LEVEL II SCOUR ANALYSIS FOR BRIDGE 37 (CONCTH00010037) on TOWN HIGHWAY 1, crossing the MOOSE RIVER, CONCORD, VERMONT

U.S. Geological Survey
Open-File Report 96-741

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

1996

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

U.S. GEOLOGICAL SURVEY
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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 37 (CONCTH00010037) ON TOWN HIGHWAY 1, 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 CONCTH00010037 on Town Highway 1 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 82.2-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest.

In the study area, the Moose River has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 111 ft and an average bank height of 6 ft. The channel bed material ranges from gravel to boulder and has a median grain size (D_{50}) of 148 mm (0.486 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 16, 1995, indicated that the reach was stable.

The Town Highway 1 crossing of the Moose River is a 78-ft-long, two-lane bridge consisting of one 75-foot steel-beam span (Vermont Agency of Transportation, written communication, March 24, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 0 degrees to the opening. The opening-skew-to-roadway is also 0 degrees.

Scour protection measure at the site included type-1 stone fill (less than 12 inches diameter) at each downstream wingwall, type-2 stone fill (less than 36 inches diameter) at the upstream right wingwall, type-3 stone fill (less than 48 inches diameter) at the upstream left wingwall, and type-4 stone fill (less than 60 inches diameter) along the left 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 was 0.0 ft. Abutment scour at the left abutment ranged from 14.3 to 16.1 ft. with the worst-case occurring at the incipient-overtopping discharge. Abutment scour at the right abutment ranged from 14.4 to 16.8 ft. with the worst-case occurring at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Miles Pond, VT. Quadrangle, 1:24,000, 1967
Photoinspected 1983

NORTH

Figure 1. Location of study area on USGS 1:24,000 scale map.

Figure 2. Location of study area on Vermont Agency of Transportation town highway map.

LEVEL II SUMMARY

Structure Number CONCTH00010037 ***Stream*** Moose River

County Essex ***Road*** TH1 ***District*** 7

Description of Bridge

Bridge length 78 ***ft*** ***Bridge width*** 21.0 ***ft*** ***Max span length*** 75 ***ft***

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

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

Stone fill on abutment? Yes, left ***Date of inspection*** 8/16/95

Description of stone fill Type-4, along base of left abutment.

Abutments and wingwalls are concrete.

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

The reach is straight except for a sharp bend immediately downstream of the bridge.

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*
	8/16/95	0	0
Level I	8/16/95	0	0
Level II			

Potential for debris Low.

--, August 16, 1995.

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

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 8/16/95

DS left: Steep channel bank to a narrow terrace and moderately sloping overbank.

DS right: Steep channel bank to a narrow terrace and moderately sloping overbank.

US left: Steep channel bank to a narrow terrace and moderately sloping overbank.

US right: Steep channel bank to a narrow terrace and moderately sloping overbank.

Description of the Channel

Average top width 111 ***ft*** ***Average depth*** 6 ***ft***

Predominant bed material Boulder / Cobbles ***Bank material*** Boulder/Cobbles

Sinuous but stable with non-alluvial channel boundaries.

8/16/95

Vegetative co Forested.

DS left: Forested.

DS right: Trees and brush.

US left: Forested.

US right: Y

Do banks appear stable? --, August 16, 1995. ***If not, describe location and type of instability and date of observation.***

None, August 16, 1995.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 82.2 ***mi***^{2}

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 ***mi***^{2}

Is there a lake/p No

Calculated Discharges

Q100 5,030 ***ft***^{3}***/s*** ***Q500*** 6,290 ***ft***^{3}***/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 X on top of the downstream end of the left abutment (elev. 899.62 ft, arbitrary survey datum). RM2 is the center of a chiseled X on top of the upstream end of the right abutment (elev. 901.41 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	-123	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	16	1	Road Grade section
APTEM	92	1	Approach section as surveyed (Used as a template)
APPRO	102	2	Modelled Approach section (Templated from APTEM)

[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 0.055 to 0.065, and overbank "n" values ranged from 0.035 to 0.055.

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 0.0131 ft/ft which was taken from the 100-year water-surface profile downstream of this 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 (0.028 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.

Bridge Hydraulics Summary

Average bridge embankment elevation 900.3 ***ft***
Average low steel elevation 896.8 ***ft***

100-year discharge 5,030 ***ft³/s***
Water-surface elevation in bridge opening 893.4 ***ft***
Road overtopping? N ***Discharge over road*** -- ***ft³/s***
Area of flow in bridge opening 405 ***ft²***
Average velocity in bridge opening 12.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.6 ***ft/s***

Water-surface elevation at Approach section with bridge 896.9
Water-surface elevation at Approach section without bridge 897.0
Amount of backwater caused by bridge -- ***ft***

500-year discharge 6,290 ***ft³/s***
Water-surface elevation in bridge opening 897.1 ***ft***
Road overtopping? Y ***Discharge over road*** 38 ***ft³/s***
Area of flow in bridge opening 645 ***ft²***
Average velocity in bridge opening 9.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.9 ***ft/s***

Water-surface elevation at Approach section with bridge 899.4
Water-surface elevation at Approach section without bridge 897.9
Amount of backwater caused by bridge 1.5

Incipient overtopping discharge 6,270 ***ft³/s***
Water-surface elevation in bridge opening 897.1 ***ft***
Area of flow in bridge opening 645 ***ft²***
Average velocity in bridge opening 9.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.9 ***ft/s***

Water-surface elevation at Approach section with bridge 899.3
Water-surface elevation at Approach section without bridge 897.9
Amount of backwater caused by bridge 1.4 ***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 100-year discharge was computed by use of Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). The 500-year and incipient roadway-overtopping discharge resulted in 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 and incipient roadway-overtopping discharges 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 these events 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	0.0	0.0	0.0
Depth to armoring	13.3	2.6	2.5
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	14.3	15.2	16.1
Right abutment	14.4	16.8	16.7
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	2.3	1.8	1.8
Right abutment	2.3	1.8	1.8
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

