LEVEL II SCOUR ANALYSIS FOR BRIDGE 12 (NEWBTH00020012) on TOWN HIGHWAY 2, crossing SCOTT BROOK, NEWBURY, VERMONT

Open-File Report 98-011

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

U.S. Department of the Interior
U.S. Geological Survey

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By RONDA L. BURNS

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Pembroke, New Hampshire

1998

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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	Max	maximum
D_{50}	median diameter of bed material	MC	main channel
DS	downstream	RAB	right abutment
elev.	elevation	RABUT	face of right abutment
f/p	flood plain	RB	right bank
ft^2	square feet	ROB	right overbank
ft/ft	feet per foot	RWW	right wingwall
FEMA	Federal Emergency Management Agency	TH	town highway
FHWA	Federal Highway Administration	UB	under bridge
JCT	junction	US	upstream
LAB	left abutment	USGS	United States Geological Survey
LABUT	face of left abutment	VTAOT	Vermont Agency of Transportation
LB	left bank	WSPRO	water-surface profile model
LOB	left overbank	yr	year

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 12 (NEWBTH00020012) ON TOWN HIGHWAY 2, CROSSING SCOTT BROOK, NEWBURY, 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 NEWBTH00020012 on Town Highway 2 crossing Scott Brook, Newbury, 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 (FHWA, 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 east-central Vermont. The 3.6-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest.

In the study area, Scott Brook has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 37 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 57.9 mm (0.190 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 31, 1995, indicated that the reach was stable.

The Town Highway 2 crossing of Scott Brook is a 25-ft-long, two-lane bridge consisting of one 21-foot concrete slab span (Vermont Agency of Transportation, written communication, March 27, 1995). The opening length of the structure parallel to the bridge face is 20.6 ft. The bridge is supported by vertical, stone masonry abutments with wingwalls. The channel is skewed approximately 55 degrees to the opening while the computed opening-skew-to-roadway is 40 degrees.

During the Level I assessment it was noted that the footings on the left abutment and the right abutment were exposed. The footings on the upstream left wingwall and the upstream right wingwall were also exposed and the footing on the downstream right wingwall was undermined. The scour countermeasure at the site included type-2 stone fill (less than 36 inches diameter) along the left bank upstream, type-3 stone fill (less than 48 inches diameter) along the right bank upstream, and type-4 stone fill (less than 60 inches diameter) along the right bank 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 Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was 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 3.1 ft. The worst-case contraction scour occurred at the 500-year discharge. The left abutment scour ranged from 4.4 to 5.6 ft. The worst-case left abutment scour occurred at the 100-year discharge. The right abutment scour ranged from 6.7 to 8.3 ft. The worst-case right abutment scour occurred at the 100- year and 500-year discharges. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and Davis, 1995, p. 46). 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 NEWBTH00020012 ***Stream*** Scott Brook

County Orange ***Road*** TH 2 ***District*** 7

Description of Bridge

Bridge length 25 ***ft*** ***Bridge width*** 20.2 ***ft*** ***Max span length*** 21 ***ft***

Alignment of bridge to road (on curve or straight) Curve, left. Straight, right.

Abutment type Vertical, stone masonry ***Embankment type*** None

Stone fill on abutment? No ***Date of inspection*** 8/31/95

Description of stone fill No stone fill at the bridge.

Brief description of piers/abutments Abutments and wingwalls are stone masonry. The footing is exposed on both abutments and all the wingwalls except the downstream left wingwall. In addition, the downstream right wingwall footing is undermined.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 55

The channel bends mildly upstream and downstream of the bridge.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	8/31/95	0	0
Level II	8/31/95	0	0

Potential for debris Moderate. The banks are all forested.

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

There is a point bar along the left abutment as of 8/31/95.

Description of the Geomorphic Setting

General topography The channel is located within a low relief valley with a steep valley wall on the right and a narrow flood plain on the left.

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

Date of inspection 8/31/95

DS left: Steep channel bank to a narrow flood plain

DS right: Steep valley wall

US left: Steep channel bank to a moderately sloped overbank

US right: Steep valley wall

Description of the Channel

Average top width 37 ***ft*** ***Average depth*** 7 ***ft***

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

Sinuous but stable with non-alluvial channel boundaries and a narrow flood plain on the downstream left.

8/31/95

Vegetative co Trees

DS left: Trees

DS right: Trees

US left: Trees

US right:

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

None as of 8/31/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 3.6 ***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***: None.

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 970 ***ft³/s*** ***Q500*** 1,430 ***ft³/s***

The 100-year discharge is based on a drainage area relationship [(3.62/8.4)exp 0.67] with bridge number 20 in Ryegate and was extended graphically to the 500-year discharge. Bridge number 20 crosses Scott Brook downstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 20 is 8.4 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 Add 8 ft to the USGS arbitrary survey datum to obtain the VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the right abutment (elev. 171.67 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the left abutment (elev. 171.67 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	-22	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXIT1)
BRIDG	0	1	Bridge section
RDWAY	14	1	Road Grade section
APPRO	44	2	Modelled Approach section (Templated from APTEM)
APTEM	59	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.050, and overbank "n" values ranged from 0.060 to 0.080.

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 0.0097 ft/ft, which was estimated from surveyed thalweg points downstream.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0043 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.

Bridge Hydraulics Summary

Average bridge embankment elevation 175.4 ***ft***
Average low steel elevation 169.7 ***ft***

100-year discharge 970 ***ft^3/s***
Water-surface elevation in bridge opening 169.7 ***ft***
Road overtopping? Yes ***Discharge over road*** 144 ***ft^3/s***
Area of flow in bridge opening 76 ***ft^2***
Average velocity in bridge opening 10.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 13.2 ***ft/s***

Water-surface elevation at Approach section with bridge 172.2
Water-surface elevation at Approach section without bridge 170.0
Amount of backwater caused by bridge 2.2 ***ft***

500-year discharge 1,430 ***ft^3/s***
Water-surface elevation in bridge opening 169.7 ***ft***
Road overtopping? Yes ***Discharge over road*** 535 ***ft^3/s***
Area of flow in bridge opening 76 ***ft^2***
Average velocity in bridge opening 11.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.4 ***ft/s***

Water-surface elevation at Approach section with bridge 173.4
Water-surface elevation at Approach section without bridge 171.6
Amount of backwater caused by bridge 1.8 ***ft***

Incipient overtopping discharge 540 ***ft^3/s***
Water-surface elevation in bridge opening 169.7 ***ft***
Area of flow in bridge opening 76 ***ft^2***
Average velocity in bridge opening 7.1 ***ft/s***
Maximum WSPRO tube velocity at bridge 8.7 ***ft/s***

Water-surface elevation at Approach section with bridge 171.0
Water-surface elevation at Approach section without bridge 168.6
Amount of backwater caused by bridge 2.4 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution. The results of the scour analysis for the 100-year and 500-year discharges are presented in tables 1 and 2 and the scour depths are presented graphically in figure 8.

At this site, the incipient roadway-overtopping discharge resulted in unsubmerged orifice flow. The 100-year and 500-year discharges resulted in submerged 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 Davis, 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 Davis, 1995, p. 32, equation 20) and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144) and is presented appendix F. Furthermore, for the incipient roadway-overtopping discharge, contraction scour was computed by substituting an estimate for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to this substitution are provided in appendix F.

