LEVEL II SCOUR ANALYSIS FOR BRIDGE 34 (CONCTH00110034) on TOWN HIGHWAY 11, crossing MILES STREAM, CONCORD, VERMONT

Open-File Report 97-776

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior

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By RONDA L. BURNS and ROBERT E. HAMMOND

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Pembroke, New Hampshire

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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 34 (CONCTH00110034) ON TOWN HIGHWAY 11, CROSSING MILES STREAM, CONCORD, VERMONT

By **Ronda L. Burns and Robert E. Hammond**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CONCTH00110034 on Town Highway 11 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 24.9-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is shrub and brush on the left bank upstream and downstream of the bridge. The surface cover on the right bank upstream is pasture while downstream it is forest.

In the study area, Miles Stream has an incised, sinuous channel with a slope of approximately 0.005 ft/ft, an average channel top width of 48 ft and an average bank height of 4 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 102 mm (0.335 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 11 crossing of Miles Stream is a 38-ft-long, two-lane bridge consisting of one 36-foot concrete slab span (Vermont Agency of Transportation, written communication, March 16, 1995). The opening length of the structure parallel to the bridge face is 33.9 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 20 degrees to the opening. The calculated opening-skew-to-roadway is 25 degrees while the VTAOT determined opening-skew-to-roadway is 22 degrees.

The scour countermeasures at the site included type-2 stone fill (less than 36 inches diameter) along the entire base length of all four wingwalls, scattered in front of the left and right abutments, and along the downstream left and right banks. Also, there is type-3 stone fill (less than 48 inches diameter) along the upstream left and right banks. 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 1.3 ft. The worst-case contraction scour occurred at the incipient roadway-overtopping discharge, which was less than the 100-year discharge. The right abutment scour ranged from 7.4 to 9.6 ft while the left abutment scour ranged from 12.8 to 14.4 ft. The worst-case abutment scour for the left and right abutments 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. However, there is exposed bedrock in the channel upstream and downstream of the bridge.

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 CONCTH00110034 ***Stream*** Miles Stream

County Essex ***Road*** TH 11 ***District*** 7

Description of Bridge

Bridge length 38 ***ft*** ***Bridge width*** 25.3 ***ft*** ***Max span length*** 36 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 8/15/95

Description of stone fill Type-2, along the entire base length of all four wingwalls and scattered in front of the left and right abutments.

Brief description of piers/abutments The abutments and wingwalls are concrete.

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

There is a mild channel bend in the upstream reach and a moderate channel bend in the downstream reach.

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

	Date of inspection	*Percent of channel blocked horizontally*	*Percent of channel blocked vertically*
Level I	8/15/95	0	0
Level II	8/15/95	0	0

Potential for debris Low. There is some debris caught on a large boulder at the upstream face of the bridge.

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

None noted as of 8/15/95.

Description of the Geomorphic Setting

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

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

Date of inspection 8/15/95

DS left: Moderately sloped channel bank to a narrow flood plain

DS right: Moderately sloped channel bank to a narrow flood plain

US left: Moderately sloped channel bank to a narrow flood plain

US right: Moderately sloped channel bank to a narrow flood plain

Description of the Channel

Average top width 48 ft ***Average depth*** 4 ft

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

Sinuous but stable with non-alluvial channel boundaries and a narrow flood plain.

8/15/95

Vegetative co Shrubs and brush near the bridge with trees further downstream

DS left: Shrubs and brush near the bridge with trees further downstream

DS right: Shrubs and brush near the bridge with trees further upstream

US left: Meadow and brush near the bridge with trees further upstream

US right: Yes

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

There are several large boulders in the upstream and downstream channel as of 8/15/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 24.9 ***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***:

Is there a USGS gage on the stream of interest? No

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 3,180 ***ft³/s*** ***Q500*** 4,400 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency estimates available from the VTAOT database. The values used were within a range defined by flood frequency curves developed from several empirical methods and extended to the 500-year discharge (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) Sea level/VTAOT plans

Datum tie between USGS survey and VTAOT plans The VTAOT plans' datum, (NGVD29) was obtained by subtracting 63.0 from the USGS survey.

Description of reference marks used to determine USGS datum. RM1 is a metal disk, State of Vermont survey mark, on top the upstream end of the left abutment (elev. 836.97 ft, VTAOT datum). RM2 is a chiseled X on top of the downstream end of the right abutment (elev. 836.88 ft, VTAOT datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-41	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	17	1	Road Grade section
APPRO	64	2	Modelled Approach section (Templated from APTEM)
APTEM	69	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.040 to 0.057, and overbank "n" values ranged from 0.057 to 0.070.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0050 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 (0.0014 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 location also provides a consistent method for determining scour variables.

For the incipient-overtopping discharge, WSPRO assumes critical depth at the bridge section. A supercritical model was developed for this discharge. After analyzing both the supercritical and subcritical profiles for this discharge, it was determined that the water surface profile does pass through critical depth within the bridge opening. Thus, the assumption of critical depth at the bridge is a satisfactory solution.

Bridge Hydraulics Summary

Average bridge embankment elevation 836.8 ***ft***
Average low steel elevation 835.2 ***ft***

100-year discharge 3,180 ***ft³/s***
Water-surface elevation in bridge opening 835.2 ***ft***
Road overtopping? Yes ***Discharge over road*** 483 ***ft³/s***
Area of flow in bridge opening 313 ***ft²***
Average velocity in bridge opening 8.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.0 ***ft/s***

Water-surface elevation at Approach section with bridge 836.7
Water-surface elevation at Approach section without bridge 832.7
Amount of backwater caused by bridge 4.0 ***ft***

500-year discharge 4,400 ***ft³/s***
Water-surface elevation in bridge opening 835.2 ***ft***
Road overtopping? Yes ***Discharge over road*** 1,336 ***ft³/s***
Area of flow in bridge opening 313 ***ft²***
Average velocity in bridge opening 9.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.6 ***ft/s***

Water-surface elevation at Approach section with bridge 837.5
Water-surface elevation at Approach section without bridge 833.8
Amount of backwater caused by bridge 3.7 ***ft***

Incipient overtopping discharge 2,870 ***ft³/s***
Water-surface elevation in bridge opening 831.4 ***ft***
Area of flow in bridge opening 199 ***ft²***
Average velocity in bridge opening 14.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 17.6 ***ft/s***

Water-surface elevation at Approach section with bridge 835.3
Water-surface elevation at Approach section without bridge 832.0
Amount of backwater caused by bridge 3.3 ***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. However, there is exposed bedrock in the channel upstream and downstream of the bridge. The results of the scour analysis for the 100-year and 500-year discharges 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 and 500-year 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). Contraction scour for the incipient roadway-overtopping discharge was computed by use of the Laursen clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). Results of this scour analysis are shown in Tables 1 and 2 and Figure 8.

