WW	ders	out	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	W-	- top	USL	from	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	foot-	of	WW	jct	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	ing	foot-	-	with	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	expo	ing	foot-	LAB	*Y- yes; N- no*
91. Attack ∠ (BF)	sed	expo	ing	UT.	
92. Pushed	at jct	sed	expo	Sub-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	with	betw	sed	foot-	
95. Cross-members	RAB	een	only	ing	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	UT	place	for	also	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	only	d	3.5	expo	
98. Exposure depth	DSR	boul-	feet	sed	

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

for 1.3 feet, 3 feet from the corner
DSLWW- concrete cap, footing exposure depth grades from 2 feet at US end to 0.5 feet at DS end

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 (Amb) - Thalweg depth (Amb) - Bed Material -

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

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

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

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.):

-
-
-
NO PIERS

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

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

3
2
43

Is channel scour present? **43** (Y or if N type ctrl-n cs) Mid-scour distance: **2**

Scour dimensions: Length **0** Width **54** Depth: **2** Positioned **2** %LB to **1** %RB

Scour comments (eg. additional scour areas, local scouring process, etc.):
1
LB protection extends from bridge to 44 feet DS. Above and beyond protection is fairly significant bank erosion. Occasional metal scrap seen in or around stream.

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

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

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

Confluence comments (eg. confluence name):

m bridge to at least 160 feet DS. At 78 feet from deck, stones are built as foundation and stream wall for old dilapidated shed. There are 2 large concrete blocks placed at streams edge at 160 feet on right side for protec-

F. Geomorphic Channel Assessment

107. Stage of reach evolution **tio**

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.

Bank material on both sides consists mainly of placed protection.

N

-

NO DROP STRUCTURE

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: CONCTH00060038   Town: Concord
Road Number: TH6   County: Essex
Stream: Moose River

Initials SAO   Date: 10/2/96 Checked: MAI

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

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

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	5910	7530	6730
Main Channel Area, ft2	812	1116	919
Left overbank area, ft2	0	0	0
Right overbank area, ft2	276	500	353
Top width main channel, ft	99	103	100
Top width L overbank, ft	0	0	0
Top width R overbank, ft	70	79	73
D50 of channel, ft	0.244	0.244	0.244
D50 left overbank, ft	0	0	0
D50 right overbank, ft	0	0	0
y1, average depth, MC, ft	8.2	10.8	9.2
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	3.9	6.3	4.8
Total conveyance, approach	112358	205951	142764
Conveyance, main channel	86682	142801	105471
Conveyance, LOB	0	0	0
Conveyance, ROB	25676	63150	37293
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	4559.4	5221.1	4972.0
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	1350.6	2308.9	1758.0
Vm, mean velocity MC, ft/s	5.6	4.7	5.4
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	4.9	4.6	5.0
Vc-m, crit. velocity, MC, ft/s	9.9	10.4	10.1
Vc-l, crit. velocity, LOB, ft/s	N/A	N/A	N/A
Vc-r, crit. velocity, ROB, ft/s	0.0	0.0	0.0

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)

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	812	1116	919
Main channel width, ft	99	103	100
y1, main channel depth, ft	8.20	10.83	9.19

Bridge Section			
(Q) total discharge, cfs	5910	7530	6730
(Q) discharge thru bridge, cfs	5910	6566	6730
Main channel conveyance	44450	65682	48112
Total conveyance	44450	65682	48112
Q2, bridge MC discharge,cfs	5910	6566	6730
Main channel area, ft2	399	649	420
Main channel width (skewed), ft	52.5	53.7	52.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	52.5	53.7	52.5
y_bridge (avg. depth at br.), ft	7.60	12.09	8.00
Dm, median (1.25*D50), ft	0.305	0.305	0.305
y2, depth in contraction,ft	9.96	10.69	11.13
ys, scour depth (y2-ybridge), ft	2.36	-1.39	3.13

ARMORING			
D90	0.550	0.550	0.550
D95	0.694	0.694	0.694
Critical grain size,Dc, ft	0.8416	0.3302	0.9655
Decimal-percent coarser than Dc	N/A	0.307	N/A
Depth to armoring,ft	ERR	2.24	ERR

IV. Pressure Flow Scour (contraction scour for orifice flow conditions)

Hb+Ys=Cq*qbr/Vc   Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)
Chang Equation   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
(Richarson and others, 1995, p. 145-146)

	Q100	Q500	OtherQ
Q, total, cfs	5910	7530	6730
Q, thru bridge, cfs	5910	6566	6730
Total Conveyance, bridge	44450	65682	48112

Main channel(MC) conveyance, bridge	44450	65682	48112
Q, thru bridge MC, cfs	5910	6566	6730
Vc, critical velocity, ft/s	9.95	10.42	10.14
Vc, critical velocity, m/s	3.03	3.18	3.09
Main channel width (skewed), ft	52.5	53.7	52.5
Cum. width of piers in MC, ft	0	0	0
W, adjusted width, ft	52.5	53.7	52.5
qbr, unit discharge, ft^2/s	112.6	122.3	128.2
qbr, unit discharge, m^2/s	10.46	11.36	11.91
Area of full opening, ft^2	399	649	420
Hb, depth of full opening, ft	7.60	12.09	8.00
Hb, depth of full opening, m	2.32	3.68	2.44
Fr, Froude number, bridge MC	0.95	0.51	1.00
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
ya, depth immediately upstream, ft	0	14.17	0
w, depth of overflow, ft	0	0	0
Cc, vert contrac correction (<=1.0)	ERR	0.96	ERR
Ys, ft	ERR	0.12	ERR

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	5910	7530	6730	5910	7530	6730
a', abut.length blocking flow, ft	15.6	18.4	16.7	100.8	110.1	104.2
Ae, area of blocked flow ft2	64.8	106.6	79.1	530.6	698.5	640
Qe, discharge blocked abut.,cfs	205.8	292.3	250.9	2793	--	3348
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.18	2.74	3.17	5.26	4.72	5.23
ya, depth of f/p flow, ft	4.15	5.79	4.74	5.26	6.34	6.14
--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	0.275	0.201	0.257	0.404	0.300	0.372
ys, scour depth, ft	10.36	12.45	11.35	25.34	25.67	27.27

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)	15.6	18.4	16.7	100.8	110.1	104.2
y1 (depth f/p flow, ft)	4.15	5.79	4.74	5.26	6.34	6.14
a'/y1	3.76	3.18	3.53	19.15	17.35	16.97
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.27	0.20	0.26	0.40	0.30	0.37
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR

spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.95	0.51	1	0.95	0.51	1
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	7.6	12.1	8.0	7.6	12.1	8.0
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	1.95	ERR	ERR	1.95	ERR
Fr>0.8 (vertical abut.)	3.13	ERR	3.35	3.13	ERR	3.35
Fr<=0.8 (spillthrough abut.)	ERR	1.70	ERR	ERR	1.70	ERR
Fr>0.8 (spillthrough abut.)	2.77	ERR	2.96	2.77	ERR	2.96