LEVEL II SCOUR ANALYSIS FOR BRIDGE 8 (ANDOTH00010008) on TOWN HIGHWAY 1, crossing the ANDOVER BRANCH, ANDOVER , VERMONT

U.S. Geological Survey
Open-File Report 97-374

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

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By ROBERT H. FLYNN AND EMILY C. WILD

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U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Slope	
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Velocity and Flow	
foot per second (ft/s)	0.3048	meter per second (m/s)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
cubic foot per second per square mile [$(ft^3/s)/mi^2$]	0.01093	cubic meter per second per square kilometer [$(m^3/s)/km^2$]

OTHER ABBREVIATIONS

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

In this report, the words “right” and “left” refer to directions that would be reported by an observer facing downstream.

Sea level: In this report, “sea level” refers to the National Geodetic Vertical Datum of 1929-- a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

In the appendices, the above abbreviations may be combined. For example, USLB would represent upstream left bank.

LEVEL II SCOUR ANALYSIS FOR BRIDGE 8 (ANDOTH00010008) ON TOWN HIGHWAY 1, CROSSING ANDOVER BRANCH, ANDOVER , VERMONT

By **Robert H. Flynn and Emily C. Wild**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure ANDOTH00010008 on Town Highway 1 crossing the Andover Branch, Andover , 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 Green Mountain section of the New England physiographic province in south-central Vermont. The 5.30-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover along the immediate banks, both upstream and downstream of the bridge, is grass while farther upstream and downstream, the surface cover is primarily forest.

In the study area, the Andover Branch has an incised, straight channel with a slope of approximately 0.01 ft/ft, an average channel top width of 35 ft and an average bank height of 3 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 63.6 mm (0.209 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 27, 1996, indicated that the reach was stable.

The Town Highway 1 crossing of the Andover Branch is a 54-ft-long, two-lane bridge consisting of one 51-foot steel-beam span (Vermont Agency of Transportation, written communication, March 28, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 45 degrees to the opening while the opening-skew-to-roadway is 30 degrees.

A scour hole 0.7 ft deeper than the mean thalweg depth was observed approximately 52 feet downstream of the downstream face of the bridge during the Level I assessment. Scour countermeasures at the site include type-2 stone fill (less than 36 inches diameter) along the entire base length of the left and right abutments and along the left bank from 65 ft to 89 ft upstream. Type-1 stone fill was found along the right bank from the bridge to 47 ft upstream and along the left bank from 40 ft to 65 ft upstream. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

Scour depths and rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and others, 1995). Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 0.1 ft. The worst case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 5.0 to 8.1 ft along the left abutment and from 2.1 to 4.6 ft along the right abutment. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

Andover, VT. Quadrangle, 1:24,000, 1971

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 ANDOTH00010008 ***Stream*** Andover Branch

County Windsor ***Road*** TH01 ***District*** 2

Description of Bridge

Bridge length 54 ***ft*** ***Bridge width*** 29.6 ***ft*** ***Max span length*** 51 ***ft***

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

Abutment type Spill-through ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 8/27/96

Description of stone fill Type-2 along the entire base length of the left and right spill-through slopes and extending up the spill-through slope to abutments..

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

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 45

There is a moderate channel bend in both the upstream and 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	8/27/96	0	0
Level II	8/27/96	0	0

Potential for debris Moderate. There is some debris caught on boulders and there are trees leaning over the channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) A point bar along the left bank has kept flow along the right bank and along the toe of the right abutment spill-through as of 8/27/96.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley setting with little to no flood plain.

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

Date of inspection 8/27/96

DS left: Moderately sloped channel bank and overbank

DS right: Moderately sloped channel bank and overbank

US left: Moderately sloped channel bank and overbank

US right: Moderately sloped channel bank and overbank

Description of the Channel

Average top width 35 ft ***Average depth*** 3 ft

Predominant bed material Cobbles / Gravel ***Bank material*** Boulder to Sand

Straight, incised and stable with semi-alluvial channel boundaries and little to no flood plain.

8/27/96

Vegetative co

DS left: Grass along immediate banks with trees beyond.

DS right: Grass along immediate banks with trees beyond.