For comparison, contraction scour for the discharges resulting in orifice flow was also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and others, 1995, p. 144) and presented in Appendix F. Furthermore, for those discharges resulting 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 was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. Variables for the HIRE equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	1.3
Depth to armoring	11.2	10.5	27.7
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	13.8	14.4	12.8
Right abutment	7.4	9.6	7.5
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	2.8	3.0	2.7
Right abutment	2.8	3.0	2.7
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

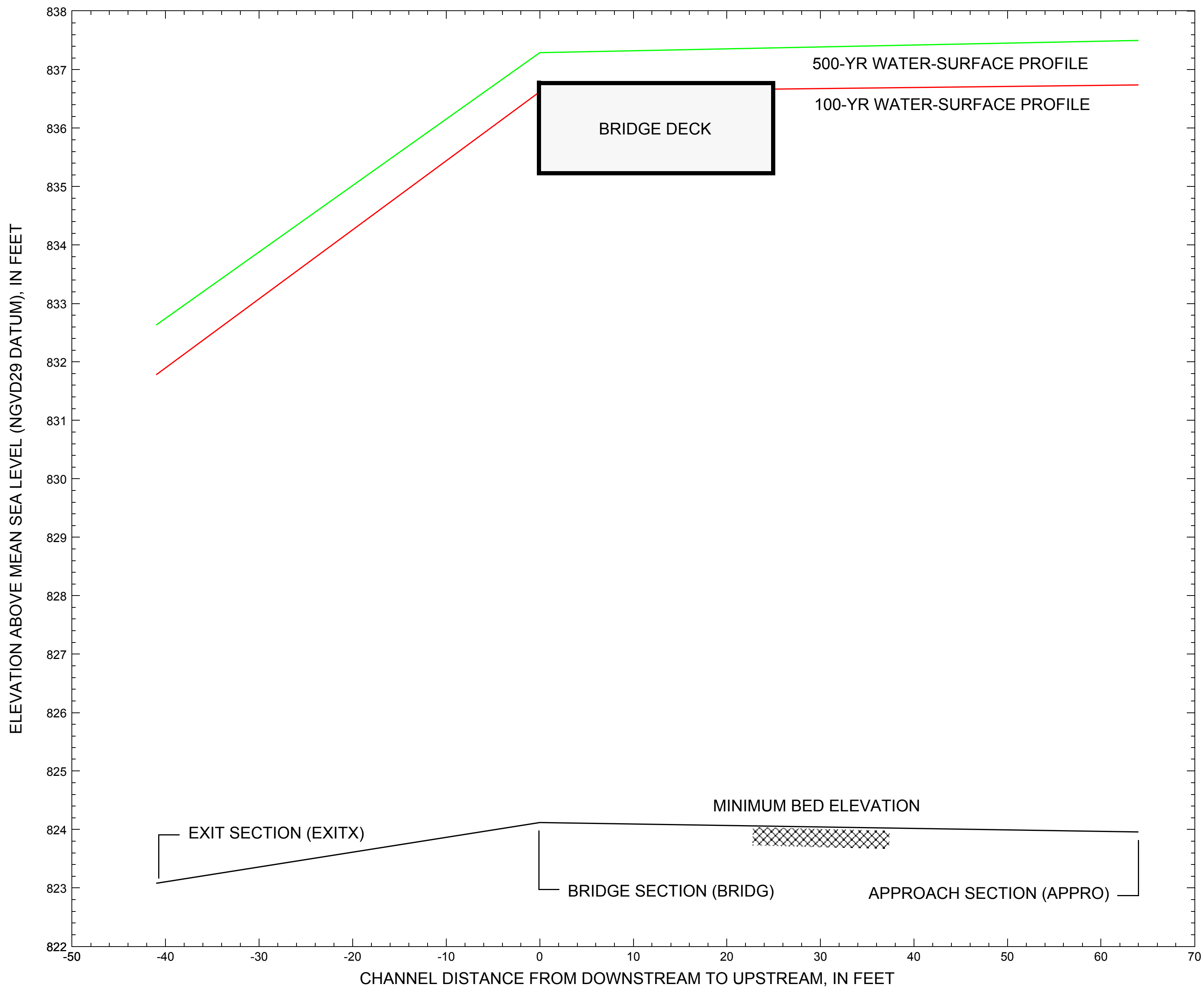

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CONCTH00110034 on Town Highway 11, crossing Miles Stream, Concord, Vermont.

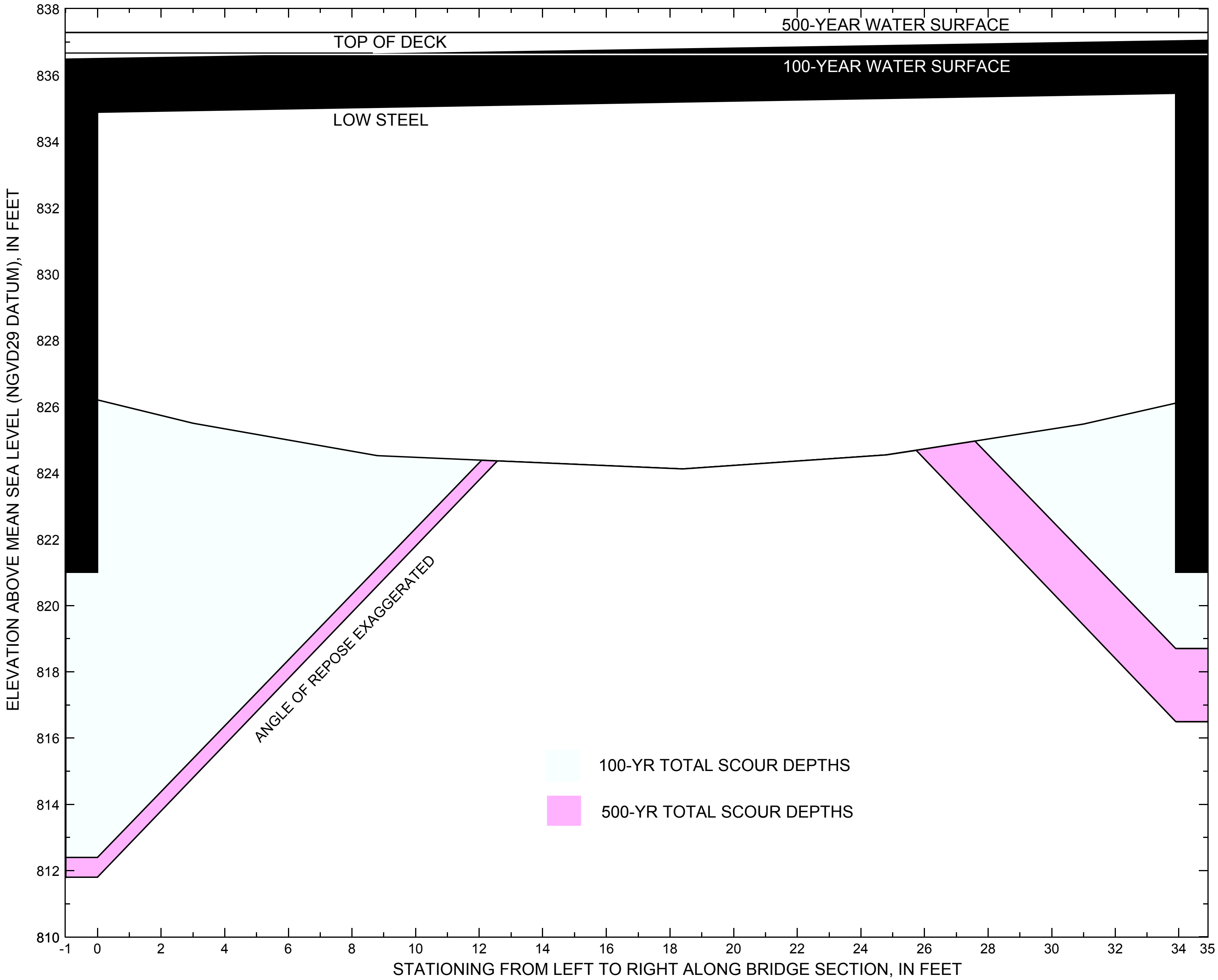

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CONCTH00110034 on Town Highway 11, crossing Miles Stream, Concord, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CONCTH00110034 on Town Highway 11, 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 3,180 cubic-feet per second											
Left abutment	0.0	834.9	834.9	821.0	826.2	0.0	13.8	--	13.8	812.4	-8.6
Right abutment	33.9	835.5	835.4	821.0	826.1	0.0	7.4	--	7.4	818.7	-2.3

1.Measured along the face of the most constricting side of the bridge.
2.Mean sea level (NGVD29).

