LEVEL II SCOUR ANALYSIS FOR BRIDGE 33 (CONCTH00580033) on TOWN HIGHWAY 58, crossing MILES STREAM, CONCORD, VERMONT

U.S. Geological Survey
Open-File Report 97-650

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

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By RONDA L. BURNS

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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 33 (CONCTH00580033) ON TOWN HIGHWAY 58, CROSSING MILES STREAM, CONCORD, VERMONT

By Ronda L. Burns

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CONCTH00580033 on Town Highway 58 crossing Miles Stream, 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.

The site is in the New England Upland section of the New England physiographic province in northeastern Vermont. The 17.9-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture upstream of the bridge while the immediate banks have dense woody vegetation. Downstream of the bridge, the right bank is forested and the left bank has shrubs and brush.

In the study area, Miles Stream has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 91 ft and an average bank height of 7 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 61.6 mm (0.188 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 15, 1995, indicated that the reach was stable.

The Town Highway 58 crossing of Miles Stream is a 44-ft-long, two-lane bridge consisting of one 39-foot steel-beam span (Vermont Agency of Transportation, written communication, March 24, 1995). The opening length of the structure parallel to the bridge face is 37.4 ft. The bridge is supported by vertical, concrete abutments with stone fill in front creating spillthrough embankments. The channel is skewed approximately 20 degrees to the opening while the opening-skew-to-roadway is zero degrees.

The only scour countermeasure at the site was type-3 stone fill (less than 48 inches diameter) along the left and right banks upstream, in front of the abutments forming spill through embankments, and extending along the banks downstream. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.0 to 1.8 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 4.0 to 9.7 ft. The worst-case abutment scour occurred at the 500-year discharge for the right abutment and at the incipient roadway-overtopping discharge for the left abutment. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Plymouth, VT. Quadrangle, 1:24,000, 1966
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 CONCTH00580033 ***Stream*** Miles Stream

County Essex ***Road*** TH 58 ***District*** 7

Description of Bridge

Bridge length 44 ***ft*** ***Bridge width*** 20.6 ***ft*** ***Max span length*** 39 ***ft***

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

Abutment type Vertical, concrete ***Embankment type*** None

Stone fill on abutment? Yes ***Date of inspection*** 8/15/95

Description of stone fill Type-3, along the entire baselength of both the left and right abutments creating spill through slopes.

Brief description of piers/abutments Abutments are concrete with spill through slopes of stone fill in front.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 20

If so, describe (mild, moderate, severe) The stream bends moderately through 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*
	8/15/95	0	0
Level I	8/15/95	0	0
Level II			

Potential for debris Low. The banks have sparse tree cover.

Describe any features near or at the bridge that may affect flow (include observation date) None as of 8/15/95.

Description of the Geomorphic Setting

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

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

Date of inspection 8/15/95

DS left: Steep channel bank to a moderately sloped overbank.

DS right: Steep channel bank to a moderately sloped overbank.

US left: Steep channel bank to a moderately sloped overbank.

US right: Steep channel bank to a moderately sloped overbank.

Description of the Channel

Average top width 91 *ft* ***Average depth*** 7 *ft*

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

Sinuous but stable with non-alluvial channel boundaries.

8/15/95

Vegetative co

Shrubs and brush.

DS left: Trees.

DS right: Brush with short grass on the overbank.

US left: Brush with short grass on the overbank.

US right:

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

The type-3 stone fill along the abutments constricts the channel as of 8/15/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 17.9 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/New England Upland	100

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: There are houses on all the overbanks except the downstream right overbank.

No

--

Is there a USGS gage on the stream of interest?

--

USGS gage description

--

USGS gage number

No

Gage drainage area ***mi²***

-

Is there a lake/p

-

2,550

Calculated Discharges

3,530 The

Q100 ***ft³/s*** ***Q500*** ***ft³/s***

100- and 500-year discharges are based on a drainage area relationship [(17.9/24.9)exp 0.67] with bridge number 34 in Concord. Bridge number 34 crosses the Miles Stream downstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 34 is 24.9 square miles. The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream left corner of the bridge deck (elev. 499.29 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream right corner of the bridge deck (elev. 499.14 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-39	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	10	1	Road Grade section
APTEM	46	1	Approach section as surveyed (Used as a template)
APPR1	58	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 0.060.

Normal depth at the exit section (EXIT1) 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 0.0133 ft/ft, which was estimated from the topographic map (U.S. Geological Survey, 1967).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0076 ft/ft) to establish the modelled approach section (APPR1), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.5 ***ft***
Average low steel elevation 496.8 ***ft***

100-year discharge 2,550 ***ft³/s***
Water-surface elevation in bridge opening 497.0 ***ft***
Road overtopping? Yes ***Discharge over road*** 324 ***ft³/s***
Area of flow in bridge opening 238 ***ft²***
Average velocity in bridge opening 9.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.7 ***ft/s***

Water-surface elevation at Approach section with bridge 499.4
Water-surface elevation at Approach section without bridge 495.3
Amount of backwater caused by bridge 4.1 ***ft***

500-year discharge 3,530 ***ft³/s***
Water-surface elevation in bridge opening 496.8 ***ft***
Road overtopping? Yes ***Discharge over road*** 1,140 ***/s***
Area of flow in bridge opening 236 ***ft²***
Average velocity in bridge opening 10.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.5 ***/s***

Water-surface elevation at Approach section with bridge 500.1
Water-surface elevation at Approach section without bridge 496.4
Amount of backwater caused by bridge 3.7 ***ft***

Incipient overtopping discharge 1,810 ***ft³/s***
Water-surface elevation in bridge opening 497.0 ***ft***
Area of flow in bridge opening 238 ***ft²***
Average velocity in bridge opening 7.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.5 ***ft/s***

Water-surface elevation at Approach section with bridge 498.2
Water-surface elevation at Approach section without bridge 494.3
Amount of backwater caused by bridge 3.9 ***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.

At this site, the 100-year, 500-year and incipient roadway-overtopping discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). The computed streambed armoring depths suggest that armoring will not limit the depth of contraction scour.

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20) and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and presented in Appendix F. Furthermore, since the discharges resulted in unsubmerged orifice flow, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions are provided in Appendix F.