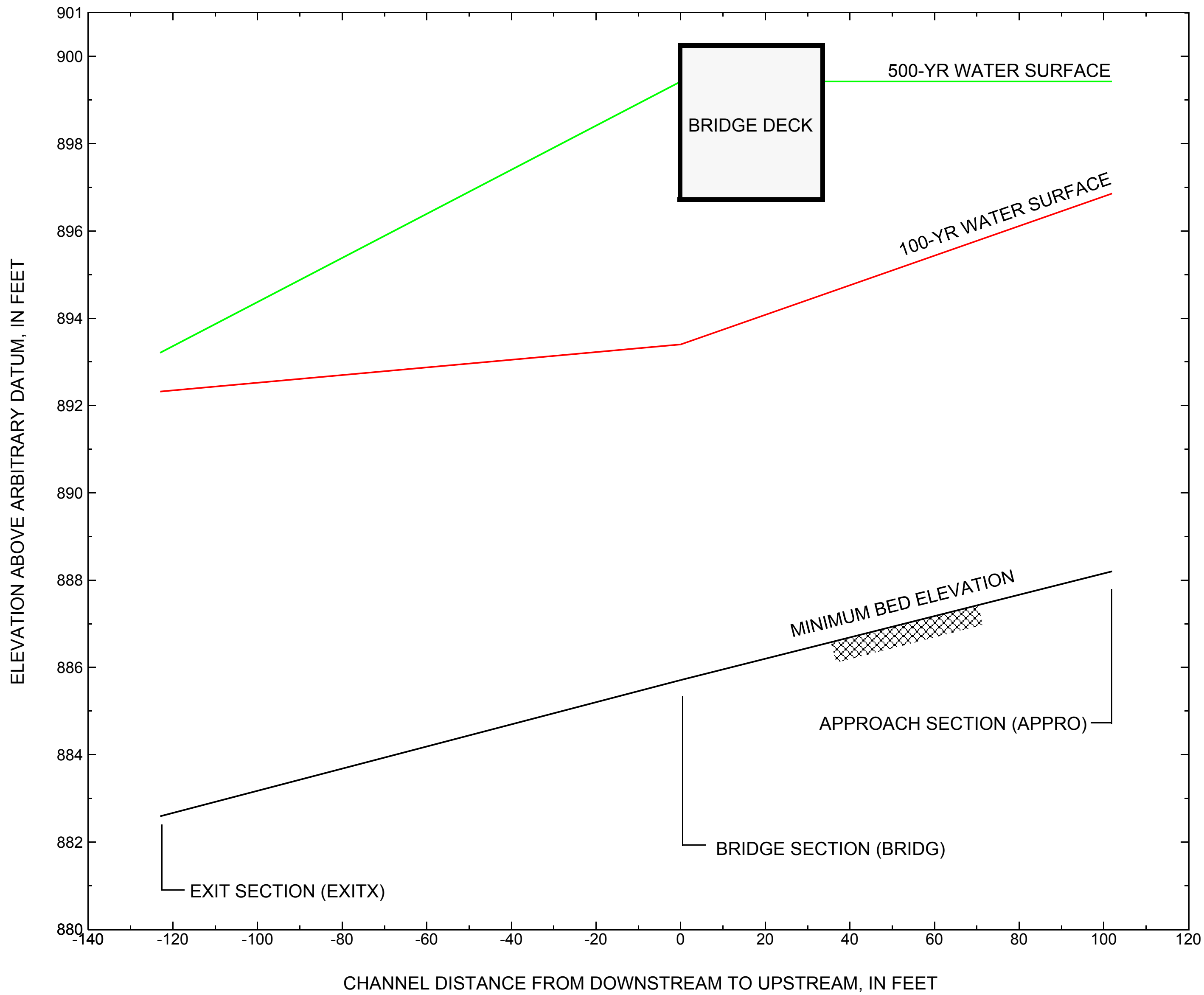

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CONCTH00010037 on Town Highway 1, crossing the Moose River, Concord, Vermont.

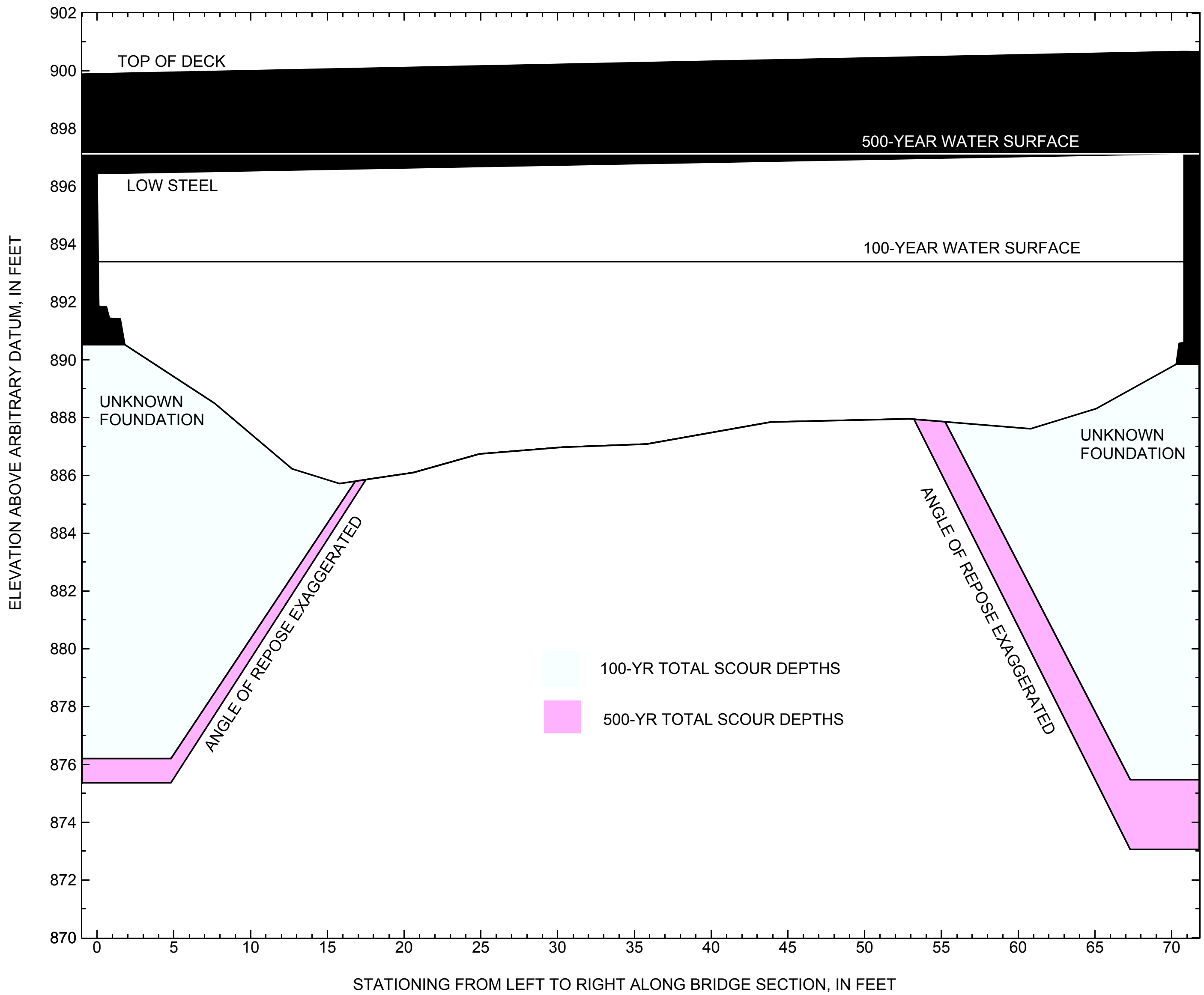

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CONCTH00010037 on Town Highway 1, crossing the Moose River, Concord, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CONCTH00010037 on Town Highway 1, 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 5,030 cubic-feet per second											
Left abutment	0.0	--	896.4	--	890.5	0.0	14.3	--	14.3	876.2	--
Right abutment	70.8	--	897.1	--	889.8	0.0	14.4	--	14.4	875.4	--