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	2.0	3.1	0.0
Depth to armoring	15.7	30.3	22.3
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	5.6	5.2	4.4
Right abutment	8.3	8.3	6.7
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	2.0	2.1	1.4
Right abutment	2.0	2.1	1.4
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

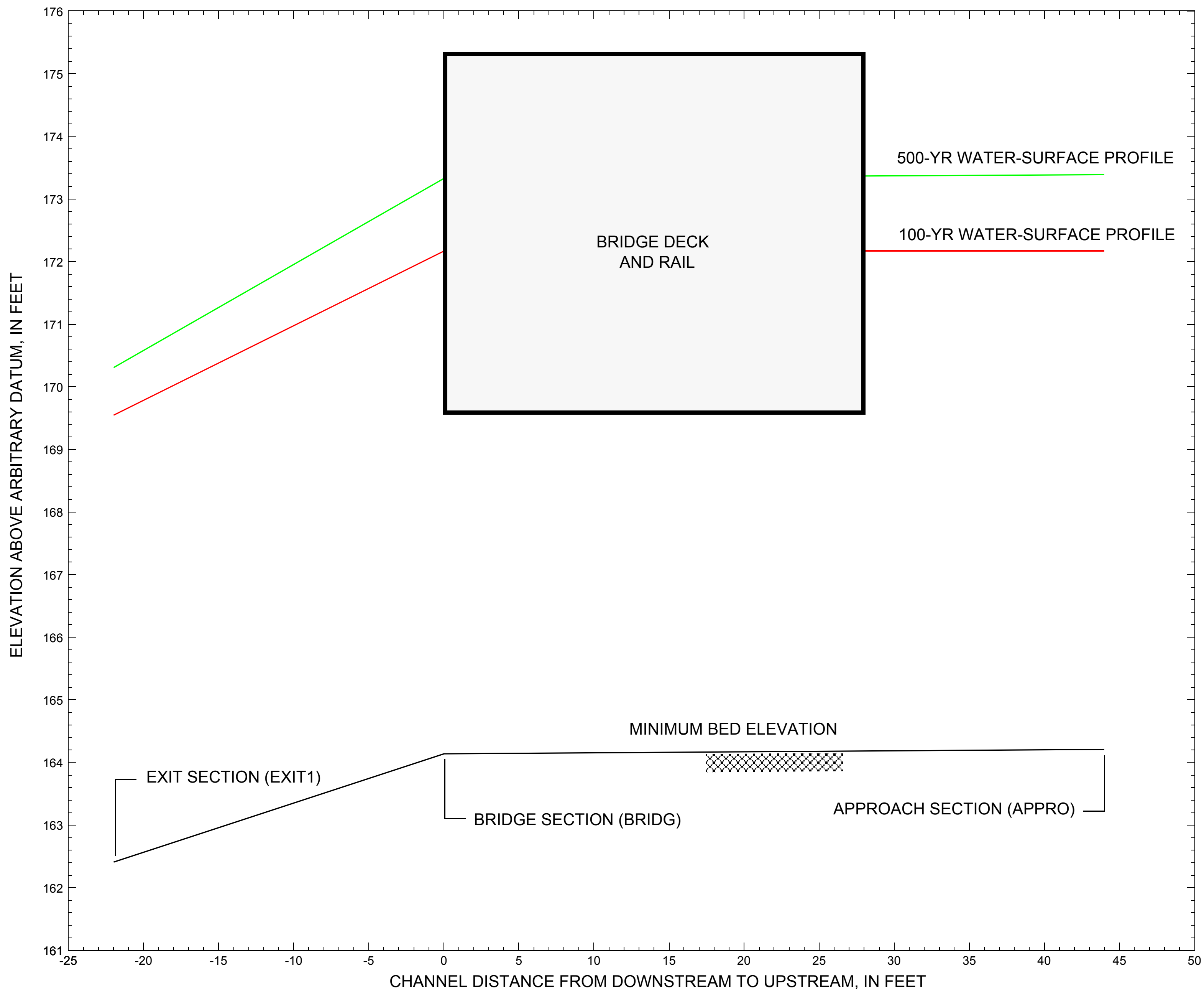

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure NEWBTH00020012 on Town Highway 2, crossing Scott Brook, Newbury, Vermont.

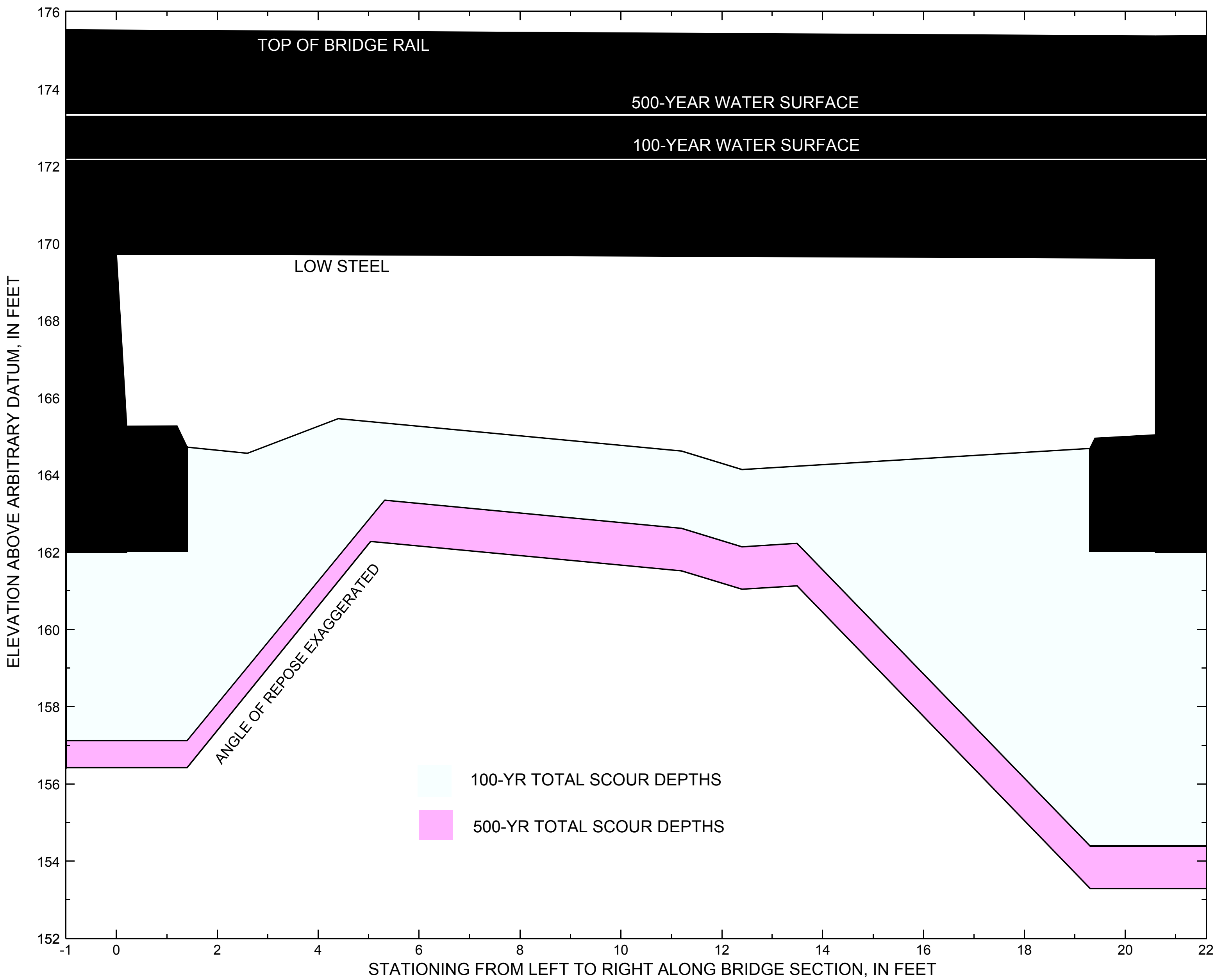

Figure 8. Scour elevations for the 100- and 500-year discharges at structure NEWBTH00020012 on Town Highway 2, crossing Scott Brook, Newbury, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure NEWBTH00020012 on Town Highway 2, crossing Scott Brook, Newbury, 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-year discharge is 970 cubic-feet per second											
Left abutment	0.0	178.0	169.7	162.0	164.7	2.0	5.6	--	7.6	157.1	-4.9
Right abutment	20.6	178.0	169.6	162.0	164.7	2.0	8.3	--	10.3	154.4	-7.6