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

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	1.1	1.8	0.0
Depth to armoring	19.7	12.5	16.2
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	4.0	4.0	7.4
Right abutment	8.8	9.7	7.7
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	2.3	2.0
Right abutment	2.3	2.3	2.0
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

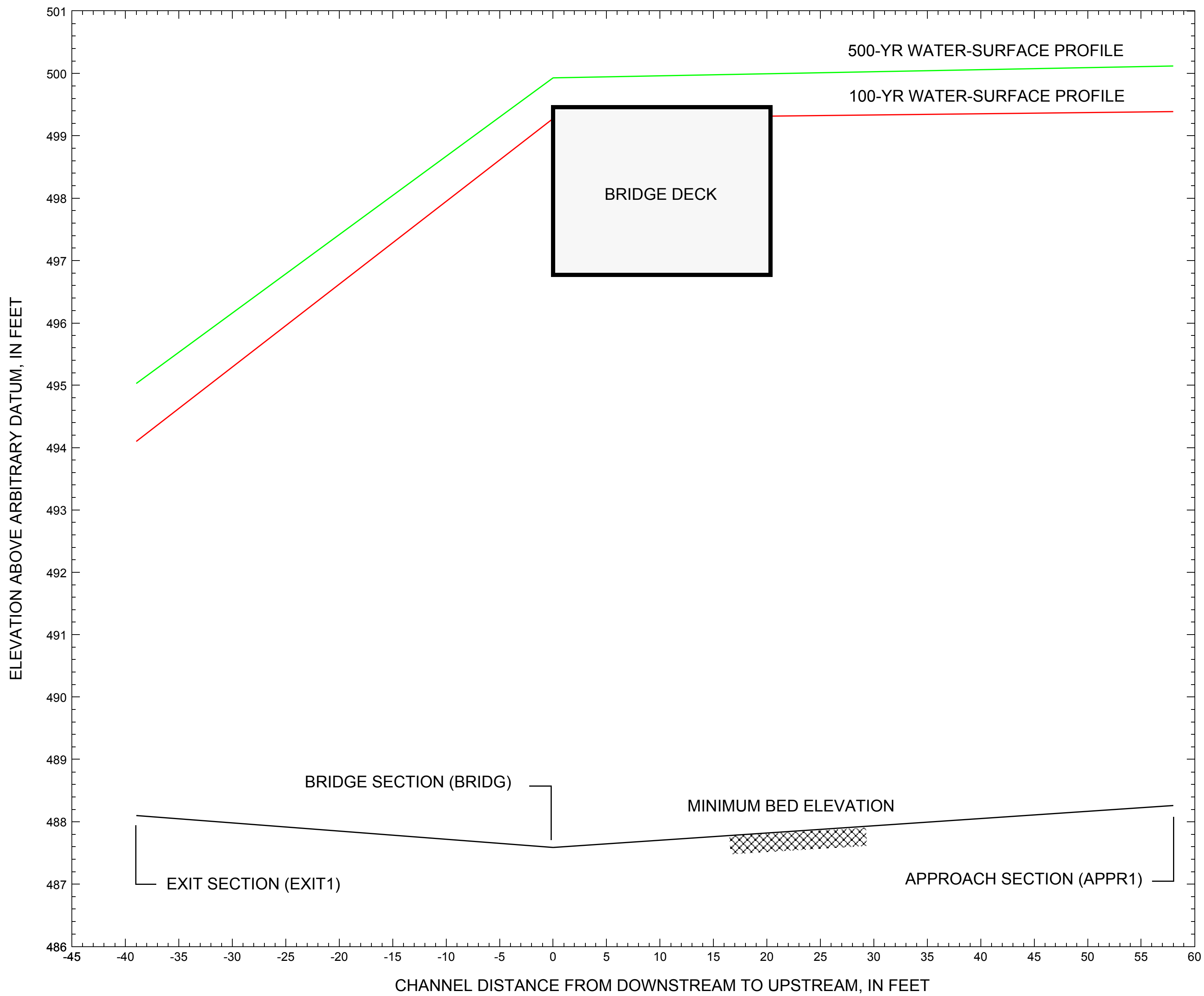

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CONCTH00580033 on Town Highway 58, crossing Miles Stream, Concord, Vermont.