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure CONCTH00110034 on Town Highway 11, 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 4,400 cubic-feet per second											
Left abutment	0.0	834.9	834.9	821.0	826.2	0.0	14.4	--	14.4	811.8	-9.2
Right abutment	33.9	835.5	835.4	821.0	826.1	0.0	9.6	--	9.6	816.5	-4.5

1.Measured along the face of the most constricting side of the bridge.
2.Mean sea level (NGVD29).

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

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File conc034.wsp
T2        Hydraulic analysis for structure CONCTH00110034   Date: 29-JUL-97
T3        TH 11 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           3180.0   4400.0  2870.0
SK          0.0050   0.0050  0.0050
*
XS   EXITX    -41          0.
GR         -182.8, 841.78   -155.9, 836.48   -135.1, 836.13
GR         -106.9, 834.53    -82.9, 830.10    -13.8, 827.46      0.0, 828.47
GR            7.5, 824.76     11.6, 823.08     18.4, 823.61     26.5, 823.79
GR           30.8, 824.55     34.0, 824.75     46.1, 829.53    130.4, 830.48
GR          170.9, 833.50    203.3, 839.23
*          -159.0, 835.52
*
N           0.062        0.057        0.070
SA                   0.0         46.1
*
XS   FULLV      0  * * *   0.0033
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    835.16      25.0
GR            0.0, 834.88      0.5, 826.20      3.0, 825.50      8.8, 824.52
GR           18.4, 824.12     24.8, 824.54     31.0, 825.47     33.9, 826.10
GR           33.9, 835.45      0.0, 834.88
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      34.0      2.8    836.8     44.0
N           0.040
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     17      25.3     2
GR         -212.3, 844.64   -199.9, 839.94   -183.6, 836.87   -160.4, 835.45
GR         -115.8, 835.63    -78.3, 835.86      0.0, 836.48
GR           33.1, 837.05    131.9, 838.85    188.8, 839.55
GR          281.6, 839.89    356.8, 847.59
*           206.0, 837.09    223.2, 835.52   -131.2, 833.85
*
XT   APTEM     69          0.
GR         -175.3, 850.42   -118.9, 830.14    -71.5, 831.81    -32.3, 832.57
GR           -5.1, 833.61      0.0, 831.07      8.0, 825.54     12.1, 824.33
GR           18.0, 823.99     21.0, 823.97     25.5, 824.53     29.3, 825.01
GR           31.2, 825.53     39.3, 830.14     44.8, 832.69     82.0, 834.98
GR          147.1, 836.43    169.9, 839.06    208.5, 840.42    245.2, 840.77
GR          281.6, 839.89    356.8, 847.59
*
AS   APPRO     64  * * *   0.0014
GT
N           0.070        0.052        0.057
SA                  -5.1         44.8
*
HP 1 BRIDG  835.16 1 835.16
HP 2 BRIDG  835.16 * * 2699
HP 1 BRIDG  832.01 1 832.01
HP 2 RDWAY  836.62 * * 483
HP 1 APPRO  836.74 1 836.74
HP 2 APPRO  836.74 * * 3180
*
HP 1 BRIDG  835.16 1 835.16
HP 2 BRIDG  835.16 * * 3060
HP 1 BRIDG  832.87 1 832.87
HP 2 RDWAY  837.29 * * 1336
```

APPENDIX B:

WSPRO OUTPUT FILE

```
       U.S. Geological Survey WSPRO Input File conc034.wsp
       Hydraulic analysis for structure CONCTH00110034   Date: 29-JUL-97
       TH 11 CROSSING MILES STREAM IN CONCORD, VT                  RLB
          *** RUN DATE & TIME: 08-27-97  12:21

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      313     33821     16     63                         7957
  835.16           313     33821     16     63  1.00      0     34     7957

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

        WSEL     LEW     REW    AREA         K        Q    VEL
      835.16     0.0    33.9   313.3   33821.    2699.   8.62

X STA.        0.0         3.9         6.2         8.2        10.0        11.8
  A(I)            30.6        20.4        18.5        17.3        16.5
  V(I)            4.42        6.61        7.30        7.82        8.16

X STA.       11.8        13.5        15.1        16.7        17.8        19.0
  A(I)            16.5        15.7        15.9        11.9        11.5
  V(I)            8.17        8.57        8.50       11.38       11.71

X STA.       19.0        20.2        21.3        22.5        23.6        24.8
  A(I)            11.5        11.4        11.4        11.3        11.7
  V(I)           11.77       11.85       11.80       11.97       11.55

X STA.       24.8        26.1        27.4        28.9        30.7        33.9
  A(I)            11.9        12.7        13.5        15.9        27.3
  V(I)           11.36       10.67       10.00        8.47        4.95

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      219     24352     31     42                         3322
  832.01           219     24352     31     42  1.00      0     34     3322

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      17.

        WSEL     LEW     REW    AREA         K        Q    VEL
      836.62  -179.5     8.1   128.0    2438.     483.   3.77

X STA.     -179.5      -163.1      -158.3      -153.8      -149.4      -144.9
  A(I)             8.2         5.4         5.1         5.0         5.1
  V(I)            2.94        4.45        4.72        4.79        4.78

X STA.     -144.9      -140.4      -135.6      -130.8      -125.7      -120.4
  A(I)             4.9         5.1         5.2         5.2         5.4
  V(I)            4.90        4.70        4.67        4.64        4.44

X STA.     -120.4      -114.9      -109.0      -102.6       -95.6       -88.0
  A(I)             5.5         5.7         5.9         6.2         6.4
  V(I)            4.38        4.24        4.06        3.90        3.77

X STA.      -88.0       -79.4       -69.4       -57.0       -40.1         8.1
  A(I)             6.9         7.3         7.9         8.9        12.5
  V(I)            3.52        3.33        3.04        2.72        1.93

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      64.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      612     36009    132    133                         7480
            2      476     57984     50     54                         8344
            3      177      6522    105    105                         1299
  836.74          1265    100515    287    293  1.57   -136    150    12042

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

        WSEL     LEW     REW    AREA         K        Q    VEL
      836.74  -137.3   149.8  1265.1  100515.    3180.   2.51

X STA.     -137.3      -113.4      -101.6       -88.3       -73.4       -56.3
  A(I)            96.8        73.0        76.8        78.4        81.9
  V(I)            1.64        2.18        2.07        2.03        1.94

X STA.      -56.3       -36.6       -10.7         4.8         9.0        12.1
  A(I)            88.1        99.2        75.9        43.9        36.9
  V(I)            1.81        1.60        2.10        3.62        4.31

X STA.       12.1        15.0        17.6        20.3        23.1        25.9
  A(I)            35.6        33.9        34.4        34.7        34.5
  V(I)            4.47        4.70        4.62        4.58        4.61

X STA.       25.9        28.9        32.3        37.5        53.0       149.8
  A(I)            36.1        39.4        46.9        73.3       145.4
  V(I)            4.41        4.04        3.39        2.17        1.09
```