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 NEWBTH00020012 on Town Highway 2, crossing Scott Brook, Newbury, 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-year discharge is 1,430 cubic-feet per second											
Left abutment	0.0	178.0	169.7	162.0	164.7	3.1	5.2	--	8.3	156.4	-5.6
Right abutment	20.6	178.0	169.6	162.0	164.7	3.1	8.3	--	11.4	153.3	-8.7

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

SELECTED REFERENCES

Arcement, G.J., Jr., and Schneider, V.R., 1989, Guide for selecting Manning's roughness coefficients for natural channels and flood plains: U.S. Geological Survey Water-Supply Paper 2339, 38 p.

Barnes, H.H., Jr., 1967, Roughness characteristics of natural channels: U.S. Geological Survey Water-Supply Paper 1849, 213 p.

Benson, M. A., 1962, Factors Influencing the Occurrence of Floods in a Humid Region of Diverse Terrain: U.S. Geological Survey Water-Supply Paper 1580-B, 64 p.

Brown, S.A. and Clyde, E.S., 1989, Design of riprap revetment: Federal Highway Administration Hydraulic Engineering Circular No. 11, Publication FHWA-IP-89-016, 156 p.

Federal Highway Administration, 1983, Runoff estimates for small watersheds and development of sound design: Federal Highway Administration Report FHWA-RD-77-158.

Federal Highway Administration, 1993, Stream Stability and Scour at Highway Bridges: Participant Workbook: Federal Highway Administration Report FHWA-HI-91-011.

Froehlich, D.C., 1989, Local scour at bridge abutments *in* Ports, M.A., ed., Hydraulic Engineering--Proceedings of the 1989 National Conference on Hydraulic Engineering: New York, American Society of Civil Engineers, p. 13-18.

Hayes, D.C.,1993, Site selection and collection of bridge-scour data in Delaware, Maryland, and Virginia: U.S. Geological Survey Water-Resources Investigation Report 93-4017, 23 p.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: U.S. Geological Survey, Bulletin 17B of the Hydrology Subcommittee, 190 p.

Johnson, C.G. and Tasker, G.D.,1974, Progress report on flood magnitude and frequency of Vermont streams: U.S. Geological Survey Open-File Report 74-130, 37 p.

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Chang, F., 1995, Stream Stability at Highway Structures: Federal Highway Administration Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 144 p.

Laursen, E.M., 1960, Scour at bridge crossings: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 86, no. HY2, p. 39-53.

Potter, W. D., 1957a, Peak rates of runoff in the Adirondack, White Mountains, and Maine woods area, Bureau of Public Roads

Potter, W. D., 1957b, Peak rates of runoff in the New England Hill and Lowland area, Bureau of Public Roads

Richardson, E.V. and Davis, S.R., 1995, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 p.

Richardson, E.V., Simons, D.B., and Julien, P.Y., 1990, Highways in the river environment: Federal Highway Administration Publication FHWA-HI-90-016.

Ritter, D.F., 1984, Process Geomorphology: W.C. Brown Co., Debuque, Iowa, 603 p.

Shearman, J.O., 1990, User's manual for WSPRO--a computer model for water surface profile computations: Federal Highway Administration Publication FHWA-IP-89-027, 187 p.

Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model; research report: Federal Highway Administration Publication FHWA-RD-86-108, 112 p.

Talbot, A.N., 1887, The determination of water-way for bridges and culverts.