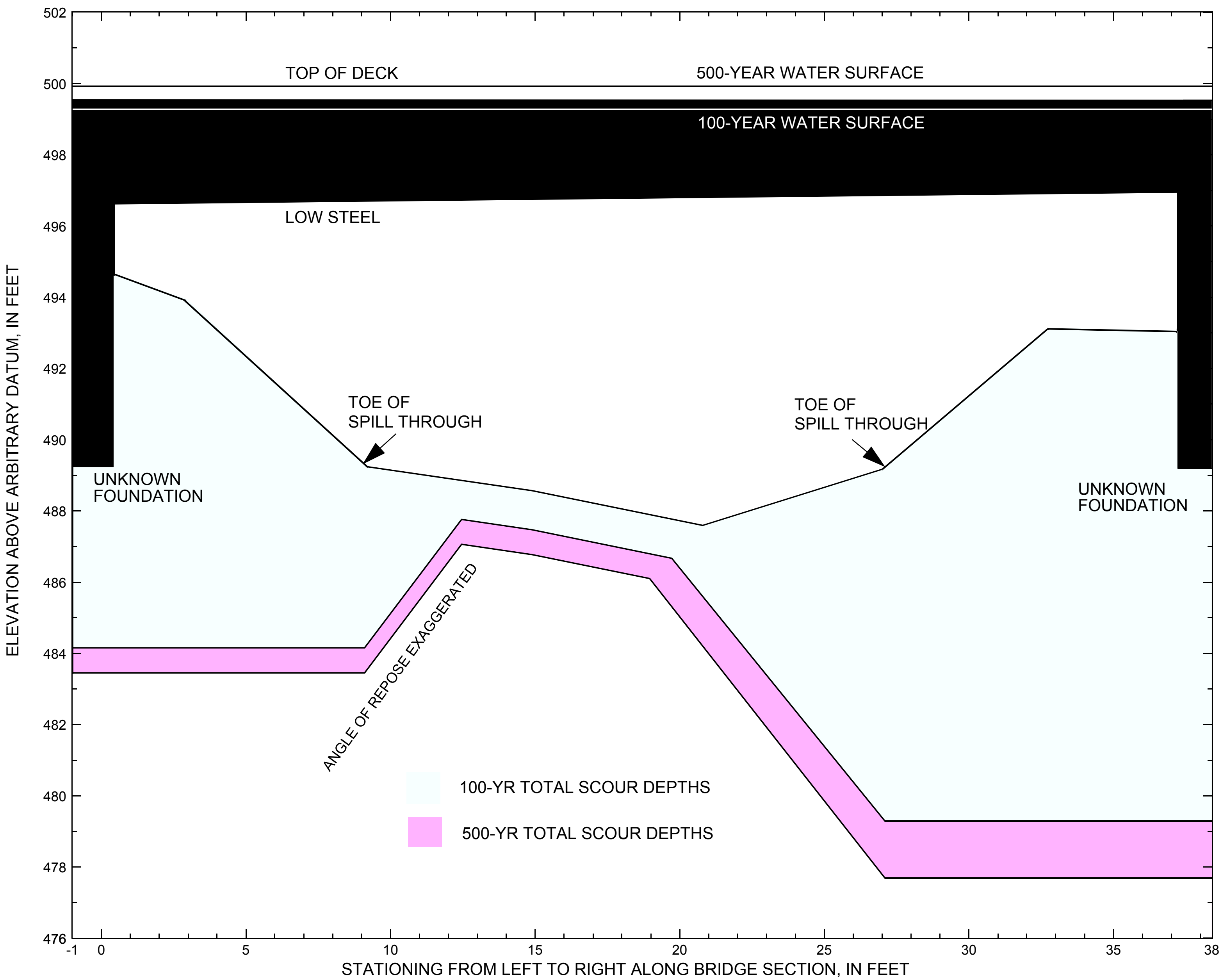

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CONCTH00580033 on Town Highway 58, crossing Miles Stream, Concord, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CONCTH00580033 on Town Highway 58, crossing Miles Stream, 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/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 2,550 cubic-feet per second											
Left abutment	0.0	--	496.6	--	494.6	--	--	--	--	--	--
Toe of LABUT	9.1	--	--	--	489.2	1.1	4.0	--	5.1	484.1	--
Toe of RABUT	27.1	--	--	--	489.2	1.1	8.8	--	9.9	479.3	--
Right abutment	37.4	--	497.0	--	493.0	--	--	--	--	--	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure CONCTH00580033 on Town Highway 58, crossing Miles Stream, 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/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 3,530 cubic-feet per second											
Left abutment	0.0	--	496.6	--	494.6	--	--	--	--	--	--
Toe of LABUT	9.1	--	--	--	489.2	1.8	4.0	--	5.8	483.4	--
Toe of RABUT	27.1	--	--	--	489.2	1.8	9.7	--	11.5	477.7	--
Right abutment	37.4	--	497.0	--	493.0	--	--	--	--	--	--

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

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T1        U.S. Geological Survey WSPRO Input File conc033.wsp
T2        Hydraulic analysis for structure CONCTH00580033   Date: 28-JUL-97
T3        TH 58 CROSSING MILES STREAM IN CONCORD, VT                 RLB
J1         * * 0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2550.0   3530.0   1810.0
SK          0.0133   0.0133   0.0133
*
XS   EXIT1    -39          0.
GR         -383.9, 510.71   -263.2, 501.83   -207.4, 500.58   -126.6, 500.66
GR         -114.1, 498.21     -6.8, 494.07      0.0, 492.68      1.2, 491.47
GR            3.6, 489.02      4.1, 488.42      6.3, 488.10     17.1, 488.18
GR           29.9, 488.38     32.3, 489.07     51.4, 490.51     56.7, 491.21
GR           69.4, 496.70     92.0, 498.77    182.3, 502.59    243.7, 505.48
GR          282.1, 508.18
*
N           0.055        0.050        0.040
SA                  -6.8         69.4
*
XS   FULLV      0  * * *   0.0
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.78       0.0
GR            0.0, 496.62      0.4, 494.64      2.9, 493.91      9.1, 489.25
GR           14.9, 488.57     20.8, 487.59     27.1, 489.19     32.8, 493.11
GR           37.2, 493.01     37.4, 496.95      0.0, 496.62
*
*         BRTYPE  BRWDTH   EMBSS  EMBELV
CD           3      20.1     2.1  493.83
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     10      20.6     2
GR         -350.0, 510.80   -319.3, 502.65   -254.3, 502.38   -203.2, 499.37
GR         -127.3, 498.91    -98.0, 498.11    -33.3, 498.94      0.0, 499.54
GR           37.3, 499.53     63.4, 499.88    127.9, 502.05    192.1, 504.82
GR          248.3, 509.61    308.2, 511.39
*
XT   APTEM     46          0.
GR         -348.5, 511.04   -333.4, 504.79   -318.6, 502.79   -250.7, 502.08
GR         -210.2, 499.37   -140.0, 498.50   -124.1, 498.78    -71.4, 498.04
GR          -41.7, 496.86    -26.5, 494.36     -7.0, 492.18      0.0, 491.22
GR            6.2, 490.50      7.6, 489.22      7.9, 488.86     10.4, 488.36
GR           17.0, 488.17     25.1, 488.29     29.2, 488.59     29.8, 489.08
GR           32.4, 489.66     32.7, 490.92     41.7, 492.89     44.5, 493.85
GR           63.6, 497.84    125.4, 500.94    143.8, 503.27    207.1, 505.11
GR          241.2, 509.92
*
AS   APPR1     58  * * *  0.0076
GT
N           0.060        0.050        0.040
SA                  -41.7         63.6
*
HP 1 BRIDG  496.95 1 496.95
HP 2 BRIDG  496.95 * * 2233
HP 1 BRIDG  495.21 1 495.21
HP 2 RDWAY  499.28 * * 324
HP 1 APPR1  499.39 1 499.39
HP 2 APPR1  499.39 * * 2550
*
HP 1 BRIDG  496.78 1 496.78
HP 2 BRIDG  496.78 * * 2395
HP 1 BRIDG  495.88 1 495.88
HP 2 RDWAY  499.93 * * 1140
HP 1 APPR1  500.12 1 500.12
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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      U.S. Geological Survey WSPRO Input File conc033.wsp
      Hydraulic analysis for structure CONCTH00580033   Date: 28-JUL-97
      TH 58 CROSSING MILES STREAM IN CONCORD, VT                 RLB
         *** RUN DATE & TIME: 09-11-97  15:29

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      238     15837     0     83                            0
  496.95           238     15837     0     83  1.00      0     37        0

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      496.95     0.0    37.4   237.8   15837.    2233.   9.39

X STA.         0.0        6.4        8.7       10.3       11.7       13.1
  A(I)            20.5       14.2       12.1       11.0       10.8
  V(I)            5.44       7.85       9.23      10.11      10.34

X STA.        13.1       14.4       15.6       16.8       18.0       19.0
  A(I)            10.5       10.1        9.9        9.9        9.6
  V(I)           10.68      11.03      11.32      11.23      11.68

X STA.        19.0       20.1       21.2       22.2       23.4       24.6
  A(I)             9.6        9.7        9.7       10.1       10.3
  V(I)           11.67      11.47      11.55      11.06      10.86

X STA.        24.6       25.9       27.4       29.3       32.2       37.4
  A(I)            10.7       11.4       12.8       15.2       19.7
  V(I)           10.42       9.78       8.70       7.34       5.68

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      179     15414    37     43                         2237
  495.21           179     15414    37     43  1.00      0     37     2237

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

        WSEL     LEW     REW    AREA        K        Q    VEL
      499.28  -188.4   -14.4    85.9    1454.     324.   3.77

X STA.      -188.4     -131.4     -117.9     -110.9     -106.1     -102.2
  A(I)             9.8        6.1        5.0        4.3        3.9
  V(I)            1.65       2.64       3.22       3.79       4.20

X STA.      -102.2      -99.0      -96.1      -93.1      -90.2      -87.1
  A(I)             3.6        3.4        3.3        3.2        3.3
  V(I)            4.54       4.79       4.90       5.11       4.97

X STA.       -87.1      -84.0      -80.7      -77.1      -73.3      -69.1
  A(I)             3.1        3.2        3.3        3.3        3.5
  V(I)            5.15       5.04       4.86       4.89       4.64

X STA.       -69.1      -64.4      -58.9      -52.2      -42.8      -14.4
  A(I)             3.6        3.9        4.2        4.9        7.0
  V(I)            4.47       4.17       3.87       3.32       2.30

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      58.
    WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
            1      138      3068   163    163                          721
            2      713     74565   105    108                        10530
            3       21       640    29     29                          103
  499.39           872     78273   297    300  1.30   -203     93     7447

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      58.

