LEVEL II SCOUR ANALYSIS FOR BRIDGE 32 (CONCTH00030032) on TOWN HIGHWAY 3, crossing the MOOSE RIVER, CONCORD, VERMONT

U.S. Geological Survey
Open-File Report 96-582

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
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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 32 (CONCTH00030032) ON TOWN HIGHWAY 3, 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 CONCTH00030032 on Town Highway 3 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 98.7-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is primarily grass with several houses and other buildings while the immediate channel banks have dense woody vegetation.

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 83 ft and an average channel depth of 3 ft. The predominant channel bed material is cobble with a median grain size (D_{50}) of 86.2 mm (0.283 ft). There are bedrock exposures downstream of the bridge. 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 3 crossing of the Moose River is a 96-ft-long, two-lane bridge consisting of two steel-beam spans (Vermont Agency of Transportation, written communication, March 24, 1995). The bridge is supported by vertical, concrete abutments with wingwalls and a concrete pier. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is 0 degrees.

The right upstream end of the pier is undermined by 1.3 feet. The footing of the right abutment is exposed by as much as 4.0 feet vertically. The footing of the downstream right wingwall is exposed 3.5 feet and the end of the wingwall has broken and fallen into the river. Type-3 stone fill (less than 48 inches diameter) has been placed at the end of the existing wingwall. 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 0.0 to 0.7 ft. Abutment scour ranged from 9.9 to 16.4 ft. Pier scour ranged from 14.4 to 16.2 ft. The worst-case contraction, abutment, and pier scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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 CONCTH00030032 ***Stream*** Moose River

County Essex ***Road*** TH3 ***District*** 7

Description of Bridge

Bridge length 96 ***ft*** ***Bridge width*** 27.2 ***ft*** ***Max span length*** 46 ***ft***

Alignment of bridge to road (on curve or straight) Right road approach is curved.

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

Stone fill on abutment? Yes ***Date of inspection*** 8/17/95

Description of stone fill Type-2 stone fill (less than 36 inches diameter) along the right abutment and upstream right wingwall. Type-3 stone fill along and the end of the downstream right wingwall.

Abutments and the pier are concrete. The upstream right end of the pier is undermined by 1.3 feet. The footing of the right abutment is exposed by 4 feet.

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 10

There is a sharp channel bend in the upstream reach. The bridge is at the end of the bend. Downstream of the bridge the channel is straight.

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) August 17, 1995. All of the flow is going under the bridge to the right of the pier.

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 terrace.

US left: Narrow, irregular terrace.

US right: Narrow, irregular flood terrace.

Description of the Channel

Average top width 83 *ft* ***Average depth*** 3 *ft*

Predominant bed material Cobbles/Boulders ***Bank material*** Cobbles/Boulders

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

8/17/95

Vegetative co

DS left: Lawn on overbank. Immediate channel bank is forested.

DS right: Field grasses with scattered trees and brush

US left: Lawn on overbank. Immediate channel bank is forested.

US right: Lawn on far overbank. Immediate channel bank is forested.

Do banks appear stable? Y

August 17, 1995. The river impacts the right abutment just upstream of the bridge. However, the bank is protected.

date of observation.

None, August 17, 1995.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 98.7 ***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 5,930 ***ft³/s*** ***Q500*** 7,570 ***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 a chiseled X on top of the upstream end of the right abutment (elev. 897.03 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the left abutment (elev. 896.54 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	-70	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	13	1	Road Grade section
APTEM	90	1	Approach section as surveyed (Used as a template)
APPRO	117	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 0.045 to 0.050, and overbank "n" values ranged from 0.040 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 0.00994 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 (0.011 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 897.7 *ft*
Average low steel elevation 894.0 *ft*

100-year discharge 5,930 *ft³/s*
Water-surface elevation in bridge opening 889.8 *ft*
Road overtopping? N *Discharge over road* 0 *ft³/s*
Area of flow in bridge opening 554 *ft²*
Average velocity in bridge opening 10.7 *ft/s*
Maximum WSPRO tube velocity at bridge 14.0 *ft/s*

Water-surface elevation at Approach section with bridge 891.8 *ft*
Water-surface elevation at Approach section without bridge 891.5 *ft*
Amount of backwater caused by bridge 0.3 *ft*

500-year discharge 7,570 *ft³/s*
Water-surface elevation in bridge opening 890.4 *ft*
Road overtopping? N *Discharge over road* 0 *ft³/s*
Area of flow in bridge opening 608 *ft²*
Average velocity in bridge opening 12.5 *ft/s*
Maximum WSPRO tube velocity at bridge 16.2 *ft/s*

Water-surface elevation at Approach section with bridge 893.1 *ft*
Water-surface elevation at Approach section without bridge 892.4 *ft*
Amount of backwater caused by bridge 0.7 *ft*

Incipient overtopping discharge -- *ft³/s*
Water-surface elevation in bridge opening -- *ft*
Area of flow in bridge opening -- *ft²*
Average velocity in bridge opening -- *ft/s*
Maximum WSPRO tube velocity at bridge -- *ft/s*

Water-surface elevation at Approach section with bridge -- *ft*
Water-surface elevation at Approach section without bridge -- *ft*
Amount of backwater caused by bridge -- *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 was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). For contraction scour computations, the average depth in the contracted section (AREA/TOPWIDTH) is subtracted from the depth of flow computed by the scour equation (Y2) to determine the actual amount of scour.

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. It should be noted that information found in Vermont Agency of Transportation files indicated that at least part of the right abutment is constructed on bedrock (see Appendix D).

Pier scour was computed by use of the Colorado State University Pier Scour Equation (Richardson and others, 1995, p. 36, equation 21). Two methods were used for determining variables for the scour computations of the pier and the most conservative answer used. The first method used the pier width and the velocity of the maximum velocity flow tube at the upstream face of the bridge in the equation. The second method used the width of the pier footing, since it was exposed, and the velocity at the exposed footing. The velocity at the exposed footing was a depth weighted estimate of the maximum velocity flow tube (Richardson and others, 1993, p. 41, equation 23).