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 CONCTH00010037 on Town Highway 1, 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 6,290 cubic-feet per second											
Left abutment	0.0	--	896.4	--	890.5	0.0	15.2	--	15.2	875.3	--
Right abutment	70.8	--	897.1	--	889.8	0.0	16.8	--	16.8	873.0	--

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

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U.S. Geological Survey, 1967, Miles Pond, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Photoinspected 1983, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File conc037.wsp
T2        Hydraulic analysis for structure CONCTH00010037   Date: 24-JUN-96
T3        Hydraulic Analysis of CONC037 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           5030 6290 6270
SK          0.0131 0.0131 0.0131
*
XS   EXITX   -123
GR         -114.6, 907.72    -81.1, 898.38    -62.9, 898.75    -41.9, 897.03
GR          -33.7, 892.01    -10.8, 888.15      0.0, 886.58     11.9, 884.09
GR           21.0, 883.06     27.5, 882.59     36.7, 883.98     48.1, 884.19
GR           54.8, 886.16     74.3, 892.78     84.4, 898.01     91.6, 897.70
GR          101.4, 898.20    110.6, 897.33    117.9, 903.11
N           0.035        0.065        0.055
SA                 -41.9         84.4
*
XS   FULLV     0 * * * 0.028
*
BR   BRIDG     0 896.8
GR            0.0, 896.44      0.1, 891.84      0.6, 891.83      0.8, 891.43
GR            1.5, 891.41      1.8, 890.52      7.7, 888.47     12.7, 886.22
GR           15.8, 885.71     20.6, 886.09     24.9, 886.74     30.3, 886.97
GR           35.8, 887.08     43.9, 887.84     52.9, 887.95     60.8, 887.61
GR           65.1, 888.31     70.3, 889.84     70.5, 890.56     70.8, 890.59
GR           70.8, 897.13      0.0, 896.44
N            0.055
CD           1 40 * * 48 8
*
XR   RDWAY    16 21
GR         -120.6, 906.68    -82.1, 898.76    -56.4, 899.29     -2.9, 899.89
GR           -2.8, 900.64     73.8, 901.31     73.9, 900.66    125.2, 901.60
GR          228.0, 904.63    289.5, 907.59    359.7, 917.65
*
XT   APTEM     92
GR          -98.1, 908.22    -86.7, 906.97    -61.7, 901.42    -51.6, 901.31
GR          -29.8, 900.97    -18.0, 895.83     -6.3, 889.97     -5.7, 889.31
GR            0.4, 889.11      7.0, 888.44     13.6, 887.92     16.7, 887.97
GR           24.8, 888.49     31.1, 888.93     31.3, 890.02     40.7, 891.07
GR           47.1, 889.67     47.4, 889.23     54.0, 889.17     60.6, 888.90
GR           66.2, 889.09     77.0, 890.03     94.7, 896.43    120.6, 899.18
GR          130.8, 900.10    182.3, 902.67    236.1, 912.49
*
AS   APPRO    102
GT            0.28
N           0.035        0.065        0.055
SA                 -29.8         94.7
*
HP 1 BRIDG    893.40 1 893.40
HP 2 BRIDG    893.40 * * 5030
HP 1 APPRO    896.86 1 896.86
HP 2 APPRO    896.86 * * 5030
*
HP 1 BRIDG    897.13 1 897.13
HP 2 BRIDG    897.13 * * 6280
HP 2 RDWAY    899.42 * * 38
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File conc037.wsp
        Hydraulic analysis for structure CONCTH00010037   Date: 24-JUN-96
        Hydraulic Analysis of CONC037 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     406.  33034.    71.    78.                         5510.
   893.40          406.  33034.    71.    78.  1.00     0.    71.   5510.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K         Q    VEL
       893.40     0.1    70.8   405.5   33034.    5030.  12.40
X STA.         0.1        8.8       12.3       15.0       17.3       19.6
  A(I)            31.8       22.1       19.3       17.5       17.2
  V(I)            7.92      11.37      13.02      14.35      14.59

X STA.        19.6       22.0       24.5       27.2       30.0       32.8
  A(I)            17.6       17.5       18.0       17.8       18.1
  V(I)           14.26      14.39      14.01      14.16      13.92

X STA.        32.8       35.6       38.6       41.8       45.4       48.9
  A(I)            18.2       18.3       19.2       19.9       19.5
  V(I)           13.85      13.76      13.07      12.63      12.90

X STA.        48.9       52.6       56.3       59.9       63.8       70.8
  A(I)            20.4       20.3       20.5       21.7       30.6
  V(I)           12.32      12.38      12.28      11.58       8.21

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     102.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2     720.  54827.   114.   119.                        10246.
             3       0.       1.     1.     1.                            0.
   896.86          720.  54828.   116.   120.  1.00   -20.    96.  10184.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     102.
         WSEL     LEW     REW    AREA        K         Q    VEL
       896.86   -19.7    96.1   720.0   54828.    5030.   6.99
X STA.       -19.7       -4.7        0.4        4.8        8.8       12.5
  A(I)            55.3       37.7       33.8       32.3       31.6
  V(I)            4.55       6.67       7.45       7.79       7.96

X STA.        12.5       16.0       19.5       23.2       27.0       31.6
  A(I)            29.6       30.3       30.7       30.8       35.3
  V(I)            8.49       8.30       8.20       8.17       7.12

X STA.        31.6       37.3       43.8       49.0       53.4       57.8
  A(I)            35.4       37.3       35.1       32.6       32.8
  V(I)            7.10       6.73       7.16       7.71       7.67

X STA.        57.8       62.0       66.5       71.5       77.2       96.1
  A(I)            32.6       34.0       36.1       38.6       58.0
  V(I)            7.71       7.40       6.96       6.51       4.34
```