        WSEL     LEW     REW    AREA        K        Q    VEL
      499.39  -204.5    92.7   872.3   78273.    2550.   2.92

X STA.      -204.5      -36.8      -24.3      -16.3      -10.1       -4.7
  A(I)           151.8       53.5       44.7       40.3       37.6
  V(I)            0.84       2.38       2.85       3.17       3.39

X STA.        -4.7       -0.1        4.0        7.8       10.7       13.4
  A(I)            36.2       34.1       34.4       30.7       29.6
  V(I)            3.52       3.74       3.71       4.16       4.31

X STA.        13.4       16.0       18.7       21.4       24.1       26.9
  A(I)            29.3       29.4       29.7       30.0       30.6
  V(I)            4.35       4.33       4.29       4.25       4.16

X STA.        26.9       30.0       34.0       39.3       46.8       92.7
  A(I)            33.3       37.4       39.5       45.1       75.0
  V(I)            3.83       3.41       3.23       2.83       1.70
```

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        U.S. Geological Survey WSPRO Input File conc033.wsp
        Hydraulic analysis for structure CONCTH00580033   Date: 28-JUL-97
        TH 58 CROSSING MILES STREAM IN CONCORD, VT                 RLB
           *** RUN DATE & TIME: 09-11-97  15:29

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      236     18687     19     64                         4693
   496.78           236     18687     19     64  1.00      0     37     4693

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

         WSEL     LEW     REW    AREA         K        Q    VEL
       496.78     0.0    37.4   236.2    18687.    2395.  10.14

 X STA.         0.0        7.0        9.5       11.3       13.1       14.7
   A(I)            23.7       17.1       14.0       13.8       13.0
   V(I)            5.06       7.01       8.53       8.67       9.24

 X STA.        14.7       16.2       17.6       18.8       19.8       20.7
   A(I)            12.5       12.0       10.2        8.9        8.6
   V(I)            9.61       9.94      11.75      13.39      14.00

 X STA.        20.7       21.7       22.6       23.6       24.6       25.7
   A(I)             8.5        8.3        8.4        8.6        8.8
   V(I)           14.10      14.47      14.21      13.91      13.64

 X STA.        25.7       26.8       28.2       29.9       32.6       37.4
   A(I)             8.9        9.8       10.8       12.8       17.6
   V(I)           13.40      12.25      11.12       9.39       6.81

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      204     18748     37     44                         2712
   495.88           204     18748     37     44  1.00      0     37     2712

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

         WSEL     LEW     REW    AREA         K        Q    VEL
       499.93  -212.7    64.9   238.7     6334.    1140.   4.77

 X STA.      -212.7     -178.9     -159.3     -143.4     -129.8     -119.0
   A(I)            18.0       15.1       13.9       13.1       11.9
   V(I)            3.16       3.79       4.10       4.36       4.78

 X STA.      -119.0     -111.3     -104.8      -99.3      -94.3      -89.2
   A(I)            10.4       10.0        9.4        9.0        9.0
   V(I)            5.48       5.68       6.05       6.34       6.35

 X STA.       -89.2      -83.8      -78.1      -71.8      -65.2      -57.9
   A(I)             9.0        9.2        9.5        9.6        9.9
   V(I)            6.34       6.22       6.01       5.95       5.75

 X STA.       -57.9      -49.5      -39.4      -27.3       -4.9       64.9
   A(I)            10.5       11.5       11.9       15.2       22.8
   V(I)            5.44       4.98       4.80       3.75       2.50

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      58.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      264      8514    178    178                         1823
             2      790     88437    105    108                        12277
             3       48      1888     44     44                          283
   500.12          1102     98838    327    331  1.41   -219    107     9666

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      58.

         WSEL     LEW     REW    AREA         K        Q    VEL
       500.12  -220.0   107.2  1101.7    98838.    3530.   3.20

 X STA.      -220.0      -78.6      -36.2      -24.3      -16.4       -9.7
   A(I)           173.4      110.7       59.8       50.5       47.7
   V(I)            1.02       1.59       2.95       3.50       3.70

 X STA.        -9.7       -4.1        0.7        5.1        9.0       12.0
   A(I)            44.1       41.0       40.5       40.1       35.1
   V(I)            4.00       4.30       4.36       4.40       5.03

 X STA.        12.0       15.0       18.0       20.9       24.0       27.1
   A(I)            35.3       35.6       34.7       36.6       35.9
   V(I)            4.99       4.96       5.09       4.82       4.91

 X STA.        27.1       30.6       35.4       41.3       50.7      107.2
   A(I)            39.5       45.3       46.9       55.6       93.5
   V(I)            4.47       3.90       3.76       3.17       1.89
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        U.S. Geological Survey WSPRO Input File conc033.wsp
        Hydraulic analysis for structure CONCTH00580033   Date: 28-JUL-97
        TH 58 CROSSING MILES STREAM IN CONCORD, VT                 RLB
           *** RUN DATE & TIME: 09-11-97  15:29

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      238     15837      0     83                            0
   496.95           238     15837      0     83  1.00      0     37        0

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

         WSEL     LEW     REW    AREA         K        Q    VEL
       496.95     0.0    37.4   237.8   15837.    1810.   7.61

X STA.         0.0        6.4        8.7       10.3       11.7       13.1
  A(I)            20.5       14.2       12.1       11.0       10.8
  V(I)            4.41       6.36       7.48       8.19       8.38

X STA.        13.1       14.4       15.6       16.8       18.0       19.0
  A(I)            10.5       10.1        9.9        9.9        9.6
  V(I)            8.66       8.94       9.17       9.10       9.47

X STA.        19.0       20.1       21.2       22.2       23.4       24.6
  A(I)             9.6        9.7        9.7       10.1       10.3
  V(I)            9.46       9.30       9.36       8.97       8.80

X STA.        24.6       25.9       27.4       29.3       32.2       37.4
  A(I)            10.7       11.4       12.8       15.2       19.7
  V(I)            8.45       7.93       7.06       5.95       4.60

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      156     12464     37     41                         1818
   494.57           156     12464     37     41  1.00      1     37     1818

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      58.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       19       327     33     33                           82
             2      586     53709    105    108                         7837
             3        1         6      5      5                            1
   498.18           605     54042    143    147  1.05    -74     69     6890

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      58.

         WSEL     LEW     REW    AREA         K        Q    VEL
       498.18   -74.9    68.6   605.3   54042.    1810.   2.99

X STA.       -74.9      -25.0      -16.4       -9.9       -4.8       -0.4
  A(I)            62.5       37.8       33.9       30.2       28.3
  V(I)            1.45       2.40       2.67       3.00       3.20

X STA.        -0.4        3.5        7.0        9.7       12.1       14.4
  A(I)            27.8       26.4       25.0       22.8       23.0
  V(I)            3.26       3.43       3.62       3.97       3.94

X STA.        14.4       16.7       19.0       21.3       23.6       26.1
  A(I)            22.5       22.5       22.7       23.4       24.1
  V(I)            4.03       4.02       3.98       3.87       3.75

X STA.        26.1       28.7       31.7       36.2       42.3       68.6
  A(I)            24.7       27.4       32.1       35.0       53.4
  V(I)            3.67       3.30       2.82       2.59       1.69
```