```
       U.S. Geological Survey WSPRO Input File conc034.wsp
       Hydraulic analysis for structure CONCTH00110034   Date: 29-JUL-97
       TH 11 CROSSING MILES STREAM IN CONCORD, VT                  RLB
          *** RUN DATE & TIME: 08-27-97  12:21

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      313     33821     16     63                         7957
  835.16           313     33821     16     63  1.00      0     34     7957

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      835.16     0.0    33.9   313.3   33821.    3060.   9.77

X STA.         0.0        3.9        6.2        8.2       10.0       11.8
  A(I)            30.6       20.4       18.5       17.3       16.5
  V(I)            5.01       7.49       8.28       8.87       9.25

X STA.        11.8       13.5       15.1       16.7       17.8       19.0
  A(I)            16.5       15.7       15.9       11.9       11.5
  V(I)            9.26       9.72       9.64      12.91      13.28

X STA.        19.0       20.2       21.3       22.5       23.6       24.8
  A(I)            11.5       11.4       11.4       11.3       11.7
  V(I)           13.34      13.44      13.37      13.57      13.09

X STA.        24.8       26.1       27.4       28.9       30.7       33.9
  A(I)            11.9       12.7       13.5       15.9       27.3
  V(I)           12.87      12.09      11.34       9.60       5.61

   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      245     28655     31     44                         3936
  832.87           245     28655     31     44  1.00      0     34     3936

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      17.

        WSEL     LEW     REW    AREA        K        Q    VEL
      837.29  -185.8    46.3   269.3    7611.    1336.   4.96

X STA.      -185.8     -165.8     -158.6     -152.4     -146.0     -139.7
  A(I)            17.6       12.5       11.2       11.4       11.1
  V(I)            3.80       5.36       5.94       5.85       6.01

X STA.      -139.7     -133.4     -126.7     -120.0     -113.0     -105.8
  A(I)            11.1       11.5       11.3       11.6       11.7
  V(I)            6.02       5.83       5.91       5.75       5.72

X STA.      -105.8      -98.3      -90.2      -81.7      -72.7      -62.5
  A(I)            11.9       12.3       12.5       12.9       13.6
  V(I)            5.61       5.43       5.34       5.19       4.90

X STA.       -62.5      -51.5      -39.0      -23.9       -6.0       46.3
  A(I)            13.9       14.6       15.9       16.7       24.0
  V(I)            4.80       4.56       4.20       4.01       2.79

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      64.
    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      714     45955    134    136                         9336
            2      514     65885     50     54                         9361
            3      259     11850    112    112                         2238
  837.50          1487    123690    296    302  1.52   -138    156    15360

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

        WSEL     LEW     REW    AREA        K        Q    VEL
      837.50  -139.4   156.4  1486.6  123690.    4400.   2.96

X STA.      -139.4     -114.0     -101.7      -88.4      -73.9      -57.5
  A(I)           111.2       85.7       86.8       87.4       91.7
  V(I)            1.98       2.57       2.53       2.52       2.40

X STA.       -57.5      -39.1      -17.3        2.9        8.3       11.8
  A(I)            96.6      104.1       98.4       54.8       44.3
  V(I)            2.28       2.11       2.24       4.02       4.97

X STA.        11.8       14.9       17.9       20.9       23.9       27.1
  A(I)            41.1       40.4       40.4       40.5       41.1
  V(I)            5.35       5.45       5.45       5.43       5.35

X STA.        27.1       30.6       35.2       43.3       69.4      156.4
  A(I)            44.2       50.3       61.0      107.7      159.0
  V(I)            4.98       4.37       3.61       2.04       1.38
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File conc034.wsp
        Hydraulic analysis for structure CONCTH00110034   Date: 29-JUL-97
        TH 11 CROSSING MILES STREAM IN CONCORD, VT                  RLB
           *** RUN DATE & TIME: 08-27-97  12:21

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      199     21217    31     41                         2881
   831.36           199     21217    31     41  1.00      0     34     2881

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

         WSEL     LEW     REW    AREA         K        Q    VEL
       831.36     0.2    33.9   198.9   21217.    2870.  14.43

X STA.         0.2         3.9         5.9         7.6         9.1        10.6
  A(I)            18.0        11.3        10.0         9.3         8.9
  V(I)            7.97       12.75       14.31       15.43       16.09

X STA.        10.6        11.9        13.2        14.5        15.8        17.1
  A(I)             8.5         8.5         8.2         8.3         8.1
  V(I)           16.88       16.95       17.39       17.20       17.61

X STA.        17.1        18.3        19.6        20.9        22.2        23.6
  A(I)             8.2         8.2         8.5         8.4         8.6
  V(I)           17.56       17.58       16.98       17.01       16.61

X STA.        23.6        25.0        26.6        28.3        30.4        33.9
  A(I)             8.9         9.4        10.2        11.2        18.1
  V(I)           16.21       15.25       14.03       12.76        7.91

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      64.
     WSEL  SA#     AREA         K  TOPW   WETP  ALPH    LEW    REW      QCR
             1      430     20405   128    129                         4469
             2      406     44509    50     54                         6577
             3       59      1654    54     54                          353
   835.34           896     66567   232    237  1.58   -132     98     7942

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      64.

         WSEL     LEW     REW    AREA         K        Q    VEL
       835.34  -133.4    98.5   895.6   66567.    2870.   3.20

X STA.      -133.4      -112.1      -100.3       -86.0       -68.8       -46.8
  A(I)            72.3        56.2        61.4        64.4        71.9
  V(I)            1.98        2.55        2.34        2.23        2.00

X STA.       -46.8       -14.6         5.4         8.9        11.6        13.9
  A(I)            85.7        66.4        32.5        27.9        26.0
  V(I)            1.67        2.16        4.41        5.14        5.52

X STA.        13.9        16.2        18.4        20.6        22.8        25.1
  A(I)            25.3        24.8        24.7        24.9        25.4
  V(I)            5.67        5.78        5.80        5.75        5.65