U.S. Geological Survey, 1973, Groton, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File newb012.wsp
T2        Hydraulic analysis for structure NEWBTH00020012   Date: 11-SEP-97
T3        TH 2 CROSSING SCOTT BROOK IN NEWBURY, VT                     RLB
*
J1         * * 0.01
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           970.0   1430.0  540.0
SK          0.0097  0.0097  0.0097
*
XS   EXIT1    -22          0.
GR         -210.8, 190.43   -169.1, 174.67   -120.8, 169.43    -19.5, 169.43
GR          -12.2, 169.43      0.0, 166.51      3.3, 162.76      8.4, 162.85
GR           10.7, 162.41     13.7, 162.78     17.0, 163.12     18.6, 166.74
GR           27.4, 170.87     55.3, 170.55     68.8, 175.87    108.5, 187.86
*
N            0.080         0.050        0.060
SA                  -12.2        27.4
*
*           A depression on the left overbank, between stations -120.8 and -19.5, was
*           raised to be level with the top of the left bank as found further downstream.
*
XS   FULLV      0  * * *   0.0230
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    169.65      40.0
GR            0.0, 169.71      0.2, 165.26      1.2, 165.27      1.4, 164.72
GR            2.6, 164.56      4.4, 165.46     11.2, 164.62     12.4, 164.14
GR           15.5, 164.41     16.6, 164.69     19.4, 164.95     20.6, 165.04
GR           20.6, 169.60      0.0, 169.71
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      34.5  * *    87.0      1.7
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     14      20.2     2
GR         -310.5, 192.19   -290.0, 184.56   -201.4, 178.88   -136.2, 176.96
GR            0.0, 172.73      0.0, 175.52     19.2, 175.37     19.2, 172.18
GR           49.3, 171.35     62.6, 170.79     97.3, 185.07
* GR          -10.2, 172.08    -10.2, 175.42     14.4, 171.57
*
XT   APTEM     59          0.
GR         -302.9, 191.70   -289.1, 183.77   -262.1, 183.45   -210.5, 181.34
GR          -81.7, 175.67    -11.7, 173.09     -7.4, 172.74     -1.0, 170.06
GR            0.0, 167.76      4.6, 165.95     11.6, 165.24     14.9, 164.27
GR           17.0, 165.25     21.1, 167.86     22.2, 170.43     50.0, 171.23
GR           96.9, 193.19
*
AS   APPRO     44  * * *   0.0043
GT
N           0.060        0.050        0.080
SA                 -11.7         22.2
*
HP 1 BRIDG  169.70 1 169.70
HP 2 BRIDG  169.70 * * 820
HP 2 RDWAY  172.17 * * 144
HP 1 APPRO  172.17 1 172.17
HP 2 APPRO  172.17 * * 970
*
HP 1 BRIDG  169.71 1 169.71
HP 2 BRIDG  169.71 * * 888
HP 2 RDWAY  173.33 * * 535
HP 1 APPRO  173.39 1 173.39
HP 2 APPRO  173.39 * * 1430
```

APPENDIX B:

WSPRO OUTPUT FILE

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     U.S. Geological Survey WSPRO Input File newb012.wsp
     Hydraulic analysis for structure NEWBTH00020012   Date: 11-SEP-97
     TH 2 CROSSING SCOTT BROOK IN NEWBURY, VT                        RLB
        *** RUN DATE & TIME: 01-16-98  12:31

 CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          1      76.    3867.     1.    40.                       3140.
 169.70          76.    3867.     1.    40.  1.00     0.    21.   3140.

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    169.70     0.0    20.6    76.0    3867.     820.  10.78

X STA.        0.0        2.2        3.0        4.0        5.1        6.2
  A(I)            7.4        3.3        3.6        3.6        3.5
  V(I)           5.51      12.53      11.41      11.49      11.71

X STA.        6.2        7.2        8.1        9.0        9.9       10.8
  A(I)            3.4        3.4        3.3        3.3        3.3
  V(I)          11.92      11.97      12.30      12.40      12.53

X STA.       10.8       11.7       12.4       13.2       14.0       14.7
  A(I)            3.3        3.2        3.1        3.2        3.2
  V(I)          12.28      12.74      13.12      12.99      12.82

X STA.       14.7       15.5       16.3       17.2       18.1       20.6
  A(I)            3.1        3.2        3.3        3.3        9.0
  V(I)          13.19      12.76      12.42      12.56       4.58

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      14.

      WSEL     LEW     REW    AREA        K        Q    VEL
    172.17    19.6    66.0    29.1     574.     144.   4.94

X STA.       19.6       38.8       42.3       44.8       46.9       48.7
  A(I)            5.1        2.0        1.6        1.5        1.4
  V(I)           1.41       3.56       4.38       4.71       5.18

X STA.       48.7       50.3       51.8       53.0       54.2       54.8
  A(I)            1.3        1.3        1.2        1.1        0.7
  V(I)           5.35       5.62       6.02       6.30      10.83

X STA.       54.8       55.6       56.7       57.7       58.7       59.6
  A(I)            0.8        1.2        1.2        1.2        1.2
  V(I)           8.91       5.88       5.98       6.22       6.20

X STA.       59.6       60.5       61.4       62.2       63.0       66.0
  A(I)            1.1        1.1        1.1        1.1        1.8
  V(I)           6.34       6.51       6.39       6.73       3.98

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      44.

  WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
          2     147.   11768.    28.    34.                       1903.
          3      40.     903.    30.    30.                        264.
 172.17         187.   12672.    58.    64.  1.30    -6.    52.   1668.

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      44.

      WSEL     LEW     REW    AREA        K        Q    VEL
    172.17    -6.2    52.1   187.4   12672.     970.   5.18

X STA.       -6.2        3.7        4.8        5.7        6.7        7.7
  A(I)           28.1        6.7        6.2        6.3        6.2
  V(I)           1.73       7.27       7.82       7.74       7.80

X STA.        7.7        8.6        9.5       10.4       11.3       12.1
  A(I)            6.2        6.1        6.1        6.1        5.8
  V(I)           7.77       7.94       7.92       7.94       8.31

X STA.       12.1       13.0       13.8       14.6       15.4       16.3
  A(I)            6.2        6.4        6.2        6.3        6.3
  V(I)           7.86       7.60       7.81       7.72       7.68

X STA.       16.3       17.2       18.2       19.5       28.1       52.1
  A(I)            6.6        6.9        7.4       21.3       30.0
  V(I)           7.34       7.07       6.60       2.28       1.62
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        U.S. Geological Survey WSPRO Input File newb012.wsp
        Hydraulic analysis for structure NEWBTH00020012   Date: 11-SEP-97
        TH 2 CROSSING SCOTT BROOK IN NEWBURY, VT                        RLB
           *** RUN DATE & TIME: 01-16-98  12:31

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      76.   3777.     0.    41.                      3853350.
   169.71           76.   3777.     0.    41.  1.00     0.    21.3853350.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       169.71     0.0    20.6    76.0    3777.     888.  11.68

X STA.         0.0        2.5        3.4        4.5        5.5        6.5
  A(I)              8.9        3.4        3.5        3.4        3.3
  V(I)             5.01      13.13      12.56      12.88      13.30

X STA.         6.5        7.5        8.4        9.3       10.2       11.0
  A(I)              3.4        3.3        3.3        3.2        3.2
  V(I)            13.21      13.28      13.66      13.79      13.93

X STA.        11.0       11.8       12.6       13.4       14.1       14.9
  A(I)              3.2        3.2        3.1        3.1        3.1
  V(I)            13.75      13.84      14.14      14.35      14.16

X STA.        14.9       15.7       16.5       17.3       18.2       20.6
  A(I)              3.1        3.1        3.2        3.2        8.6
  V(I)            14.17      14.10      13.67      13.81       5.18

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      14.

         WSEL     LEW     REW    AREA        K        Q    VEL
       173.33   -19.3    68.8    90.8    3087.     535.   5.89

X STA.       -19.3       23.0       26.3       29.8       33.1       36.1
  A(I)             10.3        4.3        4.9        4.8        4.7
  V(I)             2.59       6.21       5.41       5.53       5.64

X STA.        36.1       38.8       41.3       43.7       45.8       47.9