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        U.S. Geological Survey WSPRO Input File conc033.wsp
        Hydraulic analysis for structure CONCTH00580033   Date: 28-JUL-97
        TH 58 CROSSING MILES STREAM IN CONCORD, VT                 RLB
           *** RUN DATE & TIME: 09-11-97  15:29

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

EXIT1:XS   ******     -7      293  1.18 *****  495.28  493.23    2550  494.10
       -38 ******     63    22098  1.00 ***** *******    0.75    8.69

FULLV:FV       39    -26      352  0.84  0.40  495.67 *******    2550  494.83
         0     39     65    28584  1.03  0.00   -0.01    0.66    7.24
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR1:AS       58    -31      310  1.05  0.61  496.38 *******    2550  495.33
        58     58     51    21727  1.00  0.11    0.00    0.75    8.23
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   499.94       0.00     495.66     498.11
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   495.35     499.01     499.20     496.78
 ===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       39      0      238  1.37 *****  498.32  495.21    2233  496.95
         0 ******     37    15837  1.00 ***** *******    0.66    9.39

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   5.  0.487  0.000  496.78 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    37.  0.04  0.17  499.52    0.00    324.  499.28

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    324.   175.  -189.   -14.   1.2   0.5   3.8   3.7   0.7   3.0
   RT:      0.    50.    19.    69.   0.5   0.4   3.7   5.0   0.8   2.8

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

APPR1:AS       38   -203      871  0.17  0.18  499.56  494.55    2550  499.39
        58     39     93    78193  1.30  0.42    0.00    0.34    2.93

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS      -39.    -8.    63.   2550.   22098.     293.    8.69  494.10
   FULLV:FV        0.   -27.    65.   2550.   28584.     352.    7.24  494.83
   BRIDG:BR        0.     0.    37.   2233.   15837.     238.    9.39  496.95
   RDWAY:RG       10.*******   324.    324.*********       0.    2.00  499.28
   APPR1:AS       58.  -204.    93.   2550.   78193.     871.    2.93  499.39

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS  **********************

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXIT1:XS    493.23    0.75  488.10  510.71************  1.18  495.28  494.10
   FULLV:FV  ********    0.66  488.10  510.71  0.40  0.00  0.84  495.67  494.83
   BRIDG:BR    495.21    0.66  487.59  496.95************  1.37  498.32  496.95
   RDWAY:RG  ****************  498.11  511.39  0.04******  0.17  499.52  499.28
   APPR1:AS    494.55    0.34  488.26  511.13  0.18  0.42  0.17  499.56  499.39
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        U.S. Geological Survey WSPRO Input File conc033.wsp
        Hydraulic analysis for structure CONCTH00580033   Date: 28-JUL-97
        TH 58 CROSSING MILES STREAM IN CONCORD, VT                 RLB
           *** RUN DATE & TIME: 09-11-97  15:29

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

EXIT1:XS   ******    -31      372  1.47 *****  496.50  494.24    3530  495.03
       -38 ******     66    30591  1.05 ***** *******    0.88    9.50

FULLV:FV       39    -53      464  1.01  0.40  496.88 *******    3530  495.88
         0     39     67    39921  1.12  0.00   -0.02    0.73    7.61
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR1:AS       58    -37      403  1.20  0.59  497.57 *******    3530  496.38
        58     58     56    30905  1.00  0.09    0.01    0.75    8.77
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   502.95       0.00     496.65     498.11
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                   WS,QBO,QRD =   501.49         0.      3530.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===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       39      0      236  1.60 *****  498.38  495.44    2395  496.78
         0 ******     37    18687  1.00 ***** *******    0.71   10.14

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****    5.  0.495  0.000  496.78 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    37.  0.05  0.23  500.29    0.00   1140.  499.93

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1073.   231.  -213.    19.   1.8   1.0   5.2   4.8   1.3   3.0
   RT:     67.    46.    19.    65.   0.4   0.3   3.3   5.0   0.7   2.8

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

APPR1:AS       38   -219     1100  0.23  0.19  500.34  495.45    3530  500.12
        58     40    107    98700  1.41  0.00    0.00    0.37    3.21

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -39.   -32.    66.   3530.   30591.     372.    9.50  495.03
   FULLV:FV       0.   -54.    67.   3530.   39921.     464.    7.61  495.88
   BRIDG:BR       0.     0.    37.   2395.   18687.     236.   10.14  496.78
   RDWAY:RG      10.******* 1073.   1140.*********       0.    2.00  499.93
   APPR1:AS      58.  -220.   107.   3530.   98700.    1100.    3.21  500.12