X STA.        25.1        27.5        30.2        33.4        38.7        98.5
  A(I)            26.2        27.7        30.1        37.6        84.1
  V(I)            5.48        5.19        4.77        3.82        1.71
```

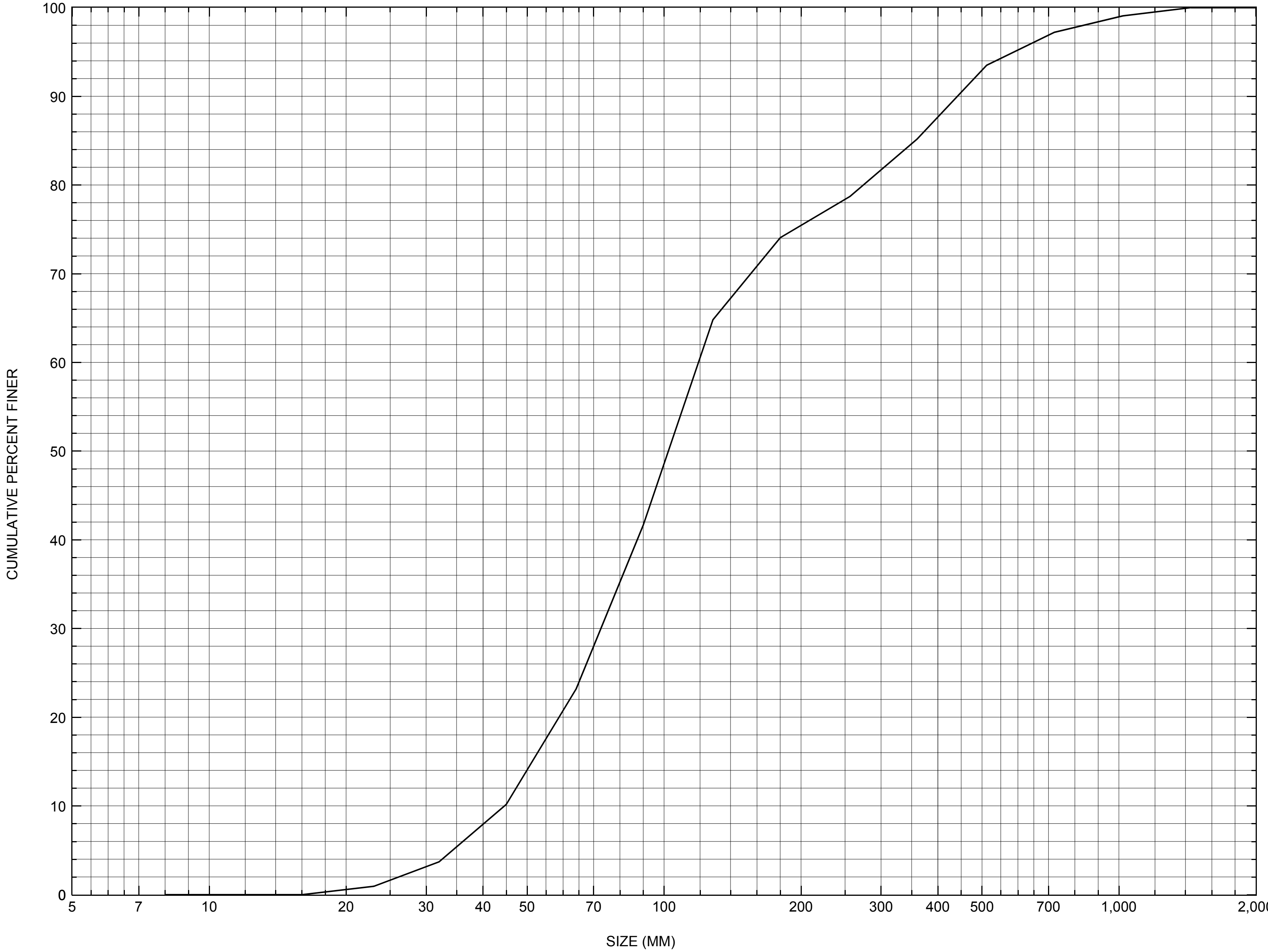
```
        U.S. Geological Survey WSPRO Input File conc034.wsp
        Hydraulic analysis for structure CONCTH00110034   Date: 29-JUL-97
        TH 11 CROSSING MILES STREAM IN CONCORD, VT                  RLB
           *** RUN DATE & TIME: 08-27-97  12:21

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

EXITX:XS   ******    -91      733  0.44 *****  832.21  830.57    3180  831.78
       -40 ******    148    44968  1.49 ***** *******    0.53    4.34

FULLV:FV       41    -92      758  0.41  0.20  832.42 *******    3180  832.01
         0     41    149    46847  1.49  0.00    0.01    0.51    4.20
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                WSLIM1,WSLIM2,DELTAY =   831.51     850.41     0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                WSLIM1,WSLIM2,CRWS =   831.51     850.41     832.68
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
           ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                WSBEG,WSEND,CRWS =   832.68     850.41     832.68

APPRO:AS       64   -125      384  1.56 *****  834.23  832.68    3180  832.68
        64     64     45    26245  1.46 ***** *******    1.08    8.29
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   836.21       0.00     831.80     835.45
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                WS,QBO,QRD =   838.71         0.      3180.
 ===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       41      0      313  1.15 *****  836.31  831.09    2699  835.16
         0 ******     34    33821  1.00 ***** *******    0.50    8.62

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.429  0.000  835.16 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q   WSEL
   RDWAY:RG      17.    39.  0.04  0.15  836.85    0.00    483.  836.62

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    483.   188.  -180.     8.   1.2   0.7   4.2   3.8   0.9   2.9
   RT:      0.     6.    17.    23.   0.1   0.1   2.3   9.8   0.3   2.6

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

APPRO:AS       30   -136     1265  0.15  0.09  836.89  832.68    3180  836.74
        64     36    150   100484  1.57  0.00    0.00    0.26    2.51

       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
   EXITX:XS     -41.   -92.   148.   3180.   44968.     733.    4.34  831.78
   FULLV:FV       0.   -93.   149.   3180.   46847.     758.    4.20  832.01
   BRIDG:BR       0.     0.    34.   2699.   33821.     313.    8.62  835.16
   RDWAY:RG      17.*******   483.    483.*********       0.    2.00  836.62
   APPRO:AS      64.  -137.   150.   3180.  100484.    1265.    2.51  836.74

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF    HO  VHD      EGL    WSEL
   EXITX:XS    830.57    0.53  823.08  841.78************  0.44  832.21  831.78
   FULLV:FV  ********    0.51  823.22  841.92  0.20  0.00  0.41  832.42  832.01
   BRIDG:BR    831.09    0.50  824.12  835.45************  1.15  836.31  835.16
   RDWAY:RG  ****************  835.45  847.59  0.04******  0.15  836.85  836.62
   APPRO:AS    832.68    0.26  823.96  850.41  0.09  0.00  0.15  836.89  836.74
```

```
        U.S. Geological Survey WSPRO Input File conc034.wsp
        Hydraulic analysis for structure CONCTH00110034   Date: 29-JUL-97
        TH 11 CROSSING MILES STREAM IN CONCORD, VT                  RLB
           *** RUN DATE & TIME: 08-27-97  12:21

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

EXITX:XS   ******    -96      945  0.49 *****  833.12  831.19    4400  832.63
       -40 ******    159    62169  1.44 ***** *******    0.51    4.66

FULLV:FV       41    -96      971  0.46  0.20  833.33 *******    4400  832.87
         0     41    161    64431  1.44  0.00    0.01    0.49    4.53
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   832.37     850.41    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   832.37     850.41     833.76
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
             ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                  WSBEG,WSEND,CRWS =   833.76     850.41     833.76

APPRO:AS       64   -128      567  1.50 *****  835.26  833.76    4400  833.76
        64     64     62    38614  1.61 ***** *******    1.01    7.76
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   839.10       0.00     833.50     835.45
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   839.23         0.      4400.
 ===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       41      0      313  1.48 *****  836.64  831.63    3060  835.16
         0 ******     34    33821  1.00 ***** *******    0.57    9.77

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.459  0.000  835.16 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR      Q    WSEL
   RDWAY:RG      17.    39.  0.05  0.21  837.66    0.00   1336.  837.29

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:  1296.   203.  -186.    17.   1.8   1.3   5.8   5.0   1.7   3.0
   RT:    40.    29.    17.    46.   0.5   0.3   3.3   5.3   0.6   2.8

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

APPRO:AS       30   -138     1486  0.21  0.13  837.71  833.76    4400  837.50
        64     38    156   123647  1.52  0.00    0.00    0.29    2.96

       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
   EXITX:XS     -41.   -97.   159.   4400.   62169.     945.    4.66  832.63
   FULLV:FV       0.   -97.   161.   4400.   64431.     971.    4.53  832.87
   BRIDG:BR       0.     0.    34.   3060.   33821.     313.    9.77  835.16
   RDWAY:RG      17.******* 1296.   1336.******************    2.00  837.29
   APPRO:AS      64.  -139.   156.   4400.  123647.    1486.    2.96  837.50