  A(I)              4.4        4.3        4.3        4.1        3.9
  V(I)             6.04       6.21       6.25       6.57       6.78

X STA.        47.9       49.9       51.8       53.6       55.4       57.0
  A(I)              3.9        4.0        3.8        3.8        3.7
  V(I)             6.79       6.74       7.03       7.09       7.23

X STA.        57.0       58.5       60.0       61.5       62.9       68.8
  A(I)              3.6        3.6        3.5        3.5        7.2
  V(I)             7.47       7.36       7.60       7.60       3.72

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      44.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       2.      14.    10.    10.                           4.
             2     185.   15577.    34.    39.                        2460.
             3      78.    2588.    33.    33.                         688.
   173.39          265.   18180.    76.    82.  1.32   -22.    55.   2442.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      44.

         WSEL     LEW     REW    AREA        K        Q    VEL
       173.39   -21.6    54.8   265.4   18180.    1430.   5.39

X STA.       -21.6        3.9        5.1        6.1        7.1        8.2
  A(I)             47.3        8.3        7.9        8.0        7.9
  V(I)             1.51       8.58       9.03       8.96       9.03

X STA.         8.2        9.2       10.1       11.1       12.1       12.9
  A(I)              7.9        7.7        7.9        7.9        7.2
  V(I)             9.02       9.23       9.01       9.06       9.98

X STA.        12.9       13.8       14.7       15.7       16.7       17.8
  A(I)              7.8        8.6        8.4        8.6        8.9
  V(I)             9.14       8.33       8.46       8.27       8.01

X STA.        17.8       19.1       20.6       29.2       38.4       54.8
  A(I)              9.1       10.0       28.1       24.7       33.0
  V(I)             7.84       7.12       2.55       2.90       2.17
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         U.S. Geological Survey WSPRO Input File newb012.wsp
         Hydraulic analysis for structure NEWBTH00020012   Date: 11-SEP-97
         TH 2 CROSSING SCOTT BROOK IN NEWBURY, VT                      RLB
            *** RUN DATE & TIME: 01-16-98  12:31

     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1      76.   3777.     0.    41.                     3853350.
    169.71           76.   3777.     0.    41.  1.00     0.    21.3853350.

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

          WSEL     LEW     REW    AREA        K        Q    VEL
        169.71     0.0    20.6    76.0    3777.     540.   7.10

 X STA.         0.0        2.5        3.4        4.5        5.5        6.5
   A(I)             8.9        3.4        3.5        3.4        3.3
   V(I)            3.05       7.99       7.64       7.83       8.09

 X STA.         6.5        7.5        8.4        9.3       10.2       11.0
   A(I)             3.4        3.3        3.3        3.2        3.2
   V(I)            8.04       8.08       8.30       8.38       8.47

 X STA.        11.0       11.8       12.6       13.4       14.1       14.9
   A(I)             3.2        3.2        3.1        3.1        3.1
   V(I)            8.36       8.42       8.60       8.73       8.61

 X STA.        14.9       15.7       16.5       17.3       18.2       20.6
   A(I)             3.1        3.1        3.2        3.2        8.6
   V(I)            8.62       8.57       8.31       8.40       3.15

     CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1      52.   3021.    16.    23.                         539.
    168.14           52.   3021.    16.    23.  1.00     0.    21.     539.

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      44.

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              2     115.   8330.    26.    30.                        1387.
              3       7.     56.    21.    21.                          21.
    170.98          122.   8386.    47.    52.  1.10    -3.    44.    1063.

     VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      44.

          WSEL     LEW     REW    AREA        K        Q    VEL
        170.98    -3.4    43.6   121.7    8386.     540.   4.44

 X STA.        -3.4        3.7        4.7        5.6        6.6        7.4
   A(I)            18.1        5.2        4.7        4.9        4.6
   V(I)            1.49       5.23       5.78       5.57       5.90

 X STA.         7.4        8.3        9.1       10.0       10.8       11.6
   A(I)             4.7        4.6        4.7        4.6        4.5
   V(I)            5.71       5.83       5.80       5.89       5.99

 X STA.        11.6       12.4       13.1       13.9       14.5       15.2
   A(I)             4.7        4.6        4.7        4.5        4.5
   V(I)            5.69       5.83       5.79       5.99       6.01

 X STA.        15.2       15.9       16.7       17.5       18.6       43.6
   A(I)             4.6        4.7        4.9        5.3       18.6
   V(I)            5.84       5.81       5.47       5.06       1.45
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WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File newb012.wsp
        Hydraulic analysis for structure NEWBTH00020012   Date: 11-SEP-97
        TH 2 CROSSING SCOTT BROOK IN NEWBURY, VT                       RLB
           *** RUN DATE & TIME: 01-16-98  12:31

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

EXIT1:XS   ******  -122.     157.  0.69 *****  170.24  167.96    970.  169.55
      -22. ******    25.    9848.  1.16 ***** *******    1.14    6.18

FULLV:FV      22.    -11.     131.  0.85  0.24  170.55 *******    970.  169.70
        0.    22.    24.    8651.  1.00  0.08   -0.01    0.67    7.38
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID “APPRO”:  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.93     170.03     169.84
 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   169.20     193.13    0.50
 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   169.20     193.13     169.84

APPRO:AS      44.     -1.      92.  1.72  0.78  171.76  169.84    970.  170.04
       44.    44.    22.    6139.  1.00  0.44    0.00    0.93   10.51
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   169.70     169.65

            <<<<<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      22.      0.      76.  1.81 *****  171.51  169.21    820.  169.70
        0. ******    21.    3858.  1.00 ***** *******    0.99   10.78

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  169.65 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.    24.  0.14  0.54  172.58   -0.01    144.  172.17

             Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.     67.   -67.     0.   2.1   1.0   6.1   7.1   1.9   3.0
   RT:    144.     46.    20.    66.   1.4   0.6   4.5   4.9   1.0   2.9

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

APPRO:AS      10.     -6.     187.  0.54  0.19  172.71  169.84    970.  172.17
       44.    12.    52.   12679.  1.30  0.00   -0.01    0.58    5.17

       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     -22.  -122.    25.    970.    9848.     157.    6.18  169.55
   FULLV:FV       0.   -11.    24.    970.    8651.     131.    7.38  169.70
   BRIDG:BR       0.     0.    21.    820.    3858.      76.   10.78  169.70
   RDWAY:RG      14.*******     0.    144.       0.       0.    2.00  172.17
   APPRO:AS      44.    -6.    52.    970.   12679.     187.    5.17  172.17

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT1:XS    167.96    1.14  162.41  190.43************  0.69  170.24  169.55
   FULLV:FV  ********    0.67  162.92  190.94  0.24  0.08  0.85  170.55  169.70
   BRIDG:BR    169.21    0.99  164.14  169.71************  1.81  171.51  169.70
   RDWAY:RG  ****************  170.79  192.19  0.14******  0.54  172.58  172.17
   APPRO:AS    169.84    0.58  164.21  193.13  0.19  0.00  0.54  172.71  172.17
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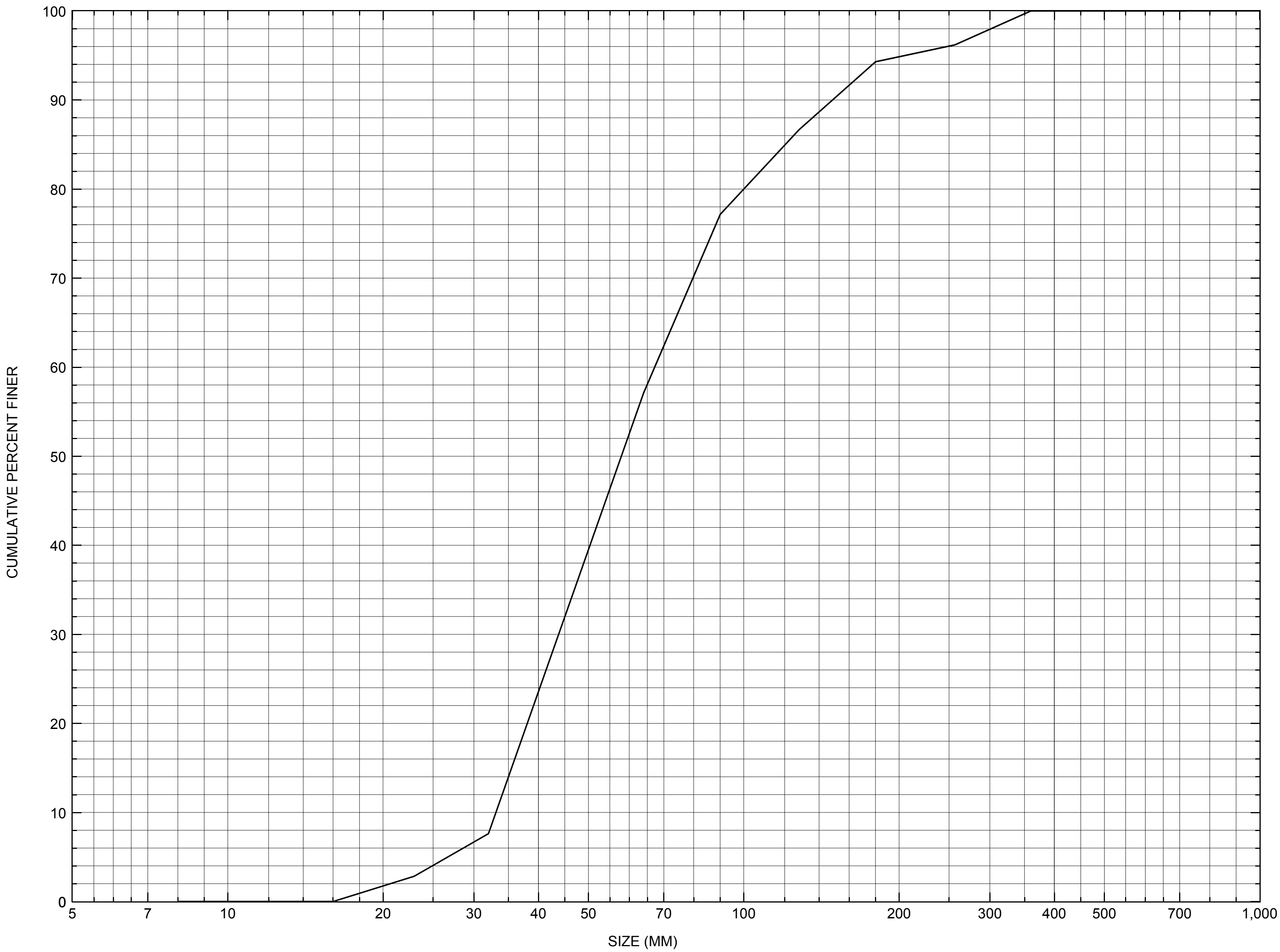
```
        U.S. Geological Survey WSPRO Input File newb012.wsp
        Hydraulic analysis for structure NEWBTH00020012   Date: 11-SEP-97
        TH 2 CROSSING SCOTT BROOK IN NEWBURY, VT                        RLB
           *** RUN DATE & TIME: 01-16-98  12:31