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS  ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF     HO   VHD      EGL    WSEL
   EXIT1:XS    494.24    0.88  488.10  510.71************  1.47  496.50  495.03
   FULLV:FV  ********    0.73  488.10  510.71  0.40  0.00  1.01  496.88  495.88
   BRIDG:BR    495.44    0.71  487.59  496.95************  1.60  498.38  496.78
   RDWAY:RG  ****************  498.11  511.39  0.05******  0.23  500.29  499.93
   APPR1:AS    495.45    0.37  488.26  511.13  0.19  0.00  0.23  500.34  500.12
```
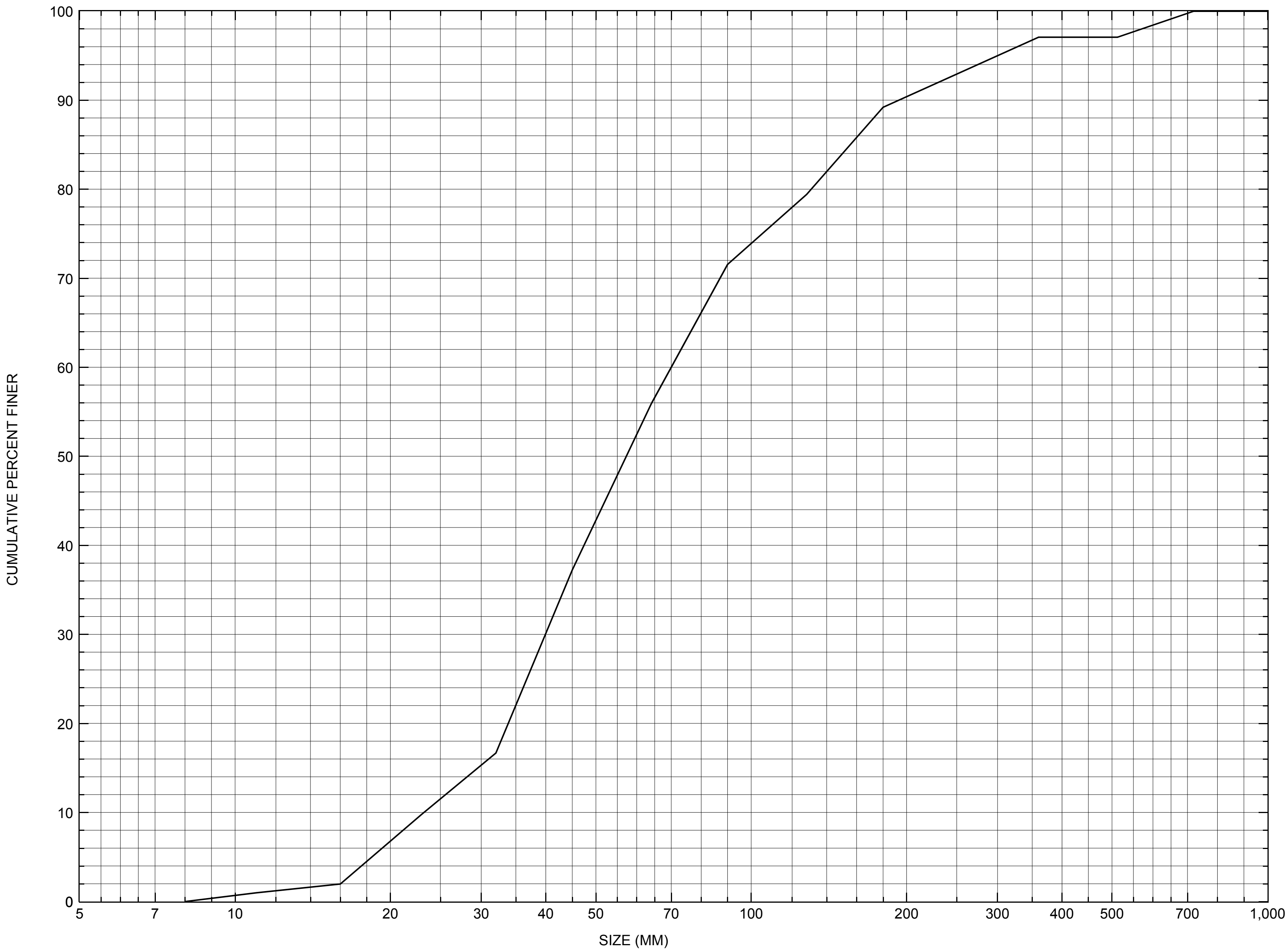

```
      U.S. Geological Survey WSPRO Input File conc033.wsp
      Hydraulic analysis for structure CONCTH00580033   Date: 28-JUL-97
      TH 58 CROSSING MILES STREAM IN CONCORD, VT                 RLB
         *** RUN DATE & TIME: 09-11-97  15:29

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

EXIT1:XS   ******     -1      229  0.97 *****  494.12  492.38    1810  493.15
       -38 ******     61    15693  1.00 ***** *******    0.73    7.89

FULLV:FV       39     -5      275  0.68  0.40  494.51 *******    1810  493.83
         0     39     63    20147  1.00  0.00   -0.01    0.58    6.59
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPR1:AS       58    -24      233  0.94  0.64  495.28 *******    1810  494.33
        58     58     46    14807  1.00  0.13    0.00    0.76    7.78
        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   494.57     497.39     497.62     496.78
 ===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       39      0      238  0.90 *****  497.85  494.57    1811  496.95
         0 ******     37    15837  1.00 ***** *******    0.53    7.61

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   2.  0.444  0.000  496.78 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR1:AS       38    -74      606  0.15  0.15  498.33  493.64    1810  498.18
        58     39     69    54067  1.05  0.43    0.00    0.26    2.99

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   498.14

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL   WSEL
   EXIT1:XS     -39.    -2.    61.   1810.   15693.     229.    7.89  493.15
   FULLV:FV       0.    -6.    63.   1810.   20147.     275.    6.59  493.83
   BRIDG:BR       0.     0.    37.   1811.   15837.     238.    7.61  496.95
   RDWAY:RG      10.**************      0.       0.       0.    2.00********
   APPR1:AS      58.   -75.    69.   1810.   54067.     606.    2.99  498.18

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS   **********************

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF     HO   VHD      EGL    WSEL
   EXIT1:XS    492.38    0.73  488.10  510.71************  0.97  494.12  493.15
   FULLV:FV  ********    0.58  488.10  510.71  0.40  0.00  0.68  494.51  493.83
   BRIDG:BR    494.57    0.53  487.59  496.95************  0.90  497.85  496.95
   RDWAY:RG  ****************  498.11  511.39************  0.15  498.29********
   APPR1:AS    493.64    0.26  488.26  511.13  0.15  0.43  0.15  498.33  498.18
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CONCTH00580033, in Concord, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CONCTH00580033

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)* MILES STREAM

Road Name *(I - 7)*: -

Route Number TH058

Vicinity *(I - 9)* 0.1 MI JCT TH 58 + TH 4

Topographic Map Miles Pond

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44255

Longitude *(i - 17; nnnnn.n)* 71453

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10050700330507

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

Maximum span length *(I - 48; nnnn)* 0039

Year built *(I - 27; YYYY)* 1971

Structure length *(I - 49; nnnnnn)* 000044

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

Deck Width *(I - 52; nn.n)* 206

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

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

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

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) -

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

Vertical clearance from streambed (*nnn.n ft*) 007.9

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

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

Comments:

The structural inspection report of 8/15/94 indicates the structure is a steel stringer type bridge with a concrete deck. The abutment walls are concrete. Approximately a ten foot section of the left abutment footing is reported undermined by 2 to 3 feet horizontally and 2 to 5 inches vertically . "Boulder stone fill" is placed in front of each abutment and around the ends. There are some boulders noted on the banks up- and downstream. While the left abutment is undermined, the report does not indicate any settling evident. Channel scour, bank erosion, and debris accumulation were not assessed in the report. The type of foundation recorded for the substructure at this site is an unknown foundation.