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN     YMAX     HF     HO  VHD      EGL     WSEL
   EXITX:XS     831.19    0.51  823.08  841.78************  0.49  833.12  832.63
   FULLV:FV   ********    0.49  823.22  841.92  0.20  0.00  0.46  833.33  832.87
   BRIDG:BR     831.63    0.57  824.12  835.45************  1.48  836.64  835.16
   RDWAY:RG  ***************  835.45  847.59  0.05******  0.21  837.66  837.29
   APPRO:AS     833.76    0.29  823.96  850.41  0.13  0.00  0.21  837.71  837.50
```

```
        U.S. Geological Survey WSPRO Input File conc034.wsp
        Hydraulic analysis for structure CONCTH00110034   Date: 29-JUL-97
        TH 11 CROSSING MILES STREAM IN CONCORD, VT                  RLB
           *** RUN DATE & TIME: 08-27-97  12:21

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

EXITX:XS   ******    -90      675  0.42 *****  831.95  830.27    2870  831.53
       -40 ******    144    40576  1.51 ***** *******    0.54    4.25

FULLV:FV       41    -90      698  0.39  0.20  832.16 *******    2870  831.77
         0     41    146    42349  1.50  0.00    0.01    0.52    4.11
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.33     831.36     831.99
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   831.27     850.41    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   831.27     850.41     831.99
 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                   WSBEG,WSEND,CRWS =   831.99     850.41     831.99

APPRO:AS       64   -123      297  1.88 *****  833.87  831.99    2870  831.99
        64     64     43    21185  1.29 ***** *******    1.17    9.67
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =    2870.     831.36
            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

BRIDG:BR       41      0      199  3.34 *****  834.70  831.36    2870  831.36
         0     41     34    21204  1.03 ***** *******    1.01   14.43

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   1.  0.984 ******  835.16 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q   WSEL
   RDWAY:RG      17.        <<<<<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       30   -132      896  0.25  0.20  835.59  831.99    2870  835.34
        64     34     99    66614  1.58  0.70    0.01    0.36    3.20

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.799  0.354   42922.     2.    36.   835.27
                   <<<<<END OF BRIDGE COMPUTATIONS>>>>>

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -41.   -91.   144.   2870.   40576.     675.    4.25  831.53
   FULLV:FV       0.   -91.   146.   2870.   42349.     698.    4.11  831.77
   BRIDG:BR       0.     0.    34.   2870.   21204.     199.   14.43  831.36
   RDWAY:RG      17.**************      0.*****************    2.00********
   APPRO:AS      64.  -133.    99.   2870.   66614.     896.    3.20  835.34

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS       2.    36.   42922.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    830.27    0.54  823.08  841.78************  0.42  831.95  831.53
   FULLV:FV  ********    0.52  823.22  841.92  0.20  0.00  0.39  832.16  831.77
   BRIDG:BR    831.36    1.01  824.12  835.45************  3.34  834.70  831.36
   RDWAY:RG ****************  835.45  847.59*********************************
   APPRO:AS    831.99    0.36  823.96  850.41  0.20  0.70  0.25  835.59  835.34
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CONCTH00110034, in Concord, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CONCTH00110034

General Location Descriptive

Data collected by *(First Initial, Full last name)* E. BOEHMLER

Date *(MM/DD/YY)* 03 / 16 / 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 TH011

Vicinity *(I - 9)* 0.4 MI JCT TH 11 + TH 4

Topographic Map Miles Pond

Hydrologic Unit Code: 01080102

Latitude *(I - 16; nnnn.n)* 44251

Longitude *(i - 17; nnnnn.n)* 71456

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10050700340507

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

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

Year built *(I - 27; YYYY)* 1989

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

Average daily traffic, ADT *(I - 29; nnnnnn)* 000030

Deck Width *(I - 52; nn.n)* 253

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

Channel & Protection *(I - 61; n)* 6

Opening skew to Roadway *(I - 34; nn)* 22

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

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

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

Structure type *(I - 43; nnn)* 101

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 031.0

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

Vertical clearance from streambed (*nnn.n ft*) 009.0

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

Waterway of full opening (*nnn.n* ft^2) 280.0

Comments:

The structural inspection report of 8/15/94 indicates that the structure is a concrete slab type bridge. The downstream roadway embankment near the right abutment is eroded. The abutment walls and wingwalls are concrete. Both abutment walls are reported as having fine cracks and small leaks at the top corners. The report also notes that stone and boulder fill protection had been placed in front of the abutments and wingwalls, and along the upstream and downstream channel banks. The previous structure was a steel stringer type bridge with a wooden deck.

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: **24.2**

Terrain character: **Hilly**

Stream character & type: **The stream is straight overall and is a tributary to the Connecticut River.**

Streambed material: **Sand, gravel, and boulders**

Discharge Data *(cfs)*: $Q_{2.33}$ **850** Q_{10} **1550** Q_{25} **2200**

Q_{50} **2700** Q_{100} **3180** Q_{500} **-**

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

Estimated Discharge *(cfs)*: **-** Velocity at Q **25** *(ft/s)*: **10.0**

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

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

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

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

Watershed storage area (*in percent*): **5** %

The watershed storage area is: **1** (*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*)	830.2	832.5	834.4	835.8	836.8
Velocity (*ft / sec*)	8.6	11.0	12.8	14.0	15.0

Long term stream bed changes: **Estimated scour expected at the bridge is indicated on the order of 2 to 4 feet.**

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): **Y** Frequency: **Q60**

Relief Elevation (*ft*): **836.2** Discharge over roadway at Q_{100} (ft^3/sec): **-**

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

Upstream distance (*miles*): **0.3** Town: **Concord** Year Built: **-**

Highway No. : **TH11** Structure No. : **20** Structure Type: **-**

Clear span (*ft*): **30.0** Clear Height (*ft*): **7.0** Full Waterway (ft^2): **210.0**

Downstream distance (*miles*): 0.4 Town: Concord Year Built: -
Highway No. : TH11 Structure No. : 35 Structure Type: -
Clear span (*ft*): 20.6 Clear Height (*ft*): 13.2 Full Waterway (ft^2): 271.0

Comments:

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 24.868 mi^2 Lake/pond/swamp area .517 mi^2
Watershed storage *(ST)* 2.08 %
Bridge site elevation 827 ft Headwater elevation 1560 ft
Main channel length 8.32 mi
10% channel length elevation 870 ft 85% channel length elevation 1294 ft
Main channel slope *(S)* 67.95 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? Y *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: 08 / 1988

Project Number BRZ 14447(13) Minimum channel bed elevation: 824.5

Low superstructure elevation: USLAB 834.88 DSLAB 834.17 USRAB 835.50 DSRAB 834.79

Benchmark location description:

BM#1, spike in a 6 in. balsam tree located approximately 20 feet left, bankward from and perpendicular to the roadway centerline and 175 feet from the left abutment parallel to the roadway , elevation 838.60.

Reference Point (*MSL, Arbitrary, Other*): MSL Datum (*NAD27, NAD83, Other*): NGVD1929

Foundation Type: 1 (*1-Spreadfooting; 2-Pile; 3- Gravity; 4-Unknown*)

If 1: Footing Thickness 2.0 Footing bottom elevation: 821.0

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:

-

Comments:

The bed elevation, after installing the bridge, is 1.5 feet above the top of both abutment footings at the bed's lowest point. Other locations shown on the plans with elevations are: 1) The point on the top of the concrete downstream left wingwall at the streamward edge where the concrete slope changes from horizontal to downward sloping, elevation 836.84, and 2) The point at the same location but on the downstream right wingwall, elevation 837.42.