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

EXIT1:XS   ******  -129.     271.  0.75 *****  171.05  169.96   1430.  170.31
      -22. ******    26.   14505.  1.73 ***** *******    0.93    5.27

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.31     170.35     170.46
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   169.81     190.94    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   169.81     190.94     170.46
 ===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 "FULLV"
                  WSBEG,WSEND,CRWS =   170.46     190.94     170.46

FULLV:FV      22.  -126.     218.  1.05 *****  171.51  170.46   1430.  170.46
        0.    22.    25.   12116.  1.57 ***** *******    1.20    6.55
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.31     170.55     171.56
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   169.96     193.13    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   169.96     193.13     171.56
 ===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 =   171.56     193.13     171.56

APPRO:AS      44.    -5.     153.  1.69 *****  173.25  171.56   1430.  171.56
       44.    44.    51.   10282.  1.24 ***** *******    1.11    9.36
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   170.46     169.65
            <<<<<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      22.     0.      76.  2.12 *****  171.83  169.46    888.  169.71
        0. ******    21.    3777.  1.00 ***** *******    1.07   11.68

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  169.65 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.    24.  0.15  0.60  173.84    0.00    535.  173.33

           Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    39.    19.   -19.     0.   0.6   0.3   3.7   6.7   0.8   2.8
   RT:   497.    50.    19.    69.   2.5   1.7   6.8   5.8   2.2   3.0

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

APPRO:AS      10.   -21.     265.  0.60  0.21  173.98  171.56   1430.  173.39
       44.    11.    55.   18153.  1.32  0.00    0.00    0.59    5.39

       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     -22.  -129.    26.   1430.   14505.     271.    5.27  170.31
   FULLV:FV       0.  -126.    25.   1430.   12116.     218.    6.55  170.46
   BRIDG:BR       0.     0.    21.    888.    3777.      76.   11.68  169.71
   RDWAY:RG      14.*******    39.    535.******************    2.00  173.33
   APPRO:AS      44.   -21.    55.   1430.   18153.     265.    5.39  173.39

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT1:XS    169.96    0.93  162.41  190.43************  0.75  171.05  170.31
   FULLV:FV    170.46    1.20  162.92  190.94************  1.05  171.51  170.46
   BRIDG:BR    169.46    1.07  164.14  169.71************  2.12  171.83  169.71
   RDWAY:RG   ****************  170.79  192.19  0.15******  0.60  173.84  173.33
   APPRO:AS    171.56    0.59  164.21  193.13  0.21  0.00  0.60  173.98  173.39
```

```
        U.S. Geological Survey WSPRO Input File newb012.wsp
        Hydraulic analysis for structure NEWBTH00020012   Date: 11-SEP-97
        TH 2 CROSSING SCOTT BROOK IN NEWBURY, VT                      RLB
           *** RUN DATE & TIME: 01-16-98  12:31

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

EXIT1:XS   ******    -6.      90.  0.55 *****  168.42  166.20    540.  167.87
      -22. ******    21.    5481.  1.00 ***** *******    0.57    5.97

FULLV:FV      22.    -4.      82.  0.68  0.24  168.71 *******    540.  168.03
        0.    22.    20.    4868.  1.00  0.06   -0.01    0.64    6.60
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.00     168.53     168.52
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   167.53     193.13    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   167.53     193.13     168.52
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "APPRO"     KRATIO =  0.65

APPRO:AS      44.     0.      59.  1.31  0.84  169.86  168.52    540.  168.55
       44.    44.    21.    3156.  1.00  0.32    0.00    0.99    9.18
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   168.14     170.52     170.67     169.65
 ===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      22.     0.      76.  0.78 *****  170.49  168.14    539.  169.71
        0. ******    21.    3777.  1.00 ***** *******    0.65    7.09

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.480  0.000  169.65 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<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      10.    -3.     122.  0.34  0.11  171.31  168.52    540.  170.98
       44.    12.    44.    8385.  1.10  1.10    0.00    0.51    4.44

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   170.88

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -22.    -6.    21.    540.    5481.      90.    5.97  167.87
   FULLV:FV       0.    -4.    20.    540.    4868.      82.    6.60  168.03
   BRIDG:BR       0.     0.    21.    539.    3777.      76.    7.09  169.71
   RDWAY:RG      14.**************      0.       0.       0.    2.00********
   APPRO:AS      44.    -3.    44.    540.    8385.     122.    4.44  170.98

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXIT1:XS    166.20    0.57  162.41  190.43************  0.55  168.42  167.87
   FULLV:FV  ********    0.64  162.92  190.94  0.24  0.06  0.68  168.71  168.03
   BRIDG:BR    168.14    0.65  164.14  169.71************  0.78  170.49  169.71
   RDWAY:RG  ****************  170.79  192.19************  0.34  171.22********
   APPRO:AS    168.52    0.51  164.21  193.13  0.11  1.10  0.34  171.31  170.98
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure NEWBTH00020012, in Newbury, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number NEWBTH00020012

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 27 / 95

Highway District Number *(I - 2; nn)* 07

County *(FIPS county code; I - 3; nnn)* 017

Town *(FIPS place code; I - 4; nnnnn)* 48175

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

Waterway *(I - 6)* SCOTT BROOK

Road Name *(I - 7):* -

Route Number C2002

Vicinity *(I - 9)* 1.5 MI JCT TH 2 + TH 21

Topographic Map Groton

Hydrologic Unit Code: 01080104

Latitude *(I - 16; nnnn.n)* 44095

Longitude *(i - 17; nnnnn.n)* 72100

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10090700120907

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

Maximum span length *(I - 48; nnnn)* 0021

Year built *(I - 27; YYYY)* 1928

Structure length *(I - 49; nnnnnn)* 000025

Average daily traffic, ADT *(I - 29; nnnnnn)* 000150

Deck Width *(I - 52; nn.n)* 202

Year of ADT *(I - 30; YY)* 93

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

Opening skew to Roadway *(I - 34; nn)* 42

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

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*) -

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

Vertical clearance from streambed (*nnn.n ft*) 5.0

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

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

Comments:

The structural inspection report of 10/11/93 indicates that the structure is a concrete slab type bridge. The abutments and wingwalls are grouted "laid up" stone blocks, with stone block footings and concrete caps. Large boulders are present on the banks both upstream and downstream with a few areas of erosion reported. Boulder point and side bars are noted in the channel. Debris accumulation is minor at this site. The channel makes a sharp bend into the crossing.