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:
-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **17.861** mi^2 Lake/pond/swamp area **.517** mi^2
Watershed storage *(ST)* **2.89** %
Bridge site elevation **865** ft Headwater elevation **1560** ft
Main channel length **7.567** mi
10% channel length elevation **910** ft 85% channel length elevation **1296** ft
Main channel slope *(S)* **68.02** 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 chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord-bed	-	-	-	-	-	-	-	-	-	-	-

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **EW** Date: **02/05/96**
Computerized by: **EW** Date: **02/05/96**
Reviewd by: **RB** Date: **08/25/97**

Structure Number **CONCTH00580033**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **M. IVANOFF** Date *(MM/DD/YY)* **08** / **15** / 19**95**

2. Highway District Number **7** Mile marker **0**

County **ESSEX (009)** Town **CONCORD (15250)**

Waterway *(I - 6)* **MILES STREAM** Road Name **-**

Route Number **TH058** Hydrologic Unit Code: **01080102**

3. Descriptive comments:
Located 0.1 miles from the junction of TH 58 and TH 4.

B. Bridge Deck Observations

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

5. Ambient water surface... US **1** UB **1** DS **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 **44** *(feet)* Span length **39** *(feet)* Bridge width **20.6** *(feet)*

Road approach to bridge:

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

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

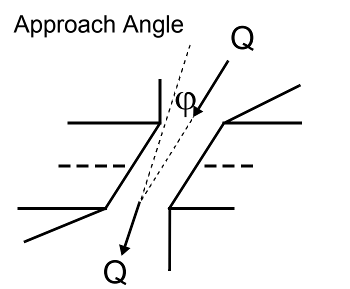
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

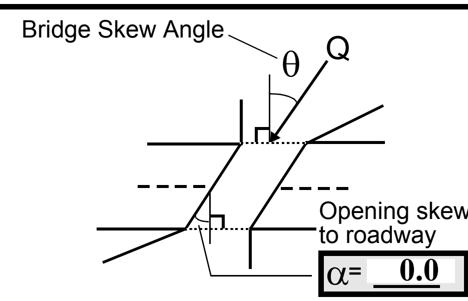
	Protection: 11.Type	Protection: 12.Cond.	13.Erosion	14.Severity
LBUS	0	-	0	0
RBUS	0	-	0	0
RBDS	0	-	0	0
LBDS	0	-	0	0

*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: **10** 16. Bridge skew: **20**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **0**
Range? **40** feet **US** *(US, UB, DS)* to **0** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **0**
Range? **40** feet **DS** *(US, UB, DS)* to **60** feet **DS**

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

18. Bridge Type: 1b

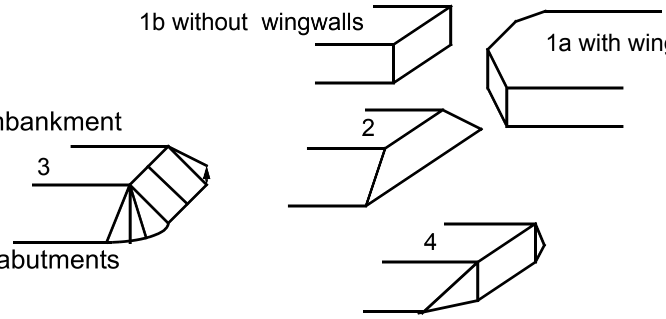
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

Values reported in #7 are from the VTAOT files. Measured bridge dimensions are: bridge length = 44 ft, bridge span = 38 ft, and bridge width = 20.3 ft.

#4: The right bank vegetation is the backyard of a residential area with some row crops (corn) and cut grass, also some trees along the bank.

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
25.5	8.0			8.0	2	2	453	543	1	0

23. Bank width 10.0   24. Channel width 15.0   25. Thalweg depth 105.5   29. Bed Material 453

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

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

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

#30: On the left bank, the placed protection extends 15 feet US. On the right bank the placed protection extends 160 feet US.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 160 35. Mid-bar width: 12

36. Point bar extent: 115 feet US (US, UB) to 170 feet US (US, UB, DS) positioned 0 %LB to 30 %RB

37. Material: 32

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

This point bar is along the left bank and consists of gravel and sand.

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: 80 42. Cut bank extent: 35 feet US (US, UB) to 115 feet US (US, UB, DS)

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

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

In this area, the bank is steepend and there are exposed roots.

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

Average thalweg depth is 2 feet upstream up to 2.5 feet near the point bar.

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

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

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

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

56. Height (BF) 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
24.5		1.0		2	7	7	-

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

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

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

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

453

-

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? 2___ *(Y or N)* Ice Blockage Potential N____ *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

1

There are very few trees along the banks in this residential area.

#68: The capture efficiency is moderate due to the constricted opening from boulder stone fill at the base of the abutments.

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		10	90	2	3	0.5	0	90.0
RABUT	1	0	90			2	0	37.5

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

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

-

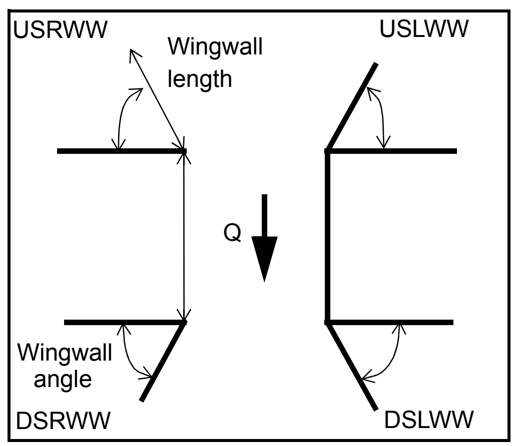
-

1

#76: The left abutment is undermined a depth of 0.5 feet along 10 feet of length at the midwall. Stone fill sits 0.5 feet from the wall into the stream.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						37.5	
USRWW:	N		-		-	1.5	
DSLWW:	-		-		N	20.0	
DSRWW:	-		-		-	20.5	



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	-	-	N	-	-	-	1	1
Condition	N	-	-	-	-	-	1	1
Extent	-	-	-	-	-	3	3	-

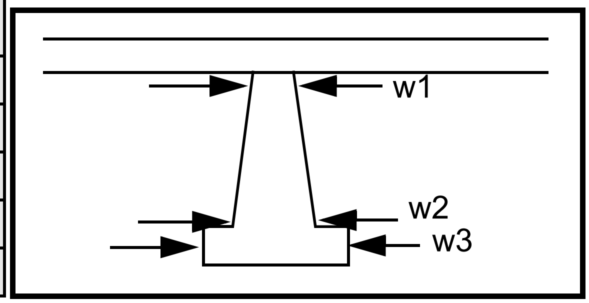
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	-	-	-	-	-	-
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e abut-		-	-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	ment		-	-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	s are		-	-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	pro-		-	-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	tecte		-	-	*Y- yes; N- no*
91. Attack ∠ (BF)	d by		-	-	
92. Pushed	boul-		-	-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	der	N	-	-	
95. Cross-members	fill.	-	-	-	***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		-	-	-	
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
-	-			-	-	-	-	-	-	-

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

Bank protection type (Qmax): LB - RB - Bank protection condition: LB - RB NO

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.):
PIERS

2
4
543
453
0

101. Is a drop structure present? **0** *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet

103. Drop: - feet 104. Structure material: **543** *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

105. Drop structure comments (eg. downstream scour depth):
3
3
1
1
The placed bank protection extends 20 feet DS on the right and 80 feet DS on the left.