```
        U.S. Geological Survey WSPRO Input File conc037.wsp
        Hydraulic analysis for structure CONCTH00010037   Date: 24-JUN-96
        Hydraulic Analysis of CONC037 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     645.  45149.     0.   155.                            0.
   897.13          645.  45149.     0.   155.  1.00     0.    71.       0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       897.13     0.0    70.8   645.1   45149.    6280.   9.74
 X STA.         0.0         7.6        11.5        14.5        17.2        19.9
  A(I)             48.8        34.6        31.6        28.7        29.0
  V(I)             6.44        9.07        9.92       10.93       10.83

 X STA.        19.9        22.6        25.6        28.5        31.5        34.5
  A(I)             28.7        29.5        29.1        29.5        29.3
  V(I)            10.94       10.65       10.80       10.65       10.70

 X STA.        34.5        37.6        40.7        44.1        47.5        51.0
  A(I)             29.6        29.7        30.8        30.6        31.3
  V(I)            10.62       10.56       10.19       10.25       10.04

 X STA.        51.0        54.4        57.9        61.2        65.0        70.8
  A(I)             30.8        31.8        31.1        34.5        46.0
  V(I)            10.20        9.89       10.08        9.09        6.82

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      16.
         WSEL     LEW     REW    AREA        K        Q    VEL
       899.42   -85.3   -44.8    12.0     226.      38.   3.18
 X STA.       -85.3       -82.8       -82.0       -81.4       -80.8       -80.1
  A(I)              0.7         0.4         0.4         0.4         0.4
  V(I)             2.91        4.23        4.53        4.72        4.76

 X STA.       -80.1       -79.4       -78.7       -78.0       -77.2       -76.3
  A(I)              0.4         0.4         0.4         0.5         0.5
  V(I)             4.58        4.53        4.36        4.20        4.07

 X STA.       -76.3       -75.4       -74.4       -73.3       -72.1       -70.7
  A(I)              0.5         0.5         0.5         0.6         0.6
  V(I)             3.83        3.73        3.47        3.29        3.10

 X STA.       -70.7       -69.0       -67.0       -64.5       -60.7       -44.8
  A(I)              0.7         0.7         0.8         1.0         1.5
  V(I)             2.80        2.62        2.31        1.95        1.26

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     102.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2    1020.  94679.   120.   125.                        16862.
             3      35.   1143.    26.    26.                          228.
   899.42         1055.  95822.   146.   151.  1.03   -26.   120.  15843.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     102.
         WSEL     LEW     REW    AREA        K        Q    VEL
       899.42   -25.6   120.2  1054.9   95822.    6290.   5.96
 X STA.       -25.6        -6.3        -0.5         4.4         9.0        13.1
  A(I)             85.5        57.8        49.9        48.9        45.3
  V(I)             3.68        5.44        6.30        6.43        6.94

 X STA.        13.1        17.1        21.3        25.3        29.7        35.4
  A(I)             44.7        45.4        43.8        45.8        52.2
  V(I)             7.04        6.92        7.19        6.86        6.03

 X STA.        35.4        41.5        47.1        51.8        56.5        61.0
  A(I)             51.2        49.5        47.3        46.2        45.8
  V(I)             6.14        6.36        6.65        6.81        6.87

 X STA.        61.0        65.6        70.5        75.7        82.8       120.2
  A(I)             46.7        48.9        49.2        58.2        92.7
  V(I)             6.73        6.43        6.40        5.41        3.39
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File conc037.wsp
        Hydraulic analysis for structure CONCTH00010037   Date: 24-JUN-96
        Hydraulic Analysis of CONC037 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     645.   45149.     0.   155.                           0.
   897.13          645.   45149.     0.   155.  1.00     0.    71.      0.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA         K        Q    VEL
       897.13     0.0    70.8   645.1   45149.    6270.   9.72
X STA.         0.0         7.6        11.5        14.5        17.2        19.9
  A(I)             48.8        34.6        31.6        28.7        29.0
  V(I)             6.43        9.06        9.91       10.91       10.81

X STA.        19.9        22.6        25.6        28.5        31.5        34.5
  A(I)             28.7        29.5        29.1        29.5        29.3
  V(I)            10.92       10.64       10.79       10.64       10.68

X STA.        34.5        37.6        40.7        44.1        47.5        51.0
  A(I)             29.6        29.7        30.8        30.6        31.3
  V(I)            10.61       10.54       10.17       10.23       10.03

X STA.        51.0        54.4        57.9        61.2        65.0        70.8
  A(I)             30.8        31.8        31.1        34.5        46.0
  V(I)            10.18        9.87       10.06        9.08        6.81

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     102.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             2    1006.   92607.   120.   125.                      16525.
             3      32.    1013.    24.    25.                         204.
   899.30         1037.   93620.   144.   150.  1.03   -25.   119.  15541.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     102.
         WSEL     LEW     REW    AREA         K        Q    VEL
       899.30   -25.3   119.1  1037.5   93620.    6270.   6.04
X STA.       -25.3        -6.2        -0.5         4.5         8.9        13.1
  A(I)             84.4        55.2        50.6        46.7        45.8
  V(I)             3.72        5.68        6.20        6.71        6.84

X STA.        13.1        17.1        21.2        25.2        29.6        35.2
  A(I)             43.9        44.6        43.0        45.0        51.3
  V(I)             7.15        7.02        7.29        6.96        6.11

X STA.        35.2        41.3        46.9        51.7        56.3        60.9
  A(I)             50.5        48.6        46.6        45.6        46.4
  V(I)             6.20        6.45        6.73        6.88        6.75

X STA.        60.9        65.4        70.2        75.6        82.4       119.1
  A(I)             45.0        46.9        50.1        56.2        90.9
  V(I)             6.96        6.69        6.25        5.58        3.45
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        U.S. Geological Survey WSPRO Input File conc037.wsp
        Hydraulic analysis for structure CONCTH00010037   Date: 24-JUN-96
        Hydraulic Analysis of CONC037 over the Moose River    SAO
           *** RUN DATE & TIME: 06-24-96  15:55

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

EXITX:XS   ******   -34.     610.  1.06 *****  893.38  890.37   5030.  892.32
     -123. ******    73.   43940.  1.00 ***** *******    0.61    8.25

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.87     894.30     893.81

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   891.82     911.16    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   891.82     911.16     893.81

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

FULLV:FV     123.   -27.     461.  1.85  2.38  896.15  893.81   5030.  894.30
        0.   123.    69.   29784.  1.00  0.40    0.00    0.88   10.92
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  1.89