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	0.7	--
Depth to armoring	7.1	13.2	--
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	9.9	11.7	--
Right abutment	14.3	16.4	--
Pier scour			
Pier 1	14.4	16.2	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	2.4	2.9	--
Right abutment	2.4	2.9	--
Piers:			
Pier 1	1.9	2.6	--
Pier 2	--	--	--
	--	--	--

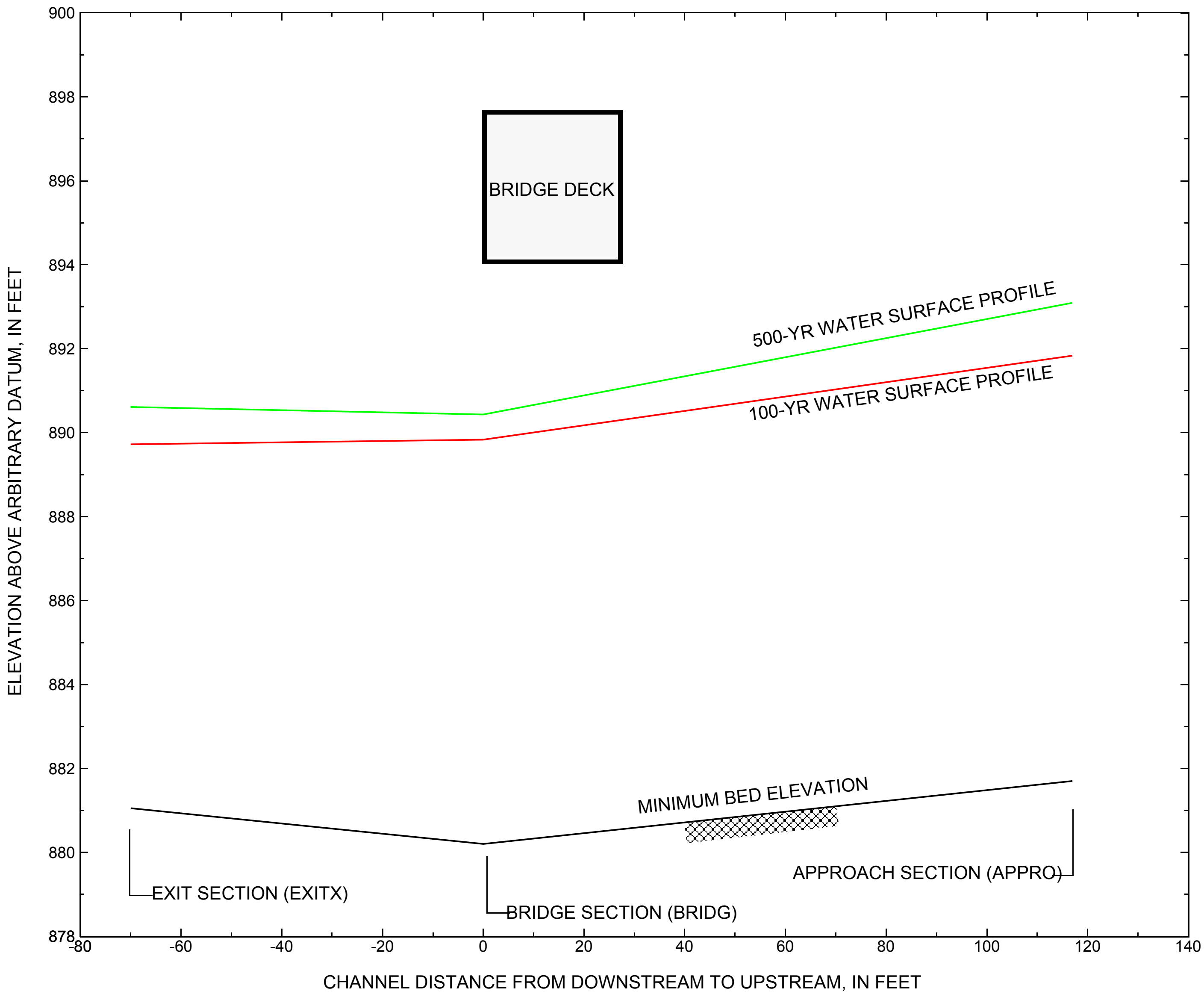

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CONCTH00030032 on Town Highway 3, crossing the Moose River, Concord, Vermont.