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)* 3.62 mi^2 Lake/pond/swamp area 0 mi^2
Watershed storage *(ST)* 0 %
Bridge site elevation 980 ft Headwater elevation 1810 ft
Main channel length 3.07 mi
10% channel length elevation 1090 ft 85% channel length elevation 1460 ft
Main channel slope *(S)* 160.69 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 / 19-

Project Number APP 65-1927 Minimum channel bed elevation: 172.32

Low superstructure elevation: USLAB N/A DSLAB N/A USRAB * DSRAB *

Benchmark location description:

There is no specific benchmark shown on the plans. A point shown with an elevation is at the top streamward side of the concrete where the upstream right wingwall meets the right abutment wall, elevation 179.67.

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

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

If 1: Footing Thickness 1.5 Footing bottom elevation: 170.0

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:

NO FOUNDATION MATERIAL INFORMATION.

Comments:

***An estimate of the low superstructure for the right abutment is 178.0. The plans are only 1 page and provide very little detail.**

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: 03/11/96
Computerized by: EW Date: 03/1196
Reviewd by: RB Date: 10/20/97

Structure Number NEWBTH00020012

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* T. SEVERANCE Date *(MM/DD/YY)* 08 / 31 / 1995
2. Highway District Number 07 Mile marker -
County ORANGE 017 Town NEWBURY 48175
Waterway *(I - 6)* SCOTT BROOK Road Name -
Route Number TH2 Hydrologic Unit Code: 01080104
3. Descriptive comments:
1.5 miles to the junction with Town Highway 21.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 6 LBDS 6 RBDS 6 Overall 6
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 2 UB 2 DS 2 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 25 *(feet)* Span length 21 *(feet)* Bridge width 20.2 *(feet)*

Road approach to bridge:

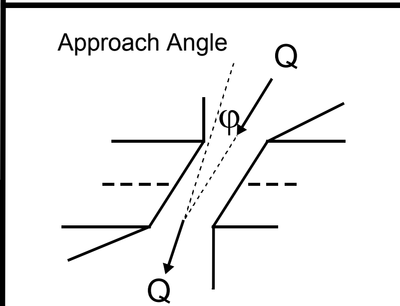
8. LB 2 RB 0 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope *(run / rise in feet / foot)*:
US left -- US right --

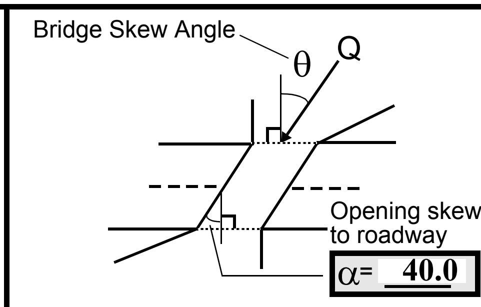
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: 15 16. Bridge skew: 55





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 35 feet US *(US, UB, DS)* to 0 feet US
Channel impact zone 2: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 14 feet DS *(US, UB, DS)* to 26 feet DS

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

18. Bridge Type: 1a

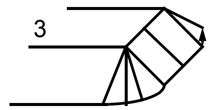
1a- Vertical abutments with wingwalls

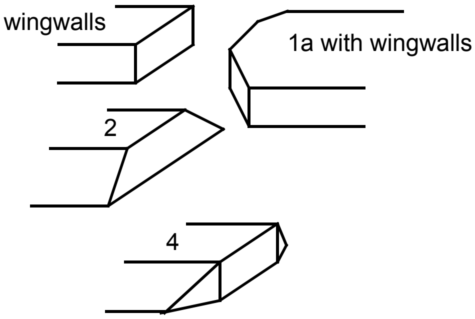
1b- Vertical abutments without wingwalls

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

#7: Values are from the VTAOT database. Measured values are; bridge length = 24.7 feet, bridge width = 20.2 feet, span length = 21 feet.

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
31.5	7.0			5.0	4	4	45	45	1	1

23. Bank width 25.0 24. Channel width 45.0 25. Thalweg depth 34.0 29. Bed Material 543

30 .Bank protection type: LB 2 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: The RB protection extends from 6 feet US to 80 feet US where there is natural boulder protection along the base of an unused road. On the left bank there is a 32 foot stone wall along Town Highway 2 that acts as road protection and bank protection.

33. Point/Side bar present? **Y** (*Y or N. if N type ctrl-n pb*) 34. Mid-bar distance: **0 US** 35. Mid-bar width: **8**

36. Point bar extent: **58** feet **US** (*US, UB*) to **10** feet **DS** (*US, UB, DS*) positioned **5** %LB to **55** %RB

37. Material: **435**

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

Breaks exist in the bar from 42 feet US to 34 feet US, and from 16 feet US to 2 feet US.
An additional bar is found on the LB starting at 58 feet US and ending at 42 feet US. The mid-bar is at 49 feet US, the mid-bar width is 4 feet, and the material is 324.

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

41. Mid-bank distance: **26** 42. Cut bank extent: **44** feet **US** (*US, UB*) to **20** 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.):

-

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)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
12.5		**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.):

543

-

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

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

2

#68: Bridge opening is constrictive and only five feet high.

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		-	90	2	2	0	0.5	90.0
RABUT	2	20	90			0	2	16.0

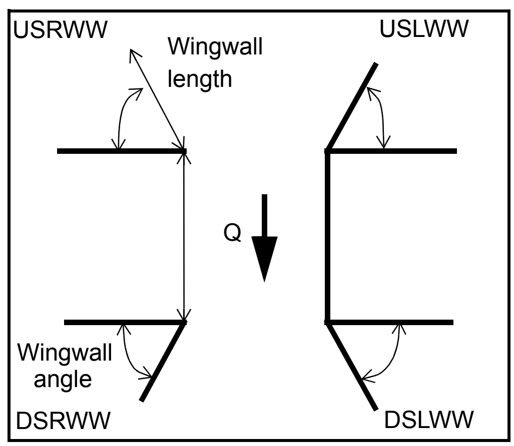
Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: 1- Concrete; 2- Stone masonry or drywall; 3- steel or metal; 4- wood

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

0
0.75
2
#76: The DS end of the RABUT is undermined with two feet of penetration.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						16.0	
USRWW:	Y		2		2	0.5	
DSLWW:	0		0.75		Y	28.5	
DSRWW:	2		2		0	28.0	



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

82. Bank / Bridge Protection:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	0.75	0	Y	0	-	-	-	-
Condition	Y	0	2	1.75	-	-	-	-
Extent	2	0	3	0	0	0	0	-

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

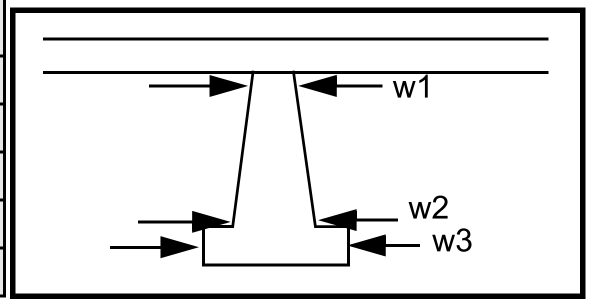
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
0
-
-
0
-
-

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		**4.5**		**40.0**	**130.0**	**13.0**
Pier 2		**9.5**	**6.0**	**130.0**	**50.0**	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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

-
-
-
-
-
-
-
-
-
-

E. Downstream Channel Assessment

100.