Cross-sectional Data

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

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

Comments: **Orientation of the cross sections is inconsistent with any cross section data surveyed for this study and is not comparable. Data was not retrieved.**

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: -

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: 2/15/96

Computerized by: EW Date: 2/15/96

Reviewd by: RB Date: 9/24/97

Structure Number CONCTH00110034

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. HAMMOND Date *(MM/DD/YY)* 08 / 15 / 1995

2. Highway District Number 7 Mile marker 0

County ESSEX (009) Town CONCORD (15250)

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

Route Number TH011 Hydrologic Unit Code: 01080102

3. Descriptive comments:

0.4 miles to the junction with TH 4 (Oregon Road).

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 2 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 38 *(feet)* Span length 36 *(feet)* Bridge width 25.3 *(feet)*

Road approach to bridge:

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

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

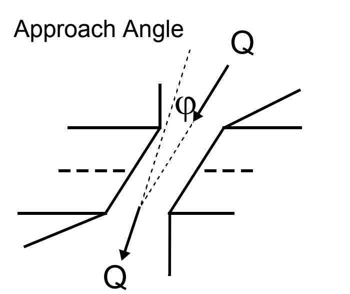
10. Embankment slope (*run / rise in feet / foot*):
US left 2.6:1 US right 3.1:1

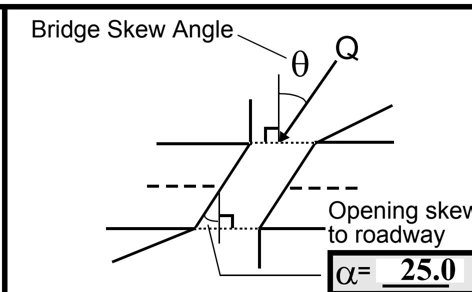
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	0
RBUS	1	1	0	0
RBDS	1	1	2	1
LBDS	2	1	2	1

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

Channel approach to bridge (BF):

15. Angle of approach: 10 16. Bridge skew: 20





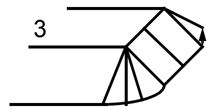
17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 40 feet US *(US, UB, DS)* to 0 feet US

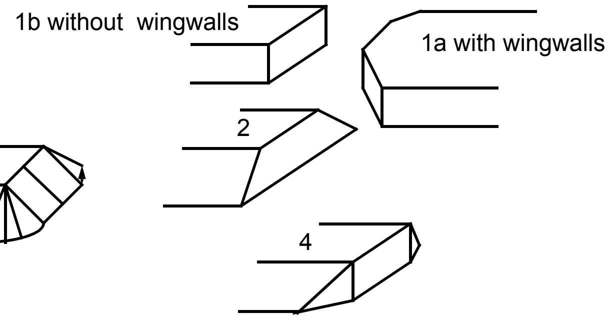
Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 2
Range? 25 feet DS *(US, UB, DS)* to 60 feet DS

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

18. Bridge Type: **4**

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.)

#4 On the left bank near the bridge, the surface cover is shrub and brushland, but further US and DS it is forest.

#7 Values are from the VTAOT database. Measured bridge dimensions are: US bridge length = 38.0 ft; US span length= 34.0 ft; bridge width= 25.5 ft; DS bridge length= 37.6 ft; DS span length= 33.5 ft.

#18 The bridge is type 1a to about 3 feet below the low chord then it is type 4 on the left. On the right, the bridge is type 1a up to the low chord and then the wingwall slopes up to the top of the bridge deck.

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
44.0	2.5			2.5	1	1	54	54	0	0

23. Bank width **25.0** 24. Channel width **25.0** 25. Thalweg depth **50.0** 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.):
#27 The bank material is also the bank protection.
#30 The right and left bank protection extends 80 feet US from the bridge.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **115** 35. Mid-bar width: **12**

36. Point bar extent: **130** feet **US** (US, UB) to **55** feet **US** (US, UB, DS) positioned **0** %LB to **60** %RB

37. Material: **4**

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

A bedrock outcrop, just upstream of this point bar, forces the channel towards the RB.

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

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

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

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

NO CUT BANKS

The channel bends into the RB at 105 feet US, however cutting is minimal to nonexistent. The channel (high flow) crosses back towards the LB at 40 feet US.

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

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
39.5		1.5		2	7	7	0

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

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

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

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

345

-

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

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

69. Is there evidence of ice build-up? **1** *(Y or N)* Ice Blockage Potential **N1** *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

#66 A small amount of debris is caught on the US side of a large boulder located 10 feet US from the bridge.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT	**0**	**90**	**2**	**0**	**-**	**-**	**1**	**90.0**
RABUT	**0**	**90**	**2**			**0**	**-**	**30.5**

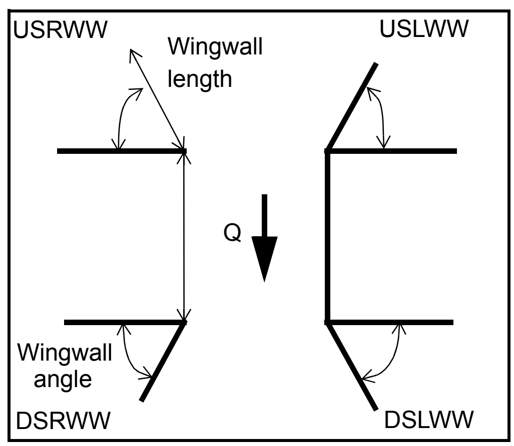
Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood

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

-
1
-

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:					**Y**	**30.5**	
USRWW:	**1**		**0**		**-**	**1.5**	
DSLWW:	**-**		**Y**		**1**	**34.0**	
DSRWW:	**0**		**-**		**-**	**34.0**	



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	**Y**	**-**	**1**	**-**	**1**	**1**	**4**	**4**
Condition	**1**	**-**	**0**	**2**	**2**	**2**	**2**	**-**
Extent	**0**	**Y**	**-**	**1**	**1**	**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.):

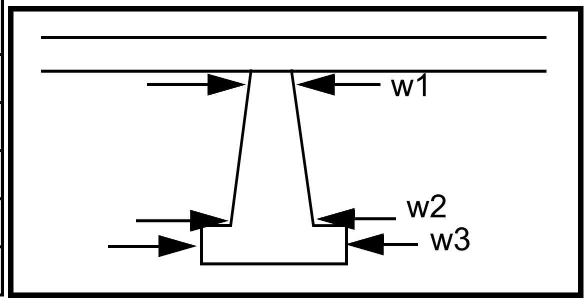
-
-
-
-
2
1
1
2
1
1

Stone fill protection in front of the LABUT and RABUT along the base is scattered and sparse.

Piers:

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

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1				**70.0**	**11.5**	**20.0**
Pier 2				**15.5**	**20.0**	**14.0**
Pier 3			**-**	**70.0**	**11.5**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)		-	-	-	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type		-	-	-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material		-	-	-	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape		-	-	-	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?		-	-	-	*Y- yes; N- no*
91. Attack ∠ (BF)		-	-	-	
92. Pushed		-	-	-	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles		-	-	-	
95. Cross-members		-	-	-	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**N**	-	-	-	***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
-	-			-	NO	PIE	RS			

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

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

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

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

2
3
5
2
1
0
345
2
2
1
1
On the LB, the bank material and the protection are the same. On the RB, the protection extends 20 feet DS then the natural bank material is evident.