APPRO:AS     102.   -20.     732.  0.74  1.54  897.70 *******   5030.  896.96
      102.   102.    97.   56212.  1.00  0.00    0.00    0.48    6.88
         <<<<<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     123.     0.     405.  2.40  2.15  895.79  893.06   5030.  893.40
        0.   123.    71.   32991.  1.00  0.27    0.00    0.91   12.41

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  896.80 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      16.        <<<<<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      62.   -20.     720.  0.76  0.90  897.62  894.22   5030.  896.86
      102.    64.    96.   54804.  1.00  0.93    0.01    0.49    6.99

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.395  0.167   45504.    -1.    70.   896.17

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXITX:XS    -123.   -34.    73.   5030.   43940.     610.    8.25  892.32
   FULLV:FV       0.   -27.    69.   5030.   29784.     461.   10.92  894.30
   BRIDG:BR       0.     0.    71.   5030.   32991.     405.   12.41  893.40
   RDWAY:RG      16.**************      0.******************    1.00********
   APPRO:AS     102.   -20.    96.   5030.   54804.     720.    6.99  896.86

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -1.    70.   45504.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    890.37    0.61  882.59  907.72************  1.06  893.38  892.32
   FULLV:FV    893.81    0.88  886.03  911.16  2.38  0.40  1.85  896.15  894.30
   BRIDG:BR    893.06    0.91  885.71  897.13  2.15  0.27  2.40  895.79  893.40
   RDWAY:RG  ****************  898.76  917.65**********************************
   APPRO:AS    894.22    0.49  888.20  912.77  0.90  0.93  0.76  897.62  896.86
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File conc037.wsp
        Hydraulic analysis for structure CONCTH00010037   Date: 24-JUN-96
        Hydraulic Analysis of CONC037 over the Moose River    SAO
           *** RUN DATE & TIME: 06-24-96  15:55

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

EXITX:XS   ******   -36.     708.  1.23 *****  894.44  891.21   6290.  893.21
     -123. ******    75.   54943.  1.00 ***** *******    0.62    8.89

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.88     895.16     894.65

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   892.71     911.16    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   892.71     911.16     894.65

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

FULLV:FV     123.   -32.     545.  2.07  2.36  897.22  894.65   6290.  895.15
        0.   123.    71.   37482.  1.00  0.42   -0.01    0.88   11.53
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  1.87

APPRO:AS     102.   -22.     846.  0.87  1.54  898.76 *******   6290.  897.89
      102.   102.   106.   69911.  1.01  0.00    0.00    0.51    7.44
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   894.09     897.28     898.15     896.80

 ===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     123.     0.     645.  1.47 *****  898.60  893.93   6280.  897.13
        0. ******    71.   45149.  1.00 ***** *******    0.57    9.73

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.453 ******  896.80 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      16.    81.  0.35  0.57  899.64    0.00     38.  899.42

            Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     38.    26.   -82.   -56.   0.7   0.4   3.6   3.7   0.6   3.0
   RT:      0.   168.    33.   202.   3.2   2.0   8.2   8.2   3.0   3.1

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

APPRO:AS      62.   -26.    1055.  0.57  0.58  899.99  894.92   6290.  899.42
      102.    64.   120.   95823.  1.03  1.02    0.00    0.40    5.96

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS    -123.   -36.    75.   6290.   54943.     708.    8.89  893.21
   FULLV:FV       0.   -32.    71.   6290.   37482.     545.   11.53  895.15
   BRIDG:BR       0.     0.    71.   6280.   45149.     645.    9.73  897.13
   RDWAY:RG      16.*******    38.     38.       0.       0.    1.00  899.42
   APPRO:AS     102.   -26.   120.   6290.   95823.    1055.    5.96  899.42

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    891.21    0.62  882.59  907.72************  1.23  894.44  893.21
   FULLV:FV    894.65    0.88  886.03  911.16  2.36  0.42  2.07  897.22  895.15
   BRIDG:BR    893.93    0.57  885.71  897.13************  1.47  898.60  897.13
   RDWAY:RG  ****************  898.76  917.65  0.35******  0.57  899.64  899.42
   APPRO:AS    894.92    0.40  888.20  912.77  0.58  1.02  0.57  899.99  899.42
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File conc037.wsp
        Hydraulic analysis for structure CONCTH00010037   Date: 24-JUN-96
        Hydraulic Analysis of CONC037 over the Moose River    SAO
           *** RUN DATE & TIME: 06-24-96  15:55

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

EXITX:XS   ******   -36.     706.  1.23 *****  894.43  891.21   6270.  893.20
     -123. ******    75.   54767.  1.00 ***** *******    0.62    8.88

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.88     895.14     894.65

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   892.70     911.16    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   892.70     911.16     894.65

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

FULLV:FV     123.   -32.     545.  2.05  2.36  897.21  894.65   6270.  895.15
        0.   123.    71.   37482.  1.00  0.41    0.01    0.88   11.49
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  1.86

APPRO:AS     102.   -22.     844.  0.87  1.54  898.74 *******   6270.  897.88
      102.   102.   106.   69662.  1.01  0.00    0.00    0.51    7.43
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   894.08     897.26     898.13     896.80

 ===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     123.     0.     645.  1.41 *****  898.54  893.84   6150.  897.13
        0. ******    71.   45149.  1.00 ***** *******    0.56    9.53

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.448 ******  896.80 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      16.        <<<<<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      62.   -25.    1037.  0.59  0.60  899.88  894.90   6270.  899.30
      102.    64.   119.   93535.  1.03  1.02   -0.02    0.40    6.05

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   898.93

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -123.   -36.    75.   6270.   54767.     706.    8.88  893.20
   FULLV:FV       0.   -32.    71.   6270.   37482.     545.   11.49  895.15
   BRIDG:BR       0.     0.    71.   6150.   45149.     645.    9.53  897.13
   RDWAY:RG      16.**************      0.       0.       0.    1.00********
   APPRO:AS     102.   -25.   119.   6270.   93535.    1037.    6.05  899.30