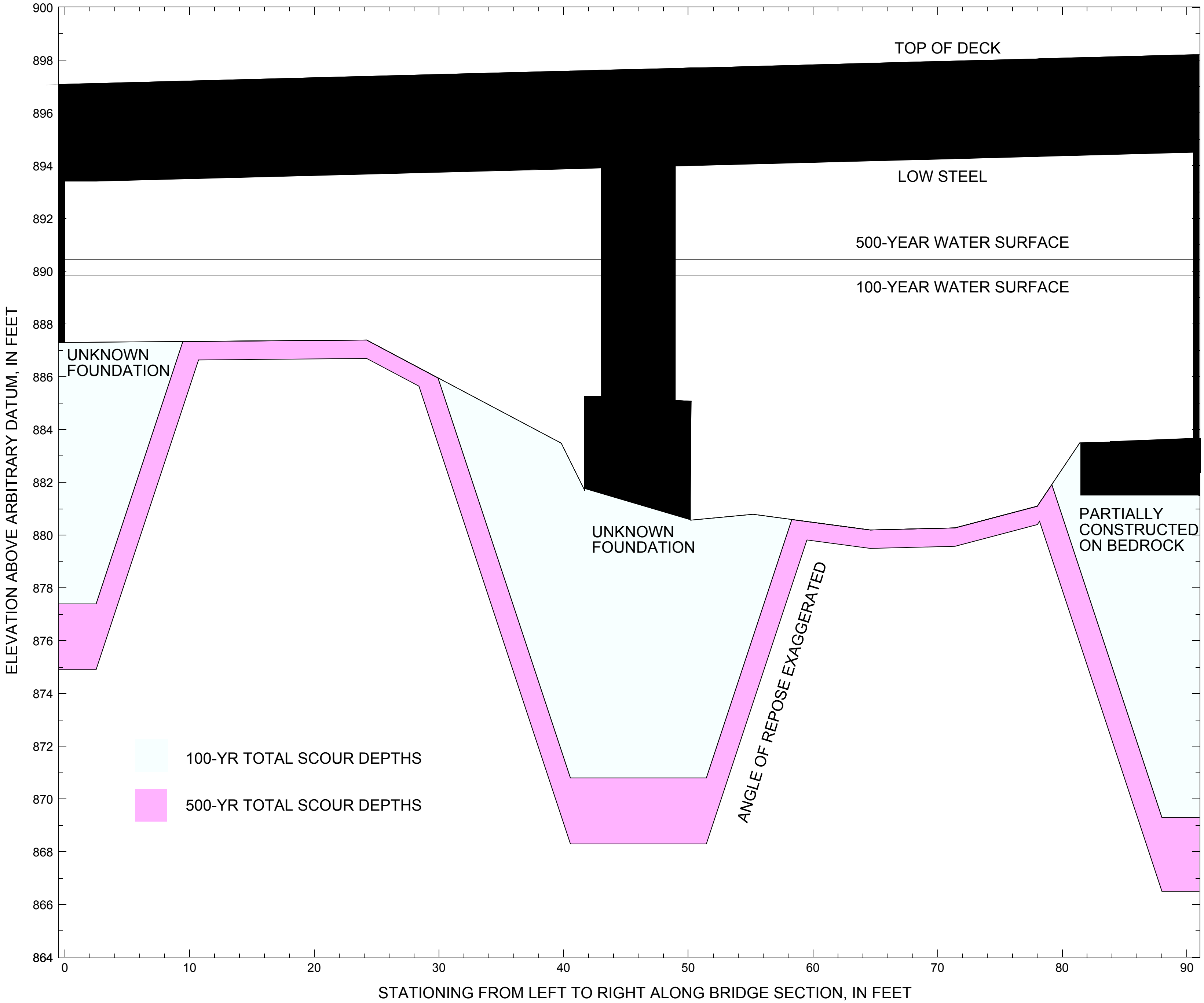

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CONCTH00030032 on Town Highway 3, crossing the Moose River, Concord, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CONCTH00030032 on Town Highway 3, 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 5,930 cubic-feet per second											
Left abutment	0.0	--	893.5	--	887.3	0.0	9.9	--	9.9	877.4	--
Pier	46.0	--	--	--	881.8	0.0	--	14.4	14.4	867.4	--
Right abutment	90.5	--	894.4	--	881.1	0.0	14.3	--	14.3	866.8	--

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 CONCTH00030032 on Town Highway 3, 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 7,570 cubic-feet per second											
Left abutment	0.0	--	893.5	--	887.3	0.7	11.7	--	12.4	874.9	--
Pier	46.0	--	--	--	881.8	0.7	--	16.2	16.9	864.9	--
Right abutment	90.5	--	894.4	--	881.1	0.7	16.4	--	17.1	864.0	--

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, 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 conc032.wsp
T2        Hydraulic analysis for structure CONCTH00030032   Date: 21-JUN-96
T3        Hydraulic Analysis of CONC032 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           5930 7570
SK          0.00994 0.00994
*
XS   EXITX    -70
GR         -310.3, 905.27   -231.5, 899.33   -208.0, 898.49   -112.5, 894.92
GR         -102.3, 892.03    -64.1, 891.34    -49.3, 889.38    -21.1, 888.16
GR          -20.4, 886.38     20.0, 885.70     30.0, 883.55     41.2, 881.51
GR           49.6, 881.07     58.6, 881.05     65.3, 881.14     75.6, 882.10
GR           81.4, 883.45     88.8, 883.41     94.5, 887.27     96.3, 889.90
GR          109.4, 892.36    124.6, 898.55    138.9, 900.29    210.2, 903.24
GR          246.0, 903.56    265.8, 916.01
N           0.055        0.050        0.040
SA                -64.1         124.6
*
XS   FULLV      0  * * *   0.011
*
BR   BRIDG     0 893.95
GR            0.0, 893.53      0.6, 887.25     24.2, 887.40     39.8, 883.49
GR           41.7, 881.69     46.1, 881.84     50.2, 880.57     55.2, 880.79
GR           64.6, 880.20     71.4, 880.28     78.0, 881.08     81.4, 883.53
GR           90.5, 883.64     90.5, 894.37      0.0, 893.53
N              0.045
CD           1 38.7 * * 72.5 3.9
PW            881.1,8.6 885.2,8.6 885.2,5.9 894.0,3.4
*
XR   RDWAY     13 27
GR         -339.1, 915.17   -322.3, 913.43   -315.4, 908.70   -252.3, 901.67
GR         -205.9, 900.05   -147.7, 896.52    -86.9, 895.91    -22.2, 896.32
GR            0.0, 897.08      0.0, 900.64     45.7, 901.08     90.6, 901.43
GR           93.8, 901.55     94.0, 898.22    132.4, 898.55    212.9, 903.62
GR          285.4, 915.03
*
XT   APTEM     90
GR         -387.0, 915.39   -360.2, 913.25   -297.4, 905.61   -216.7, 900.00
GR         -179.1, 896.51   -101.8, 895.49    -50.0, 894.38    -29.3, 892.47
GR          -20.0, 890.23      5.9, 887.10     13.4, 884.61     19.6, 884.40
GR           26.2, 883.23     38.0, 883.46     54.4, 883.60     60.2, 882.84
GR           69.8, 881.40     77.5, 881.86     85.3, 883.60     97.4, 886.40
GR          108.8, 887.90    135.1, 898.45    188.7, 902.48    214.5, 915.21
*
AS   APPRO    117
GT           0.30
N           0.055        0.045        0.045
SA                 -29.3        135.1
*
HP 1 BRIDG    889.83 1 889.83
HP 2 BRIDG    889.83 * * 5930
HP 2 BRIDG    890.35 * * 5930
HP 1 APPRO    891.83 1 891.83
HP 2 APPRO    891.83 * * 5930
*
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
         U.S. Geological Survey WSPRO Input File conc032.wsp
         Hydraulic analysis for structure CONCTH00030032   Date: 21-JUN-96
         Hydraulic Analysis of CONC032 over the Moose River    SAO
            *** RUN DATE & TIME: 06-24-96  09:07
     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1     554.   57069.    90.   101.                        7792.
    889.83          554.   57069.    90.   101.  1.00     0.    91.   7792.

     VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
          WSEL     LEW     REW    AREA        K        Q    VEL
        889.83     0.4    90.5   554.0   57069.    5930.  10.70
 X STA.        0.4       22.0       34.6       40.5       44.2       47.6
   A(I)            54.0       44.4       34.1       29.8       27.3
   V(I)            5.49       6.68       8.70       9.96      10.85

 X STA.       47.6       50.5       53.1       55.6       58.2       60.5
   A(I)            25.6       23.8       23.2       23.0       22.0
   V(I)           11.59      12.47      12.76      12.87      13.47

 X STA.       60.5       62.8       65.0       67.2       69.5       71.7
   A(I)            21.6       21.2       21.1       21.4       21.8
   V(I)           13.72      13.95      14.02      13.84      13.62

 X STA.       71.7       74.1       76.6       79.6       83.9       90.5
   A(I)            21.8       22.8       25.3       28.9       40.8
   V(I)           13.60      13.03      11.73      10.28       7.26

     VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
          WSEL     LEW     REW    AREA        K        Q    VEL
        890.35     0.3    90.5   600.8   64898.    5930.   9.87
 X STA.        0.3       18.0       32.0       38.5       42.9       46.3
   A(I)            53.3       49.2       37.2       33.8       29.3
   V(I)            5.56       6.03       7.97       8.76      10.11

 X STA.       46.3       49.4       52.1       54.7       57.3       59.8
   A(I)            27.5       26.4       25.4       24.6       24.2
   V(I)           10.76      11.23      11.67      12.07      12.25

 X STA.       59.8       62.1       64.4       66.7       69.0       71.4
   A(I)            23.6       23.2       23.2       23.0       23.8
   V(I)           12.55      12.76      12.77      12.87      12.46

 X STA.       71.4       73.8       76.4       79.5       83.9       90.5
   A(I)            23.9       25.0       27.9       31.5       44.6
   V(I)           12.39      11.86      10.62       9.40       6.65

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     117.
      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              2     871.   95101.   143.   146.                       12194.
    891.83          871.   95101.   143.   146.  1.00   -25.   118.  12194.