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 **N** *(US, UB, DS)* to **-** feet **NO** *(US, UB, DS)* positioned **DR** %LB to **OP** %RB

Material: **ST**

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

RUCTURE

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

Cut bank extent: **110** feet **16** *(US, UB, DS)* to **59** feet **DS** *(US, UB, DS)*

Bank damage: **150** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
0
60
32

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

Scour dimensions: Length **and** Width **DS** Depth: **ends** Positioned **of** %LB to **this** %RB

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

point bar are cobble with sand in the middle. The channel water surface is a riffle adjacent to the cobbles at the US and DS ends and pooled next to the middle section of the point bar.

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

Confluence 1: Distance **105** Enters on **95** *(LB or RB)* Type **DS** *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance **120** Enters on **DS** *(LB or RB)* Type **1** *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

The cutting is minimal. The soil layer is being eroded from the top of the bedrock.

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

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

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

N
-
-
-
-
-
-
NO CHANNEL SCOUR
There is local scour behind large boulders.

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: CONCTH00110034 Town: CONCORD
Road Number: TH 11 County: ESSEX
Stream: MILES STREAM

Initials RLB Date: 8/26/97 Checked: RF

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	3180	4400	2870
Main Channel Area, ft2	476	514	406
Left overbank area, ft2	612	714	430
Right overbank area, ft2	177	259	59
Top width main channel, ft	50	50	50
Top width L overbank, ft	132	134	128
Top width R overbank, ft	105	112	54
D50 of channel, ft	0.3352	0.3352	0.3352
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	9.5	10.3	8.1
y1, average depth, LOB, ft	4.6	5.3	3.4
y1, average depth, ROB, ft	1.7	2.3	1.1
Total conveyance, approach	100515	123690	66567
Conveyance, main channel	57984	65885	44509
Conveyance, LOB	36009	45955	20405
Conveyance, ROB	6522	11850	1654
Percent discrepancy, conveyance	0.0000	0.0000	-0.0015
Qm, discharge, MC, cfs	1834.4	2343.7	1919.0
Ql, discharge, LOB, cfs	1139.2	1634.7	879.8
Qr, discharge, ROB, cfs	206.3	421.5	71.3
Vm, mean velocity MC, ft/s	3.9	4.6	4.7
Vl, mean velocity, LOB, ft/s	1.9	2.3	2.0
Vr, mean velocity, ROB, ft/s	1.2	1.6	1.2
Vc-m, crit. velocity, MC, ft/s	11.3	11.5	11.0
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	3180	4400	2870
(Q) discharge thru bridge, cfs	2699	3060	2870
Main channel conveyance	33821	33821	21217
Total conveyance	33821	33821	21217
Q2, bridge MC discharge,cfs	2699	3060	2870
Main channel area, ft2	313	313	199
Main channel width (normal), ft	30.7	30.7	30.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	30.7	30.7	30.5
y_bridge (avg. depth at br.), ft	10.20	10.20	6.52
Dm, median (1.25*D50), ft	0.419	0.419	0.419
y2, depth in contraction,ft	7.36	8.20	7.80
ys, scour depth (y2-ybridge), ft	-2.84	-2.00	1.28

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	2699	3060	2870
Main channel area (DS), ft2	219	245	199
Main channel width (normal), ft	30.7	30.7	30.5
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	30.7	30.7	30.5
D90, ft	1.4477	1.4477	1.4477
D95, ft	1.9252	1.9252	1.9252
Dc, critical grain size, ft	0.9123	0.8878	1.3056
Pc, Decimal percent coarser than Dc	0.197	0.202	0.124
Depth to armoring, ft	11.16	10.52	27.67

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	3180	4400	2870
Q, thru bridge MC, cfs	2699	3060	2870
Vc, critical velocity, ft/s	11.34	11.48	11.04
Va, velocity MC approach, ft/s	3.85	4.56	4.73
Main channel width (normal), ft	30.7	30.7	30.5
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	30.7	30.7	30.5
qbr, unit discharge, ft2/s	87.9	99.7	94.1
Area of full opening, ft2	313.0	313.0	199.0
Hb, depth of full opening, ft	10.20	10.20	6.52
Fr, Froude number, bridge MC	0.5	0.57	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	219	245	N/A
**Hb, depth at downstream face, ft	7.13	7.98	N/A
**Fr, Froude number at DS face	0.81	0.78	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A
Elevation of Low Steel, ft	835.16	835.16	0
Elevation of Bed, ft	824.96	824.96	-6.52
Elevation of Approach, ft	836.74	837.5	0
Friction loss, approach, ft	0.09	0.13	0
Elevation of WS immediately US, ft	836.65	837.37	0.00
ya, depth immediately US, ft	11.69	12.41	6.52
Mean elevation of deck, ft	836.77	836.77	0
w, depth of overflow, ft (>=0)	0.00	0.60	0.00
Cc, vert contrac correction (<=1.0)	0.97	0.96	1.00
**Cc, for downstream face (<=1.0)	0.861039	0.897702	ERR
Ys, scour w/Chang equation, ft	-2.17	-1.19	N/A
Ys, scour w/Umbrell equation, ft	-3.48	-2.59	N/A

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

**Ys, scour w/Chang equation, ft	1.87	1.69	N/A

**Ys, scour w/Umbrell equation, ft	-0.42	-0.38	ERR

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

y2, from Laursen's equation, ft	7.36	8.20	7.80
WSEL at downstream face, ft	832.01	832.87	--
Depth at downstream face, ft	7.13	7.98	N/A
Ys, depth of scour (Laursen), ft	0.23	0.22	N/A

Abutment Scour

Froehlich's Abutment Scour

Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1

(Richardson and others, 1995, p. 48, eq. 28)

	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	3180	4400	2870	3180	4400	2870
a', abut.length blocking flow, ft	138.9	141	135.2	117.5	124.1	66.2
Ae, area of blocked flow ft2	565.31	571.11	466.35	265.6	352.99	132.05
Qe, discharge blocked abut.,cfs	--	--	978.67	477	--	336.33
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.89	2.31	2.10	1.80	2.22	2.55
ya, depth of f/p flow, ft	4.07	4.05	3.45	2.26	2.84	1.99
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	115	115	115	65	65	65
K2	1.03	1.03	1.03	0.96	0.96	0.96
Fr, froude number f/p flow	0.154	0.176	0.199	0.211	0.230	0.318
ys, scour depth, ft	15.47	16.46	15.44	10.78	13.35	9.97

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)	138.9	141	135.2	117.5	124.1	66.2
y1 (depth f/p flow, ft)	4.07	4.05	3.45	2.26	2.84	1.99
a'/y1	34.13	34.81	39.20	51.98	43.63	33.19
Skew correction (p. 49, fig. 16)	1.06	1.06	1.06	0.92	0.92	0.92
Froude no. f/p flow	0.15	0.18	0.20	0.21	0.23	0.32
Ys w/ corr. factor K1/0.55:						
vertical	16.86	17.53	15.55	9.01	11.68	9.11
vertical w/ ww's	13.82	14.38	12.75	7.39	9.58	7.47
spill-through	9.27	9.64	8.55	4.96	6.42	5.01

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	0.81	0.78	1.01	0.81	0.78	1.01
y, depth of flow in bridge, ft	7.13	7.98	6.52	7.13	7.98	6.52
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	3.00	ERR	ERR	3.00	ERR
Fr>0.8 (vertical abut.)	2.81	ERR	2.73	2.81	ERR	2.73