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    891.21    0.62  882.59  907.72************  1.23  894.43  893.20
   FULLV:FV    894.65    0.88  886.03  911.16  2.36  0.41  2.05  897.21  895.15
   BRIDG:BR    893.84    0.56  885.71  897.13************  1.41  898.54  897.13
   RDWAY:RG   ****************  898.76  917.65************  0.59  899.52********
   APPRO:AS    894.90    0.40  888.20  912.77  0.60  1.02  0.59  899.88  899.30
```
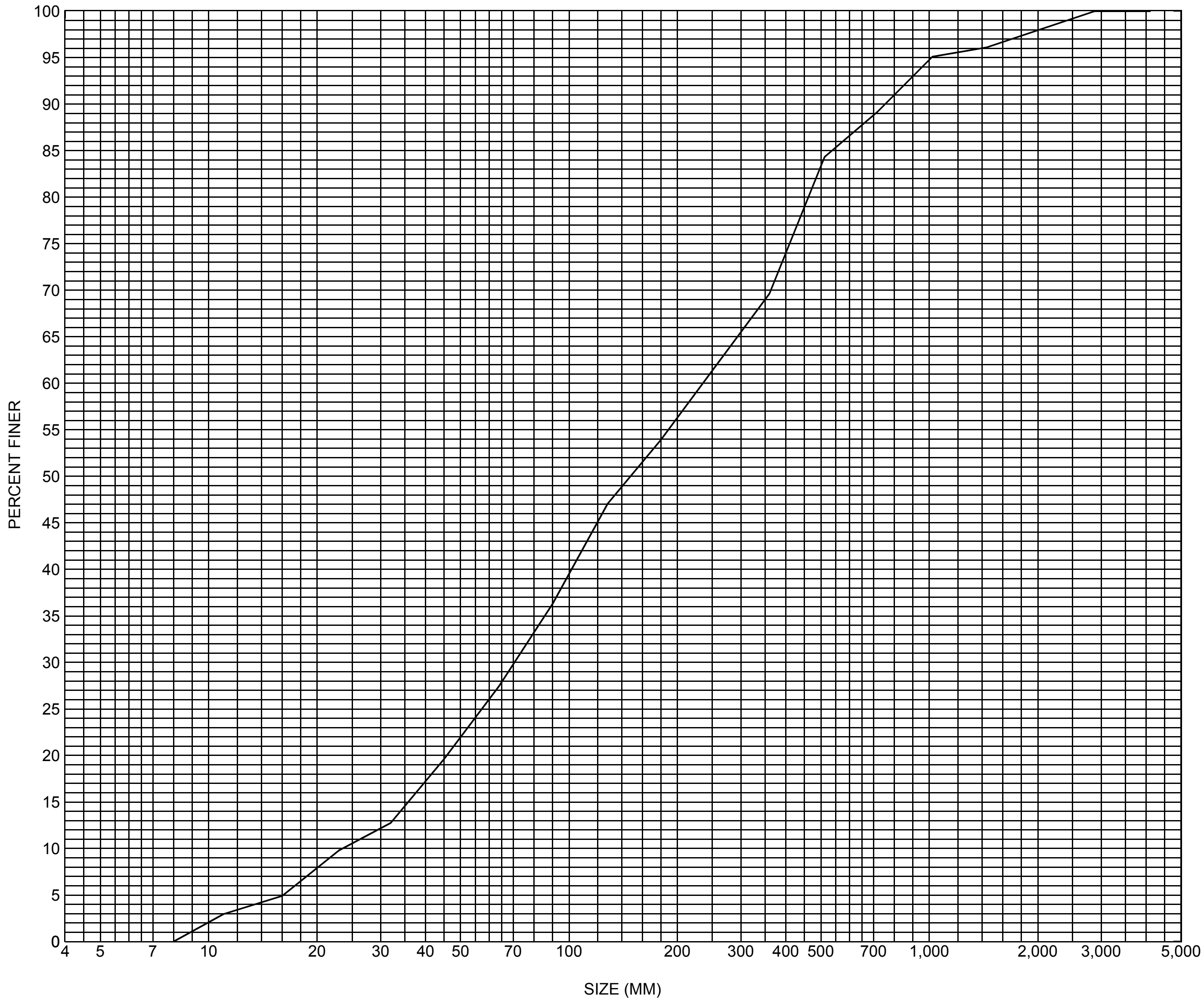

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CONCTH00010037, in Concord, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CONCTH00010037

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)* 001190

Waterway *(I - 6)* MOOSE RIVER

Road Name *(I - 7):* -

Route Number TH001

Vicinity *(I - 9)* FAS 277 1.2 MI N JCT U.S.2

Topographic Map Miles.Pond

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44290

Longitude *(i - 17; nnnnn.n)* 71518

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20027700370507

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

Maximum span length *(I - 48; nnnn)* 0075

Year built *(I - 27; YYYY)* 1933

Structure length *(I - 49; nnnnnn)* 000078

Average daily traffic, ADT *(I - 29; nnnnnn)* 000372

Deck Width *(I - 52; nn.n)* 210

Year of ADT *(I - 30; YY)* 91

Channel & Protection *(I - 61; n)* 7

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

Waterway adequacy *(I - 71; n)* 5

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*) 009.0

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

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

Comments:

The structural inspection report of 5/12/94 indicates the structure is a steel stringer type bridge with a concrete deck and an asphalt roadway surface. The abutments and wingwalls are concrete. On the left abutment an older portion of the footing is exposed. A new concrete subfooting is present in front of the older footing. The right abutment footing also is exposed for nearly its entire length. The footing concrete has some minor scaling reported. All four wingwalls are new virtually. The downstream end of the right abutment footing was poured directly on top of a few massive granite boulders. Both abutments reportedly are protected with heavy stone fill. The channel consists mainly of gravel **(Continued, page 33)**

Bridge Hydrologic Data

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

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} (*ft³/ 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 (*ft²*): -

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): -

Comments:

and boulders. The channel proceeds straight through the crossing. The water is brackish. The report notes some previous undermining at the left abutment, but no settling occurred apparently before the subfooting was installed. There is no streambank erosion or debris accumulation problems indicated.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **82.169** mi^2 Lake and pond area **3.01** mi^2
Watershed storage *(ST)* **3.66** %
Bridge site elevation **1013** ft Headwater elevation **3174** ft
Main channel length **22.03** mi
10% channel length elevation **1075** ft 85% channel length elevation **2060** ft
Main channel slope *(S)* **59.616** 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: **2/16/96**

Reviewd by: **SAO** Date: **12/3/96**

Structure Number **CONCTH00010037**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R. HAMMOND** Date *(MM/DD/YY)* **08** / **16** / 19**95**

2. Highway District Number **7** Mile marker **001190**

County **ESSEX 009** Town **CONCORD 15250**

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

Route Number **TH1** Hydrologic Unit Code: **01080102**

3. Descriptive comments:

FEDERAL AID SYSTEM 277, 1.2 MILES FROM JCT WITH US2
VERMONT PLATE ON DS BRIDGE CURB- STATE BRIDGE NUMBER 26

B. Bridge Deck Observations

4. Surface cover... LBUS **5** RBUS **6** LBDS **6** RBDS **6** Overall **6**
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*

5. Ambient water surface... US **2** UB **2** DS **2** *(**1**- pool; **2**- riffle)*

6. Bridge structure type **1** *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*

7. Bridge length **78** *(feet)* Span length **75** *(feet)* Bridge width **21.0** *(feet)*

Road approach to bridge:

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

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

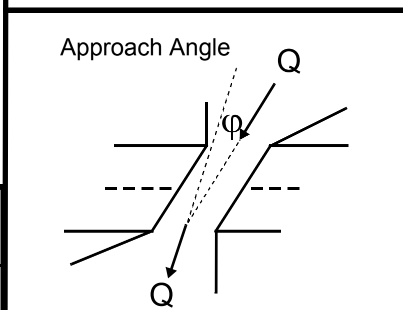
10. Embankment slope (*run / rise in feet / foot*):
US left ________ US right ________

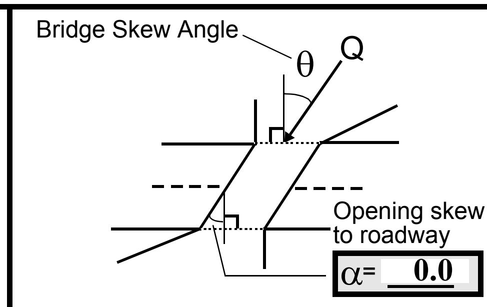
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	0	0
RBUS	1	1	0	0
RBDS	1	1	0	0
LBDS	2	1	0	0

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

Channel approach to bridge (BF):

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





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **20** feet **US** *(US, UB, DS)* to **10** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **3**
Range? **75** feet **DS** *(US, UB, DS)* to **200** feet **DS**

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

18. Bridge Type: 1a

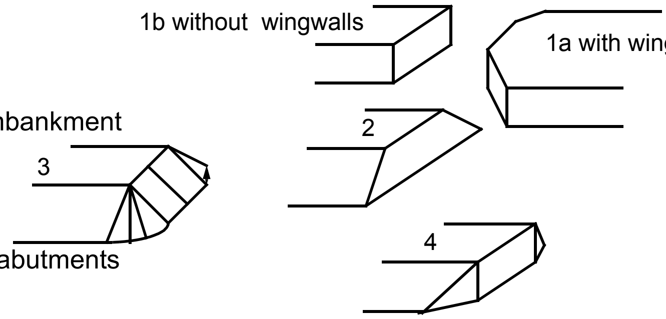
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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.)

#15 and #16: The US channel bends in from the LB then straightens into bridge. The channel bends to the left after exiting the bridge

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	4	4	54	54	0	0

23. Bank width 25.0   24. Channel width 20.0   25. Thalweg depth 112.5   29. Bed Material 543

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

SRD - Section ref. dist. to US face   *% Vegetation (Veg) cover: **1**- 0 to 25%; **2**- 26 to 50%; **3**- 51 to 75%; **4**- 76 to 100%*

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

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

*Bank protection types: **0**- absent; **1**- < 12 inches; **2**- < 36 inches; **3**- < 48 inches; **4**- < 60 inches; **5**- wall / artificial levee*

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

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