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     117.
          WSEL     LEW     REW    AREA        K        Q    VEL
        891.83   -25.4   117.8   871.3   95101.    5930.   6.81
 X STA.      -25.4        6.6       15.8       22.3       27.7       32.6
   A(I)            81.0       55.9       47.0       43.1       40.8
   V(I)            3.66       5.30       6.31       6.88       7.26

 X STA.       32.6       37.5       42.3       47.1       51.8       56.6
   A(I)            39.5       38.4       38.5       37.9       38.0
   V(I)            7.50       7.72       7.70       7.83       7.80

 X STA.       56.6       60.8       64.8       68.4       71.8       75.3
   A(I)            35.9       36.0       34.6       34.7       34.8
   V(I)            8.27       8.23       8.56       8.55       8.52

 X STA.       75.3       79.1       83.5       89.1       97.0      117.8
   A(I)            36.5       39.0       43.0       48.4       68.3
   V(I)            8.13       7.60       6.89       6.12       4.34
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File conc032.wsp
        Hydraulic analysis for structure CONCTH00030032   Date: 21-JUN-96
        Hydraulic Analysis of CONC032 over the Moose River    SAO
           *** RUN DATE & TIME: 06-24-96  09:07
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     608.   66133.    90.   102.                        8959.
   890.43          608.   66133.    90.   102.  1.00     0.    91.   8959.

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       890.43     0.3    90.5   608.1   66133.    7570.  12.45
 X STA.        0.3       17.9       31.6       38.3       42.8       46.1
   A(I)            54.6       48.5       38.2       34.6       29.0
   V(I)            6.94       7.81       9.91      10.94      13.04

 X STA.       46.1       49.2       51.9       54.6       57.2       59.6
   A(I)            28.2       26.2       25.8       25.3       24.1
   V(I)           13.40      14.46      14.69      14.98      15.71

 X STA.       59.6       62.0       64.4       66.7       69.0       71.3
   A(I)            24.0       23.6       23.6       23.4       24.2
   V(I)           15.76      16.03      16.03      16.15      15.64

 X STA.       71.3       73.8       76.4       79.4       83.9       90.5
   A(I)            24.4       25.4       27.6       32.1       45.3
   V(I)           15.54      14.88      13.70      11.79       8.35

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       890.94     0.2    90.5   654.1   74189.    7570.  11.57
 X STA.        0.2       15.8       29.3       36.5       41.6       45.0
   A(I)            56.1       51.2       41.1       38.0       31.2
   V(I)            6.74       7.40       9.22       9.95      12.13

 X STA.       45.0       48.2       51.1       53.7       56.4       58.9
   A(I)            30.5       28.9       27.1       27.0       26.5
   V(I)           12.39      13.11      13.96      14.02      14.30

 X STA.       58.9       61.4       63.8       66.2       68.6       71.0
   A(I)            25.9       25.5       25.6       25.4       25.6
   V(I)           14.59      14.83      14.80      14.90      14.78

 X STA.       71.0       73.5       76.2       79.3       83.8       90.5
   A(I)            26.4       27.6       30.1       35.5       48.9
   V(I)           14.35      13.72      12.55      10.67       7.75

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     117.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       1.       4.     3.     3.                           1.
             2    1057.  126934.   150.   153.                       15903.
   893.09         1057.  126939.   154.   156.  1.00   -33.   121.  15728.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     117.
         WSEL     LEW     REW    AREA        K        Q    VEL
       893.09   -32.8   121.0  1057.4  126939.    7570.   7.16
 X STA.      -32.8        1.2       12.2       19.1       25.0       30.2
   A(I)            95.5       67.6       56.6       52.2       49.3
   V(I)            3.96       5.60       6.69       7.25       7.68

 X STA.       30.2       35.2       40.3       45.3       50.2       55.1
   A(I)            47.9       47.2       46.3       45.6       45.4
   V(I)            7.91       8.02       8.17       8.30       8.33

 X STA.       55.1       59.8       64.1       68.0       71.8       75.6
   A(I)            44.9       43.6       42.5       42.6       42.8
   V(I)            8.42       8.69       8.91       8.89       8.83

 X STA.       75.6       79.8       84.6       90.5       99.1      121.0
   A(I)            44.7       47.8       51.5       60.1       83.3
   V(I)            8.46       7.92       7.35       6.29       4.55
```

```
        U.S. Geological Survey WSPRO Input File conc032.wsp
        Hydraulic analysis for structure CONCTH00030032   Date: 21-JUN-96
        Hydraulic Analysis of CONC032 over the Moose River    SAO
           *** RUN DATE & TIME: 06-24-96  09:07

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

EXITX:XS   ******   -52.     713.  1.07 *****  890.80  888.15   5930.  889.72
      -70. ******    96.   59478.  1.00 ***** *******    0.67    8.31

FULLV:FV      70.   -51.     702.  1.11  0.71  891.53 *******   5930.  890.42
        0.    70.    96.   58112.  1.00  0.02    0.00    0.68    8.44
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  1.52

APPRO:AS     117.   -24.     828.  0.80  0.80  892.32 *******   5930.  891.53
      117.   117.   117.   88217.  1.00  0.00   -0.01    0.52    7.16
         <<<<<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      70.     0.     554.  1.78  0.72  891.61  889.35   5930.  889.83
        0.    70.    91.   57077.  1.00  0.09    0.00    0.76   10.70

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   0.   1.  1.000  0.107  893.95 ****** ****** ******

    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      78.   -25.     871.  0.72  0.52  892.55  889.08   5930.  891.83
      117.    81.   118.   95078.  1.00  0.42    0.01    0.49    6.81

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.361  0.053   89868.    -2.    88.  891.48