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

Bank width (BF) - Channel width - 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.):

4
4
542
540
1
1
543
0
4
-
1
The RB bank protection extends from 18 feet DS, at the end of the wingwall, to 50 feet DS.

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

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

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

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

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

Material: **OP**

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

STRUCTURE

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

Cut bank extent: **44** feet **3.5** *(US, UB, DS)* to **18** feet **DS** *(US, UB, DS)*

Bank damage: **50** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
80
100
523

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

Scour dimensions: Length ______ Width ______ Depth: **Y** Positioned **LB** %LB to **26** %RB

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

14
DS
39
DS

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

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

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

Confluence comments (eg. confluence name):

-
-

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)*:

-

NO CHANNEL SCOUR

N

-

-

-

-

-

-

-

109. G. Plan View Sketch

\- N

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: NEWBTH00020012 Town: NEWBURY
Road Number: TH 2 County: ORANGE
Stream: SCOTT BROOK

Initials RLB Date: 10/2/97 Checked: ECW

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	970	1430	540
Main Channel Area, ft2	147	185	115
Left overbank area, ft2	0	2	0
Right overbank area, ft2	40	78	7
Top width main channel, ft	28	34	26
Top width L overbank, ft	0	10	0
Top width R overbank, ft	30	33	21
D50 of channel, ft	0.1897	0.1897	0.1897
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.3	5.4	4.4
y1, average depth, LOB, ft	ERR	0.2	ERR
y1, average depth, ROB, ft	1.3	2.4	0.3
Total conveyance, approach	12672	18180	8386
Conveyance, main channel	11768	15577	8330
Conveyance, LOB	0	14	0
Conveyance, ROB	903	2588	56
Percent discrepancy, conveyance	0.0079	0.0055	0.0000
Qm, discharge, MC, cfs	900.8	1225.3	536.4
Ql, discharge, LOB, cfs	0.0	1.1	0.0
Qr, discharge, ROB, cfs	69.1	203.6	3.6
Vm, mean velocity MC, ft/s	6.1	6.6	4.7
Vl, mean velocity, LOB, ft/s	ERR	0.6	ERR
Vr, mean velocity, ROB, ft/s	1.7	2.6	0.5
Vc-m, crit. velocity, MC, ft/s	8.5	8.5	8.3
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	970	1430	540
(Q) discharge thru bridge, cfs	820	888	540
Main channel conveyance	3867	3777	3777
Total conveyance	3867	3777	3777
Q2, bridge MC discharge,cfs	820	888	540
Main channel area, ft2	76	76	76
Main channel width (normal), ft	15.8	15.8	15.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	15.8	15.8	15.8
y_bridge (avg. depth at br.), ft	4.81	4.81	4.81
Dm, median (1.25*D50), ft	0.237125	0.237125	0.237125
y2, depth in contraction,ft	5.51	5.90	3.85
ys, scour depth (y2-ybridge), ft	0.70	1.09	-0.96

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	820	888	540
Main channel area (DS), ft2	76	76	52
Main channel width (normal), ft	15.8	15.8	15.8
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	15.8	15.8	15.8
D90, ft	0.4875	0.4875	0.4875
D95, ft	0.6739	0.6739	0.6739
Dc, critical grain size, ft	0.5115	0.5998	0.5587
Pc, Decimal percent coarser than Dc	0.089	0.056	0.070
Depth to armoring, ft	15.71	30.33	22.27

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	970	1430	540
Q, thru bridge MC, cfs	820	888	540
Vc, critical velocity, ft/s	8.49	8.54	8.25
Va, velocity MC approach, ft/s	6.13	6.62	4.66
Main channel width (normal), ft	15.8	15.8	15.8
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	15.8	15.8	15.8
qbr, unit discharge, ft2/s	51.9	56.2	34.2
Area of full opening, ft2	76.0	76.0	76.0
Hb, depth of full opening, ft	4.81	4.81	4.81
Fr, Froude number, bridge MC	0.99	1.07	0.65
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	N/A	N/A	52
**Hb, depth at downstream face, ft	N/A	N/A	3.29
**Fr, Froude number at DS face	ERR	ERR	1.01
**Cf, for downstream face (<=1.0)	N/A	N/A	1.00
Elevation of Low Steel, ft	169.65	169.65	169.65
Elevation of Bed, ft	164.84	164.84	164.84
Elevation of Approach, ft	172.17	173.39	170.98
Friction loss, approach, ft	0.19	0.21	0.11
Elevation of WS immediately US, ft	171.98	173.18	170.87
ya, depth immediately US, ft	7.14	8.34	6.03
Mean elevation of deck, ft	175.45	175.45	175.45
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.90	0.83	0.94
**Cc, for downstream face (<=1.0)	ERR	ERR	0.79
Ys, scour w/Chang equation, ft	2.01	3.11	-0.42
Ys, scour w/Umbrell equation, ft	1.65	3.07	-0.10

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

**Ys, scour w/Chang equation, ft	N/A	N/A	1.95

**Ys, scour w/Umbrell equation, ft	N/A	N/A	1.42

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	5.51	5.90	3.85
WSEL at downstream face, ft	--	--	168.14
Depth at downstream face, ft	N/A	N/A	3.29
Ys, depth of scour (Laursen), ft	N/A	N/A	0.56

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	970	1430	540	970	1430	540
a', abut.length blocking flow, ft	6.2	21.6	3.4	36.3	39	27.8
Ae, area of blocked flow ft2	17.6	35.37	8.67	61.47	67.03	34.16
Qe, discharge blocked abut.,cfs	30.37	--	12.93	--	--	111.86
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.73	1.51	1.49	3.56	4.06	3.27
ya, depth of f/p flow, ft	2.84	1.64	2.55	1.69	1.72	1.23
--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	130	130	130	50	50	50
K2	1.05	1.05	1.05	0.93	0.93	0.93
Fr, froude number f/p flow	0.180	0.196	0.165	0.434	0.405	0.521
ys, scour depth, ft	5.57	5.22	4.42	8.25	8.26	6.67

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)	6.2	21.6	3.4	36.3	39	27.8
y1 (depth f/p flow, ft)	2.84	1.64	2.55	1.69	1.72	1.23
a'/y1	2.18	13.19	1.33	21.44	22.69	22.62
Skew correction (p. 49, fig. 16)	1.09	1.09	1.09	0.83	0.83	0.83
Froude no. f/p flow	0.18	0.20	0.16	0.43	0.41	0.52
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.99	1.07	1.01	0.99	1.07	1.01
y, depth of flow in bridge, ft	4.81	4.81	3.29	4.81	4.81	3.29
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr>0.8 (vertical abut.)	2.01	2.05	1.38	2.01	2.05	1.38