#30 and #31: bank protection from ends of wingwalls extends 35 feet US, LB and RB- good condition

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

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

37. Material: -

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

NO POINT BARS

Mid-channel bar due to bedrock outcrop starting 190 feet US to 135 feet US
Mid-channel bar 135 feet US to 20 feet US

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

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

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

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

NO CUT BANKS

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

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

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

NO CHANNEL SCOUR

local scour behind many boulders and along side of bedrock outcrop

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

51. Confluence 1: Distance 47 52. Enters on RB (LB or RB) 53. Type 1 (1- perennial; 2- ephemeral)

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

54. Confluence comments (eg. confluence name):

#53: flowing during visit

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
83.5		2.0		2	7	7	0

58. Bank width (BF) - 59. Channel width (Amb) - 60. Thalweg depth (Amb) 90.0 63. Bed Material 0

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.):

543

#62: LB abutment and footing exposed but is protected by large boulders

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

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

#65: small debris on LB above bridge

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	90	2	2	0	4	90.0
RABUT	1	0	90			2	2	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

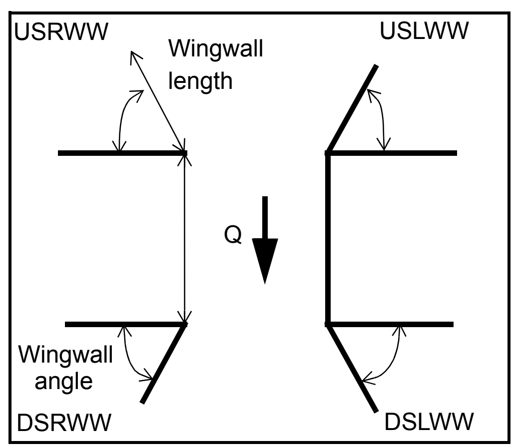
79. Abutment comments (eg. undermined penetration, unusual scour processes, debris, etc.):

0
1.5
1

#76: RB footing exposed max. 1.5 feet- DS buried
LB footing exposed max. 4 feet- minimum 1 foot (both ends)

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						71.0	
USRWW:	Y		1		0	2.5	
DSLWW:	0		-		Y	33.0	
DSRWW:	1		0		0	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	Y	0	1	1	1	--
Condition	Y	0	1	-	1	1	1	--
Extent	1	-	0	3	2	4	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

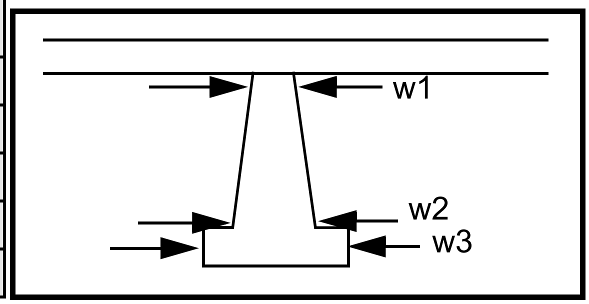
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

1
1
1
1
1
1

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				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)		-	-	-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type		-	-	-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material		-	-	-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape		-	-	-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?		-	-	-	*Y- yes; N- no*
91. Attack ∠ (BF)		-	-	-	
92. Pushed		-	-	-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles		-	-	-	
95. Cross-members		-	-	-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition		-	-	-	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	N	-	-	-	
98. Exposure depth	-	-	-	-	

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

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	NO	PIE	RS		

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

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

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

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

4
4
54
54
0
0
54
0
0
-
-
Bank protection at ends of wingwalls extends to 20 feet DS on RB and LB

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

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

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

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

Point bar extent: ______ feet ____ *(US, UB, DS)* to **N** feet **-** *(US, UB, DS)* positioned **NO** %LB to **DR** %RB

Material: **OP**

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

STRUCTURE

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

Cut bank extent: **200** feet **15** *(US, UB, DS)* to **75** feet **DS** *(US, UB, DS)*

Bank damage: **250** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
0
25
45

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

Scour dimensions: Length **bar** Width ______ Depth: _____ Positioned ____ %LB to **Y** %RB

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

RB
175
100
DS

Are there major confluences? **20** *(Y or if N type ctrl-n mc)* How many? **0**

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

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

Confluence comments (eg. confluence name):

off dirt and soil from between large boulders

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

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

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

N
-
-
-
-
-
-
NO CHANNEL SCOUR

local scour behind large boulders and between boulders where flow constriction occurs

N

109. G. Plan View Sketch

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

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: CONCTH00010037 Town: CONCORD
Road Number: TH1 County: ESSEX
Stream: MOOSE RIVER

Initials SAO Date: 11/13/96 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	5030	6290	6270
Main Channel Area, ft2	720	1020	1006
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0.5	35	32
Top width main channel, ft	114	120	120
Top width L overbank, ft	0	0	0
Top width R overbank, ft	1	26	24
D50 of channel, ft	0.486	0.486	0.486
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.3	8.5	8.4
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	0.5	1.3	1.3
Total conveyance, approach	54828	95822	93620
Conveyance, main channel	54827	94679	92607
Conveyance, LOB	0	0	0
Conveyance, ROB	1	1143	1013
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	5029.9	6215.0	6202.2
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	0.1	75.0	67.8
Vm, mean velocity MC, ft/s	7.0	6.1	6.2
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	0.2	2.1	2.1
Vc-m, crit. velocity, MC, ft/s	12.0	12.6	12.6
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