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

  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -70.   -52.    96.   5930.   59478.     713.    8.31  889.72
   FULLV:FV       0.   -51.    96.   5930.   58112.     702.    8.44  890.42
   BRIDG:BR       0.     0.    91.   5930.   57077.     554.   10.70  889.83
   RDWAY:RG      13.**************      0.******************    1.00********
   APPRO:AS     117.   -25.   118.   5930.   95078.     871.    6.81  891.83

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -2.    88.   89868.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX     HF     HO   VHD      EGL    WSEL
   EXITX:XS    888.15    0.67  881.05  916.01************  1.07  890.80  889.72
   FULLV:FV  ********    0.68  881.82  916.78  0.71  0.02  1.11  891.53  890.42
   BRIDG:BR    889.35    0.76  880.20  894.37  0.72  0.09  1.78  891.61  889.83
   RDWAY:RG  ****************  895.91  915.17*********************************
   APPRO:AS    889.08    0.49  881.70  915.69  0.52  0.42  0.72  892.55  891.83
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File conc032.wsp
        Hydraulic analysis for structure CONCTH00030032   Date: 21-JUN-96
        Hydraulic Analysis of CONC032 over the Moose River    SAO
           *** RUN DATE & TIME: 06-24-96  09:07

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

EXITX:XS   ******   -59.     849.  1.24 *****  891.84  889.15   7570.  890.61
      -70. ******   100.   75889.  1.00 ***** *******    0.68    8.92

FULLV:FV      70.   -58.     836.  1.27  0.71  892.57 *******   7570.  891.30
        0.    70.   100.   74374.  1.00  0.02    0.00    0.69    9.05
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPRO"     KRATIO =  1.47

APPRO:AS     117.   -28.     957.  0.97  0.83  893.39 *******   7570.  892.42
      117.   117.   119.  109098.  1.00  0.00   -0.01    0.55    7.91
         <<<<<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      70.     0.     608.  2.41  0.80  892.84  890.29   7570.  890.43
        0.    70.    91.   66103.  1.00  0.19   -0.01    0.85   12.45

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   0.   1.  1.000  0.102  893.95 ****** ****** ******

    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      78.   -33.    1058.  0.80  0.55  893.89  889.93   7570.  893.09
      117.    80.   121.  126969.  1.00  0.51    0.02    0.48    7.16

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.386  0.085  115608.    -2.    88.   892.77

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

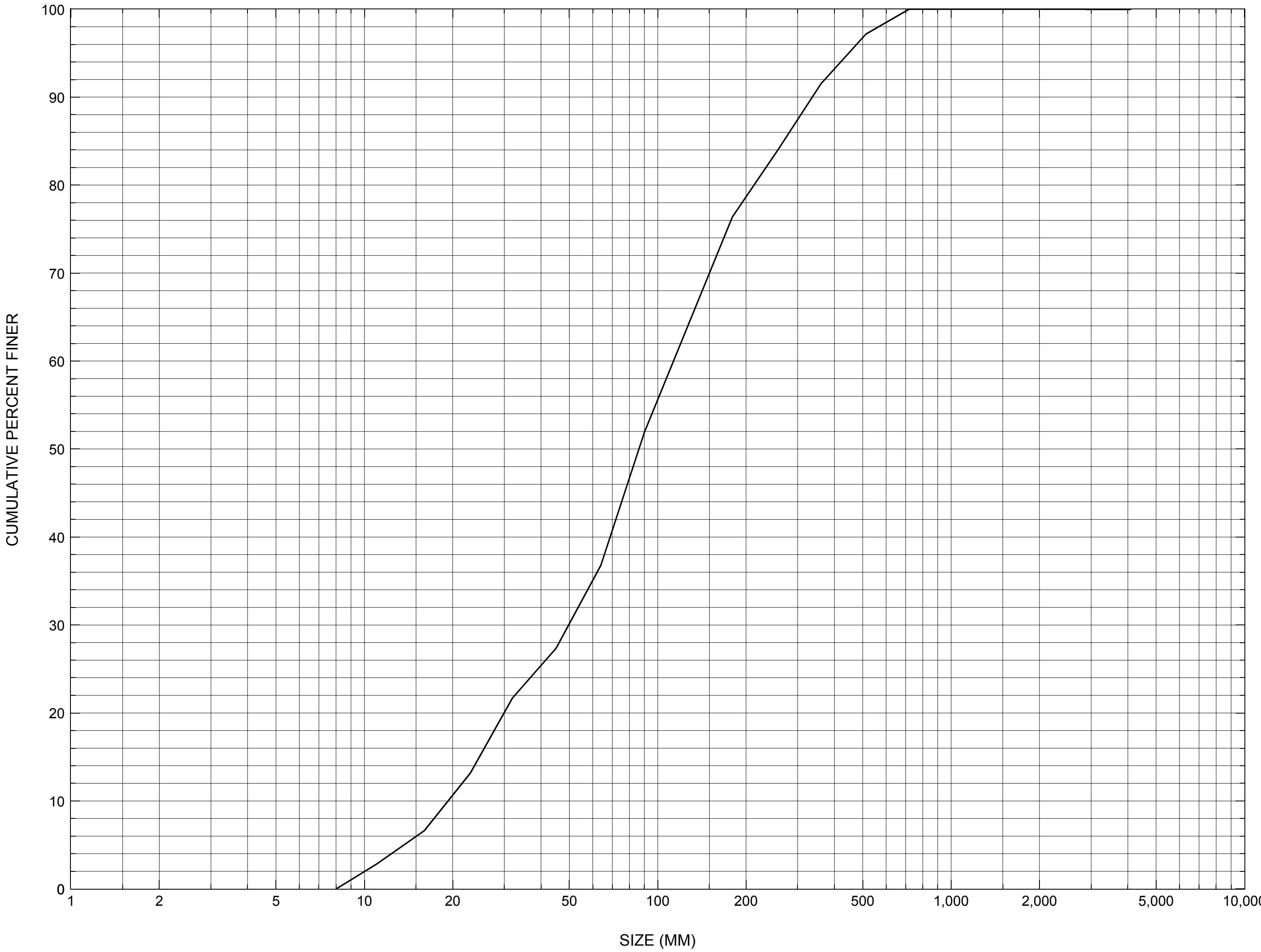
  FIRST USER DEFINED TABLE.
    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
    EXITX:XS     -70.   -59.   100.   7570.   75889.     849.    8.92  890.61
    FULLV:FV       0.   -58.   100.   7570.   74374.     836.    9.05  891.30
    BRIDG:BR       0.     0.    91.   7570.   66103.     608.   12.45  890.43
    RDWAY:RG      13.**************       0.******************    1.00********
    APPRO:AS     117.   -33.   121.   7570.  126969.    1058.    7.16  893.09

    XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS      -2.    88.  115608.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
    EXITX:XS    889.15    0.68  881.05  916.01************  1.24  891.84  890.61
    FULLV:FV  ********    0.69  881.82  916.78  0.71  0.02  1.27  892.57  891.30
    BRIDG:BR    890.29    0.85  880.20  894.37  0.80  0.19  2.41  892.84  890.43
    RDWAY:RG  ****************  895.91  915.17********************************
    APPRO:AS    889.93    0.48  881.70  915.69  0.55  0.51  0.80  893.89  893.09
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for one pebble count transect in the channel approach of structure CONCTH00030032, in Concord, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CONCTH00030032

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 TH003

Vicinity *(I - 9)* 0.07 MI TO JCT W US2

Topographic Map Concord

Hydrologic Unit Code: 01080102

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

Longitude *(i - 17; nnnnn.n)* 71533

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10050700320507

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

Maximum span length *(I - 48; nnnn)* 0046

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

Structure length *(I - 49; nnnnnn)* 000096

Average daily traffic, ADT *(I - 29; nnnnnn)* 000220

Deck Width *(I - 52; nn.n)* 272

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

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

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

Number of spans *(I - 45; nnn)* 002

Vertical clearance from streambed (*nnn.n ft*) 011.7

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 and an asphalt roadway surface. The abutment walls and wingwalls are concrete. The concrete footing is exposed with small voids under the footing on the right abutment. The face of the right abutment and its right upstream wingwall have fine cracks, leaks, and surface spalling noted overall. There also is a random vertical crack near the centerline of the roadway. The left abutment and its wingwalls have minor cracks and leaks. There is a solid concrete pier. The pier footing has a deep spall on the right side near the roadway centerline with minor cracks and small spalls **(Continued, page 31)**

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:

elsewhere. At present, all of the flow is through the right span. Under the left span there is a partially vegetated coarse gravel and sand point bar. The right abutment is partially constructed into bedrock. Some "boulder stone fill" is noted placed at the ends of both right wingwalls. Some of the stone fill is evident on the embankments up- and downstream.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **98.718** mi^2 Lake and pond area **3.179** mi^2

Watershed storage *(ST)* **3.22** %

Bridge site elevation **859** ft Headwater elevation **3174** ft

Main channel length **26.803** mi

10% channel length elevation **970** ft 85% channel length elevation **1960** ft

Main channel slope *(S)* **49.248** 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: RB Date: 2/6/96

Computerized by: RB Date: 2/5/96

Reviewd by: SAO Date: 9/17/96

Structure Number CONCTH00030032

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* L. MEDALIE Date *(MM/DD/YY)* 8 / 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 TH3 Hydrologic Unit Code: 01080102

3. Descriptive comments:

Structure located 0.07 miles from junction of TH3 with US 2
Upstream right end of rail has a VT plaque stating bridge 54

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 6 LBDS 6 RBDS 4 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 1 DS 2 *(**1**- pool; **2**- riffle)*

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

7. Bridge length 96 *(feet)* Span length 46 *(feet)* Bridge width 27.2 *(feet)*

Road approach to bridge:

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

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

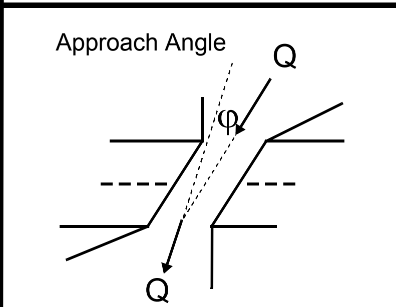
10. Embankment slope (*run / rise in feet / foot*):
US left ________ US right ________

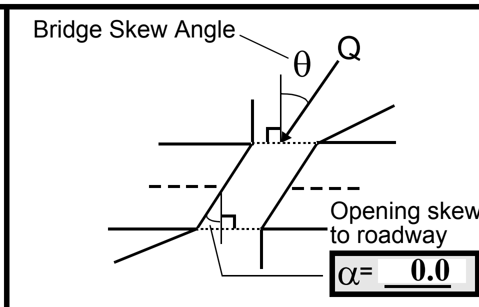
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	2	1	0	-
RBDS	2	1	0	-
LBDS	0	-	0	-

*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: 10





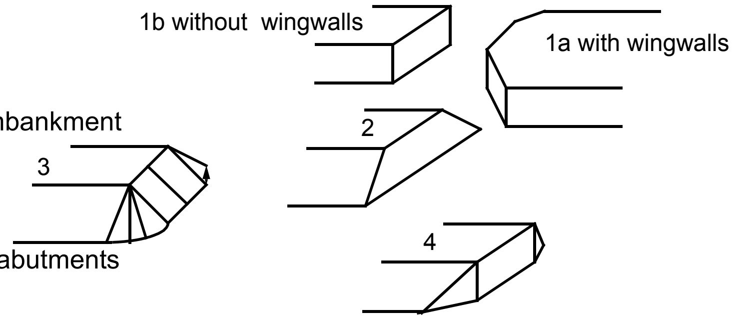
17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 2
Range? 5 feet US *(US, UB, DS)* to 100 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 3
Range? 220 feet US *(US, UB, DS)* to 310 feet US

*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.)

7. Measured bridge length is 95.7 feet, span length is 91.5 feet, and deck width is 26.9 feet. Values reported in #7 are from VT AOT files.
4. RBDS and LBUS have several suburban features such as paved road, houses, big lawns, plus trees., but the immediate banks are forested.
11. Historical form indicates protection on embankments on the right side both US and DS also at the ends of the wingwalls.

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
63.0	2.5			3.0	3	4	453	543	0	0

23. Bank width **20.0** 24. Channel width **15.0** 25. Thalweg depth **91.5** 29. Bed Material **45**

30 .Bank protection type: LB **0** RB **1** 31. Bank protection condition: LB **-** 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.):
Right bank protection extends from bridge face to 125 feet upstream.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 95 35. Mid-bar width: 25

36. Point bar extent: 180 feet US (US, UB) to 5 feet DS (US, UB, DS) positioned 5 %LB to 30 %RB

37. Material: 4

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

Difficult to discern where point bar ends (at US end) and where it is just sloping bank into the stream, the extent is determined at greatest change in slope.

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

41. Mid-bank distance: 250 42. Cut bank extent: 160 feet US (US, UB) to 310 feet US (US, UB, DS)

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

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

Protection on right bank appears to have prevented cut banks at impact zone 1.