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.):

N

Is a cut-bank present? - *(Y or if N type ctrl-n cb)* Where? **NO** *(LB or RB)* Mid-bank distance: **DR**

Cut bank extent: **OP** feet **ST** *(US, UB, DS)* to **RUC** feet **TU** *(US, UB, DS)*

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

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

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

Scour dimensions: Length - Width - Depth: - Positioned - %LB to - %RB

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

-
-
-
-

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

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

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

Confluence comments (eg. confluence name):

der riffle begins 45 feet DS from the bridge.

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

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

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

N

-

-

-

-

-

-

-

NO CUT BANKS

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: CONCTH00580033 Town: CONCORD
Road Number: TH 58 County: ESSEX
Stream: MILES STREAM

Initials RLB Date: 8/5/97 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	2550	3530	1810
Main Channel Area, ft2	713	790	586
Left overbank area, ft2	138	264	19
Right overbank area, ft2	21	48	1
Top width main channel, ft	105	105	105
Top width L overbank, ft	163	178	33
Top width R overbank, ft	29	44	5
D50 of channel, ft	0.1879	0.1879	0.1879
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.8	7.5	5.6
y1, average depth, LOB, ft	0.8	1.5	0.6
y1, average depth, ROB, ft	0.7	1.1	0.2
Total conveyance, approach	78273	98838	54042
Conveyance, main channel	74565	88437	53709
Conveyance, LOB	3068	8514	327
Conveyance, ROB	640	1888	6
Percent discrepancy, conveyance	0.0000	-0.0010	0.0000
Qm, discharge, MC, cfs	2429.2	3158.5	1798.8
Ql, discharge, LOB, cfs	100.0	304.1	11.0
Qr, discharge, ROB, cfs	20.9	67.4	0.2
Vm, mean velocity MC, ft/s	3.4	4.0	3.1
Vl, mean velocity, LOB, ft/s	0.7	1.2	0.6
Vr, mean velocity, ROB, ft/s	1.0	1.4	0.2
Vc-m, crit. velocity, MC, ft/s	8.8	9.0	8.6
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

Clear Water Contraction Scour in MAIN CHANNEL

y2 = (Q2^2/(131*Dm^(2/3)*W2^2))^(3/7)   Converted to English Units
ys=y2-y_bridge
(Richardson and others, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	2550	3530	1810
(Q) discharge thru bridge, cfs	2233	2395	1810
Main channel conveyance	15837	18687	15837
Total conveyance	15837	18687	15837
Q2, bridge MC discharge,cfs	2233	2395	1810
Main channel area, ft2	238	236	238
Main channel width (normal), ft	27.7	27.7	27.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	27.7	27.7	27.7
y_bridge (avg. depth at br.), ft	8.59	8.52	8.59
Dm, median (1.25*D50), ft	0.234875	0.234875	0.234875
y2, depth in contraction,ft	8.06	8.56	6.73
ys, scour depth (y2-ybridge), ft	-0.53	0.04	-1.86

Armoring

Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)
(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	2233	2395	1810
Main channel area (DS), ft2	179	204	156
Main channel width (normal), ft	27.7	27.7	27.7
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	27.7	27.7	27.7
D90, ft	0.6337	0.6337	0.6337
D95, ft	0.9875	0.9875	0.9875
Dc, critical grain size, ft	0.6744	0.5663	0.6181
Pc, Decimal percent coarser than Dc	0.093	0.120	0.103
Depth to armoring, ft	19.73	12.46	16.15

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation   Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and other, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	2550	3530	1810
Q, thru bridge MC, cfs	2233	2395	1810
Vc, critical velocity, ft/s	8.84	8.99	8.55
Va, velocity MC approach, ft/s	3.41	4.00	3.07
Main channel width (normal), ft	27.7	27.7	27.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	27.7	27.7	27.7
qbr, unit discharge, ft2/s	80.6	86.5	65.3
Area of full opening, ft2	238.0	236.0	238.0
Hb, depth of full opening, ft	8.59	8.52	8.59
Fr, Froude number, bridge MC	0.66	0.71	0.53
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	179	204	156
**Hb, depth at downstream face, ft	6.46	7.36	5.63
**Fr, Froude number at DS face	0.86	0.76	0.86
**Cf, for downstream face (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	496.78	496.78	496.78
Elevation of Bed, ft	488.19	488.26	488.19
Elevation of Approach, ft	499.39	500.12	498.18
Friction loss, approach, ft	0.18	0.19	0.15
Elevation of WS immediately US, ft	499.21	499.93	498.03
ya, depth immediately US, ft	11.02	11.67	9.84
Mean elevation of deck, ft	499.53	499.53	499.53
w, depth of overflow, ft (>=0)	0.00	0.40	0.00
Cc, vert contrac correction (<=1.0)	0.94	0.93	0.97
**Cc, for downstream face (<=1.0)	0.79	0.886685	0.79
Ys, scour w/Chang equation, ft	1.13	1.82	-0.69
Ys, scour w/Umbrell equation, ft	-1.75	-0.79	-2.74

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

**Ys, scour w/Chang equation, ft	5.09	3.48	4.04

**Ys, scour w/Umbrell equation, ft	0.38	0.36	0.22

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

y2, from Laursen’s equation, ft	8.06	8.56	6.73
WSEL at downstream face, ft	495.21	495.88	494.57
Depth at downstream face, ft	6.46	7.36	5.63
Ys, depth of scour (Laursen), ft	1.60	1.20	1.10

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	2550	3530	1810	2550	3530	1810
a’, abut.length blocking flow, ft	209.1	224.6	79.5	60.4	74.9	36.3
Ae, area of blocked flow ft2	317.73	343.9	228.8	175.5	214.61	116.22
Qe, discharge blocked abut.,cfs	--	--	571.44	436.69	--	259.43
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.26	2.47	2.50	2.49	2.86	2.23
ya, depth of f/p flow, ft	1.52	1.53	2.88	2.91	2.87	3.20
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--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	0.287	0.275	0.259	0.257	0.290	0.220
ys, scour depth, ft	8.88	8.96	9.45	8.75	9.71	7.71

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)	209.1	224.6	79.5	60.4	74.9	36.3

y1 (depth f/p flow, ft)	1.52	1.53	2.88	2.91	2.87	3.20
a'/y1	137.61	146.69	27.62	20.79	26.14	11.34
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.29	0.28	0.26	0.26	0.29	0.22
Ys w/ corr. factor K1/0.55:						
vertical	7.32	7.27	13.41	ERR	13.85	ERR
vertical w/ ww's	6.00	5.96	11.00	ERR	11.36	ERR
spill-through	4.03	4.00	7.38	ERR	7.62	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	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.86	0.76	0.86	0.86	0.76	0.86
y, depth of flow in bridge, ft	6.46	7.36	5.63	6.46	7.36	5.63
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	2.63	ERR	ERR	2.63	ERR
Fr>0.8 (vertical abut.)	2.59	ERR	2.26	2.59	ERR	2.26
Fr<=0.8 (spillthrough abut.)	ERR	2.29	ERR	ERR	2.29	ERR
Fr>0.8 (spillthrough abut.)	2.29	ERR	2.00	2.29	ERR	2.00