```
ARMORING
 D90                                 2.474    2.474    2.474
 D95                                 3.327    3.327    3.327
 Critical grain size,Dc, ft          1.3830   0.6598   0.6577
 Decimal-percent coarser than Dc     0.238    0.436    0.437
 Depth to armoring,ft                13.28    2.56     2.54
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            720      1020     1006
   Main channel width, ft            114      120      120
 y1, main channel depth, ft            6.32     8.50     8.38
 Bridge Section
   (Q) total discharge, cfs          5030     6290     6270
   (Q) discharge thru bridge, cfs    5030     6280     6270
   Main channel conveyance           33034    45149    45149
   Total conveyance                  33034    45149    45149
 Q2, bridge MC discharge,cfs         5030     6280     6270
   Main channel area, ft2            406      645      645
   Main channel width (skewed), ft   70.7     70.8     70.8
   Cum. width of piers in MC, ft     0.0      0.0      0.0
 W, adjusted width, ft               70.7     70.8     70.8
 y_bridge (avg. depth at br.), ft    5.74     9.11     9.11
 Dm, median (1.25*D50), ft           0.6075   0.6075   0.6075
 y2, depth in contraction,ft           5.52     6.67     6.66

 ys, scour depth (y2-ybridge), ft    -0.22    -2.44    -2.45


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                       5030     6290     6270
 Q, thru bridge, cfs                 5030     6280     6270
 Total Conveyance, bridge            33034    45149    45149
 Main channel(MC) conveyance, bridge 33034    45149    45149
 Q, thru bridge MC, cfs              5030     6280     6270
 Vc, critical velocity, ft/s         11.98    12.59    12.56
 Vc, critical velocity, m/s          3.65     3.84     3.83
 Main channel width (skewed), ft     70.7     70.8     70.8
 Cum. width of piers in MC, ft       0.0      0.0      0.0
 W, adjusted width, ft               70.7     70.8     70.8
 qbr, unit discharge, ft^2/s         71.1     88.7     88.6
 qbr, unit discharge, m^2/s          6.6      8.2      8.2
 Area of full opening, ft^2          406.0    645.0    645.0
 Hb, depth of full opening, ft       5.74     9.11     9.11
 Hb, depth of full opening, m        1.75     2.78     2.78
 Fr, Froude number, bridge MC        0        0.57     0.56
 Cf, Fr correction factor (<=1.0)    0.00     1.00     1.00
```

Elevation of Low Steel, ft	0	896.79	896.79
Elevation of Bed, ft	-5.74	887.68	887.68
Elevation of Approach, ft	0	899.42	899.3
Friction loss, approach, ft	0	0.58	0.6
Elevation of WS immediately US, ft	0.00	898.84	898.70
ya, depth immediately US, ft	5.74	11.16	11.02
ya, depth immediately US, m	1.75	3.40	3.36
Mean elevation of deck, ft	0	900.98	900.98
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	1.00	0.95	0.95
Ys, depth of scour, ft	0.00	-1.70	-1.71

Comparison of Chang and Laursen results (for unsubmerged orifice flow)

y2, from Laursen's equation, ft	5.520747	6.669498	6.660394
Full valley WSEL, ft	0	895.15	895.15
Full valley depth, ft	5.742574	7.470169	7.470169
Ys, depth of scour (y2-yfullv), ft	0	-0.80067	-0.80978

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	5030	6290	6270	5030	6290	6270
a', abut.length blocking flow, ft	19.8	25.6	25.3	25.3	49.4	48.3
Ae, area of blocked flow ft2	90.8	136.4	144.7	101.7	197.3	191.6
Qe, discharge blocked abut.,cfs	488.2	--	658.4	538.2	925.4	905.7
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	5.38	4.46	4.55	5.29	4.69	4.73
ya, depth of f/p flow, ft	4.59	5.33	5.72	4.02	3.99	3.97
--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	0.442	0.326	0.335	0.465	0.414	0.418
ys, scour depth, ft	14.32	15.16	16.08	14.37	16.79	16.68

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)	19.8	25.6	25.3	25.3	49.4	48.3
y1 (depth f/p flow, ft)	4.59	5.33	5.72	4.02	3.99	3.97
a'/y1	4.32	4.80	4.42	6.29	12.37	12.18
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.44	0.33	0.34	0.47	0.41	0.42
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	0.91	0.57	0.56	0.91	0.57	0.56
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5.74	9.11	9.11	5.74	9.11	9.11
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	1.83	1.77	ERR	1.83	1.77
Fr>0.8 (vertical abut.)	2.34	ERR	ERR	2.34	ERR	ERR
Fr<=0.8 (spillthrough abut.)	ERR	1.60	1.54	ERR	1.60	1.54
Fr>0.8 (spillthrough abut.)	2.07	ERR	ERR	2.07	ERR	ERR