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.):

There is local scour around boulders.

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):

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
72.0		1.0		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.):

54

63. Some stones placed in channel to protect the pier.

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	0	-	-	90.0
RABUT	1	10	90			2	2	90.0

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.):

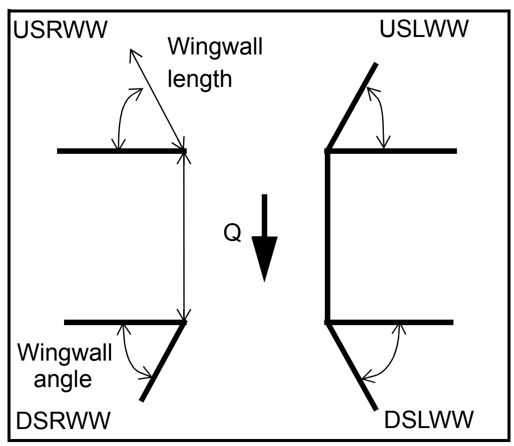
-
4
1

76. RABUT footing exposure ranges from 2.5 feet at US end to 4 feet DS.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						90.0	
USRWW:	Y		1		0	3.5	
DSLWW:	-		-		Y	27.5	
DSRWW:	1		0		-	24.0	

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



82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	-	0	Y	-	-	1	-	1
Condition	Y	-	1	3.5	-	1	-	1
Extent	1	-	2	0	2	0	2	-

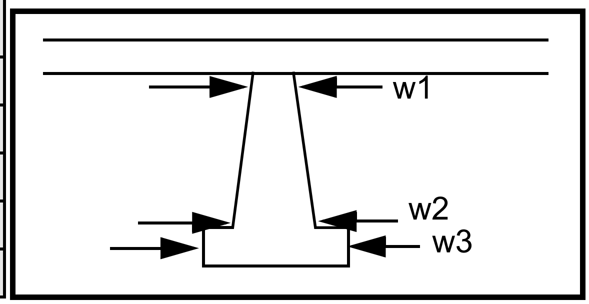
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
0
-
-
3
1
3

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		**9.0**		**70.0**	**75.0**	**18.0**
Pier 2				**90.0**	**13.5**	**45.0**
Pier 3	**9.0**		**5.87**	**3.40**	**894.0**	**885.2**
Pier 4	**8.56**	**-**	**-**	**881.1**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**LW**	**mod-**	**n**	**der**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**W**	**erate**	**into**	**stone**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**strea**	**ero-**	**the**	**fill.**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**mwa**	**sion.**	**strea**	**The**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**rd**	**DSR**	**m**	**foot-**	*Y- yes; N- no*
91. Attack ∠ (BF)	**face**	**WW**	**and**	**ing is**	
92. Pushed	**and**	**end**	**has**	**expo**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**end**	**has**	**been**	**sed**	
95. Cross-members	**of**	**faile**	**repla**	**3.5**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**wing**	**d**	**ced**	**feet**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**wall**	**and**	**with**	**at**	
98. Exposure depth	**have**	**falle**	**boul-**	**the**	

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

corner with the right abutment, 2.5 feet at the DS end.

Y

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
-	-			-	MC	M	1	2	3	Y

Bank width (BF) - Channel width (Amb) - Thalweg depth (Amb) - Bed Material 5

Bank protection type (Qmax): LB RB RB UN Bank protection condition: LB K RB 0

*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
2.3
4.8
-
-
-
-
-
-
-
-
-
-
-
-

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

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

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

-
-
-
-
-
-

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

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

Material: -_____

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

-
-
-
-

Is a cut-bank present? -____ *(Y or if N type ctrl-n cb)* Where? -_____ *(LB or RB)* Mid-bank distance: **98.**__

Cut bank extent: **The**__ feet **ma**__ *(US, UB, DS)* to **ximu** feet **m**___ *(US, UB, DS)*

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

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

dermining is on the upstream right side of the pier. The footing thickness is 3.5 feet, thus, the actual undermining is 1.3 feet depth. Penetration under the footing is 1.5 feet.
The left side is undermined along the nose 3 inches deep and with 3 inches of penetration.

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

Scour dimensions: Length ______ Width ______ Depth: _____ Positioned ____ %LB to **4**___ %RB

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

3
4
654
0

Are there major confluences? **1**___ *(Y or if N type ctrl-n mc)* How many? **65**___

Confluence 1: Distance **0**____ Enters on **2**____ *(LB or RB)* Type -_____ *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance **1**____ Enters on **Rig**__ *(LB or RB)* Type **ht**___ *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

bank protection extends to 25 feet, then there is some bedrock exposed.

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

__1__- Constructed
__2__- Stable
__3__- Aggraded
__4__- Degraded
__5__- Laterally unstable
__6__- Vertically and laterally unstable

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

N

109. G. Plan View Sketch

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: CONCTH00030032 Town: Concord
Road Number: TH3 County: Essex
Stream: Moose River

Initials SAO Date: 6/26/96 Checked:

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	5930	7570	0
Main Channel Area, ft2	871	1057	0
Left overbank area, ft2	0	1	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	143	150	0
Top width L overbank, ft	0	3	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.283	0.283	0
D50 left overbank, ft	--	--	0
D50 right overbank, ft	--	--	0
y1, average depth, MC, ft	6.1	7.0	ERR
y1, average depth, LOB, ft	ERR	0.3	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	95101	126939	0
Conveyance, main channel	95101	126934	0
Conveyance, LOB	0	4	0
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0008	ERR
Qm, discharge, MC, cfs	5930.0	7569.7	ERR
Ql, discharge, LOB, cfs	0.0	0.2	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	6.8	7.2	ERR
Vl, mean velocity, LOB, ft/s	ERR	0.2	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	9.9	10.2	N/A
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	N/A
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	N/A

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?			
Main Channel	0	0	N/A
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	871	1057	0
Main channel width, ft	143	150	0
y1, main channel depth, ft	6.09	7.05	ERR

Bridge Section			
(Q) total discharge, cfs	5930	7570	0
(Q) discharge thru bridge, cfs	5930	7570	
Main channel conveyance	57077	66103	
Total conveyance	57077	66103	
Q2, bridge MC discharge,cfs	5930	7570	ERR
Main channel area, ft2	554	608	0
Main channel width (skewed), ft	90.1	90.2	0.0
Cum. width of piers in MC, ft	5.8	5.8	0.0
W, adjusted width, ft	84.3	84.4	0
y_bridge (avg. depth at br.), ft	6.57	7.20	ERR
Dm, median (1.25*D50), ft	0.35375	0.35375	0
y2, depth in contraction,ft	6.38	7.86	ERR
ys, scour depth (y2-ybridge), ft	-0.19	0.65	N/A

ARMORING			
D90	1.103	1.103	--
D95	1.468	1.468	--
Critical grain size,Dc, ft	0.6486	0.8406	ERR
Decimal-percent coarser than Dc	0.216	0.16	
Depth to armoring,ft	7.06	13.24	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)

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	5930	7570	0	5930	7570	0
a', abut.length blocking flow, ft	25.8	33.1	0	27.3	30.5	0
Ae, area of blocked flow ft2	65.3	93	0	108.1	143.4	0
Qe, discharge blocked abut.,cfs	239.1	368.5	0	540.5	757	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.66	3.96	ERR	5.00	5.28	ERR
ya, depth of f/p flow, ft	2.53	2.81	ERR	3.96	4.70	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0	0.82	0.82	0
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	0	90	90	0
K2	1.00	1.00	0.00	1.00	1.00	0.00
Fr, froude number f/p flow	0.406	0.417	ERR	0.443	0.429	ERR
ys, scour depth, ft	9.90	11.66	N/A	14.25	16.37	N/A

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)	25.8	33.1	0	27.3	30.5	0
y1 (depth f/p flow, ft)	2.53	2.81	ERR	3.96	4.70	ERR
a'/y1	10.19	11.78	ERR	6.89	6.49	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.41	0.42	N/A	0.44	0.43	N/A
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	0.76	0.85		0.76	0.85	
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	6.57	7.2		6.57	7.2	
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	2.35	ERR	0.00	2.35	ERR	0
Fr>0.8 (vertical abut.)	ERR	2.88	ERR	ERR	2.88	ERR
Fr<=0.8 (spillthrough abut.)	2.05	ERR	0.00	2.05	ERR	0
Fr>0.8 (spillthrough abut.)	ERR	2.54	ERR	ERR	2.54	ERR

Pier Scour(both live-bed and clear water scour)

ys/y1=2.0*K1*K2*K3*K4*(a/y1)^0.65*Fr1^0.43
(Richardson and others, 1995, p. 36, eq. 21)

K1, corr. factor for pier nose shape
Sharp nose, 0.9; round nose, cylinder, or cylinder grp., 1.0; square nose, 1.1

K2, corr. factor attack angle (see Table 3, p 37)
K2=[cos(attackangle)+L/a*sin(attackangle)]^0.65

K3, corr. factor for bed condition
Clear-water, plane bed, antidune, 1.1; med. dunes, 1.1-1.2 (see Tab.4,p37)

K4, corr. factor for armoring (the following equations are in Si units)
K4=[1-0.89*(1-Vr)^2]^0.5
Vr=(V1-Vi)/(Vc90-Vi)
V1=0.645*((D50/a)^0.053)*Vc50
Vc=6.19*(y^1/6)*(Dc^1/3)

Note for round nose piers:
ys<=2.4 times the pier width (a) for Fr<=0.8
ys<=3.0 times the pier width (a) for Fr>0.8

Pier 1	Q100	Q500	Qother
Pier stationing, ft	46.1	46.1	0
Area of WSPRO flow tube, ft2	23	25.4	0
Skewed width of flow tube, ft	2.3	2.4	0
y1, pier approach depth, ft	10.00	10.58	ERR
y1 in meters	3.048	3.226	N/A
V1, pier approach velocity, ft/s	12.87	14.9	0
a, pier width, ft	5.8	5.8	0

L, pier length, ft	30.6	30.6	0
Fr1, Froude number at pier	0.717	0.807	ERR
Pier attack angle, degrees	5	5	0
K1, shape factor	0.9	0.9	0
K2, attack factor	1.28	1.28	ERR
K3, bed condition factor	1.1	1.1	0
D50, ft	0.283	0.283	0
D50, m	0.086245	0.086245	0
D90, ft	1.103	1.103	0
D90, m	0.336178	0.336178	0
Vc50,critical velocity(D50),m/s	3.293	3.324	N/A
Vc90,critical velocity(D90),m/s	5.183	5.232	N/A
Vi,incipient velocity,m/s	1.810	1.827	ERR
Vr, velocity ratio	0.626	0.797	ERR
K4, armor factor	0.94	0.98	N/A
ys, scour depth (K4 applicable) ft	14.39	16.20	ERR
ys, scour depth (K4 not applied)ft	15.38	16.50	ERR

K4 is applicable

The following is also pier 1, but the width of the pier footing
, *and the velocity approaching the footing is used in the computations.*

Pier 1 (using footer width)	Q100	Q500	Qother
Pier stationing, ft	46.1	46.1	0
Area of WSPRO flow tube, ft2	23	25.4	0
Skewed width of flow tube, ft	2.3	2.4	0
y1, pier approach depth, ft	3.78	4.78	ERR
y1 in meters	1.152	1.457	N/A
V1, pier approach velocity, ft/s	10.41	12.37	0
a, pier width, ft	8.6	8.6	0
L, pier length, ft	32.8	32.8	0
Fr1, Froude number at pier	0.944	0.997	ERR
Pier attack angle, degrees	5	5	0
K1, shape factor	0.9	0.9	0
K2, attack factor	1.20	1.20	ERR
K3, bed condition factor	1.1	1.1	0
D50, ft	0.283	0.283	0
D50, m	0.086254	0.086254	0
D90, ft	1.103	1.103	0
D90, m	0.336178	0.336178	0

Vc50,critical velocity(D50),m/s	2.800	2.912	N/A
Vc90,critical velocity(D90),m/s	4.407	4.583	N/A
Vi,incipient velocity,m/s	1.507	1.567	ERR
Vr, velocity ratio	0.574	0.731	ERR
K4, armor factor	0.92	0.97	N/A
ys, scour depth, (K4 applicable) ft	13.72	16.11	ERR
ys, scour depth, (K4 not applied)ft	14.98	16.66	ERR

D50=0.692(K*V)^2/(Ss-1)*2*g
(Richardson and others, 1995, p.115, eq. 83)

Pier-shape coefficient (K), round nose, 1.5; square nose, 1.7
Characteristic avg. channel velocity, V, (Q/A):
(Mult. by 0.9 for bankward piers in a straight, uniform reach,
up to 1.7 for a pier in main current of flow around a bend)

Pier 1	Q100	Q500	Qother
K, pier shape coeff.	1.6	1.6	0
V, char. aver. velocity, ft/s	10.7	12.5	0
	(No multiplier applied)		
D50, median stone diameter, ft	1.91	2.60	0.00