US left: Grass along immediate banks with trees beyond.

US right: Grass along immediate banks with trees beyond.

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

Describe any obstructions in channel and date of observation. Flow conditions are influenced by a point bar on the left bank side of the channel. In addition, some debris is caught on boulders in the channel upstream. 8/27/96

Hydrology

Drainage area 5.30 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England / Green Mountain	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 1,450 ***ft³/s*** ***Q500*** 2,150 ***ft³/s***

The 100- and 500-year discharges are based on flood frequency estimates available from the VTAOT database. These values were selected due to the central tendency of the discharge frequency curve with others which were developed from empirical relationships and graphically extrapolated 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) USGS survey

Datum tie between USGS survey and VTAOT plans USGS arbitrary survey datum and VTAOT plans' datum are equal to within +/- 1 ft.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the left abutment (elev. 498.41 ft, arbitrary survey datum). RM2 is a chiseled X on top of the upstream end of the right abutment (elev. 499.44 ft, arbitrary survey datum). RM3 is a State of Vermont brass survey disk on top of the upstream end of the left abutment (elev. 499.75 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXTX2	-198	1	Exit section 2
EXITX	-45	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	20	1	Road Grade section
APPRO	82	2	Modelled Approach section (Templated from APTEM)
APTEM	89	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 0.090 to 0.125.

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 0.012 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1971).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.013 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.4 *ft*
Average low steel elevation 494.2 *ft*

100-year discharge 1,450 *ft^3/s*
Water-surface elevation in bridge opening 494.9 *ft*
Road overtopping? Y *Discharge over road* 292 *ft^3/s*
Area of flow in bridge opening 189 *ft^2*
Average velocity in bridge opening 6.1 *ft/s*
Maximum WSPRO tube velocity at bridge 8.4 *ft/s*

Water-surface elevation at Approach section with bridge 495.1
Water-surface elevation at Approach section without bridge 494.4
Amount of backwater caused by bridge 0.7 *ft*

500-year discharge 2,150 *ft^3/s*
Water-surface elevation in bridge opening 494.3 *ft*
Road overtopping? Y *Discharge over road* 456 *ft^3/s*
Area of flow in bridge opening 190 *ft^2*
Average velocity in bridge opening 8.9 *ft/s*
Maximum WSPRO tube velocity at bridge 11.4 *ft/s*

Water-surface elevation at Approach section with bridge 495.7
Water-surface elevation at Approach section without bridge 495.60
Amount of backwater caused by bridge 0.1 *ft*

Incipient overtopping discharge 410 *ft^3/s*
Water-surface elevation in bridge opening 490.7 *ft*
Area of flow in bridge opening 55 *ft^2*
Average velocity in bridge opening 7.5 *ft/s*
Maximum WSPRO tube velocity at bridge 9.1 *ft/s*

Water-surface elevation at Approach section with bridge 493.5
Water-surface elevation at Approach section without bridge 492.0
Amount of backwater caused by bridge 1.5 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the incipient roadway-overtopping discharge was computed by use of Laursen’s clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). The 100-year discharge resulted in unsubmerged orifice flow with road overflow while the 500-year discharge resulted in submerged orifice flow with road overflow. 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, the Chang scour equation (Richardson and others, 1995, p. 145-146) was applied to compute contraction scour for the 100- and 500-year events. The results of Laursen's clear-water and live-bed contraction scour equations were also computed for these discharges and can be found in appendix F. The 500-year discharge model resulted in the worst case contraction scour with a scour depth of 0.1 ft. The computed depths to streambed armoring suggest armoring will not limit the depth of contraction scour.

Abutment scour was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping. Because scour processes on the spill-through embankment material is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, the total scour depths were applied for the entire spill-through embankment below the elevation at the toe of each embankment and extended to the vertical concrete abutment wall as shown in figure 8.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	0.1	--
Clear-water scour	0.0	--	0.0
Depth to armoring	0.2	3.2	5.5
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	6.2	8.1	5.0
Right abutment	3.8	4.6	2.1
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	0.9	1.9	0.7
Right abutment	0.9	1.9	0.7
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

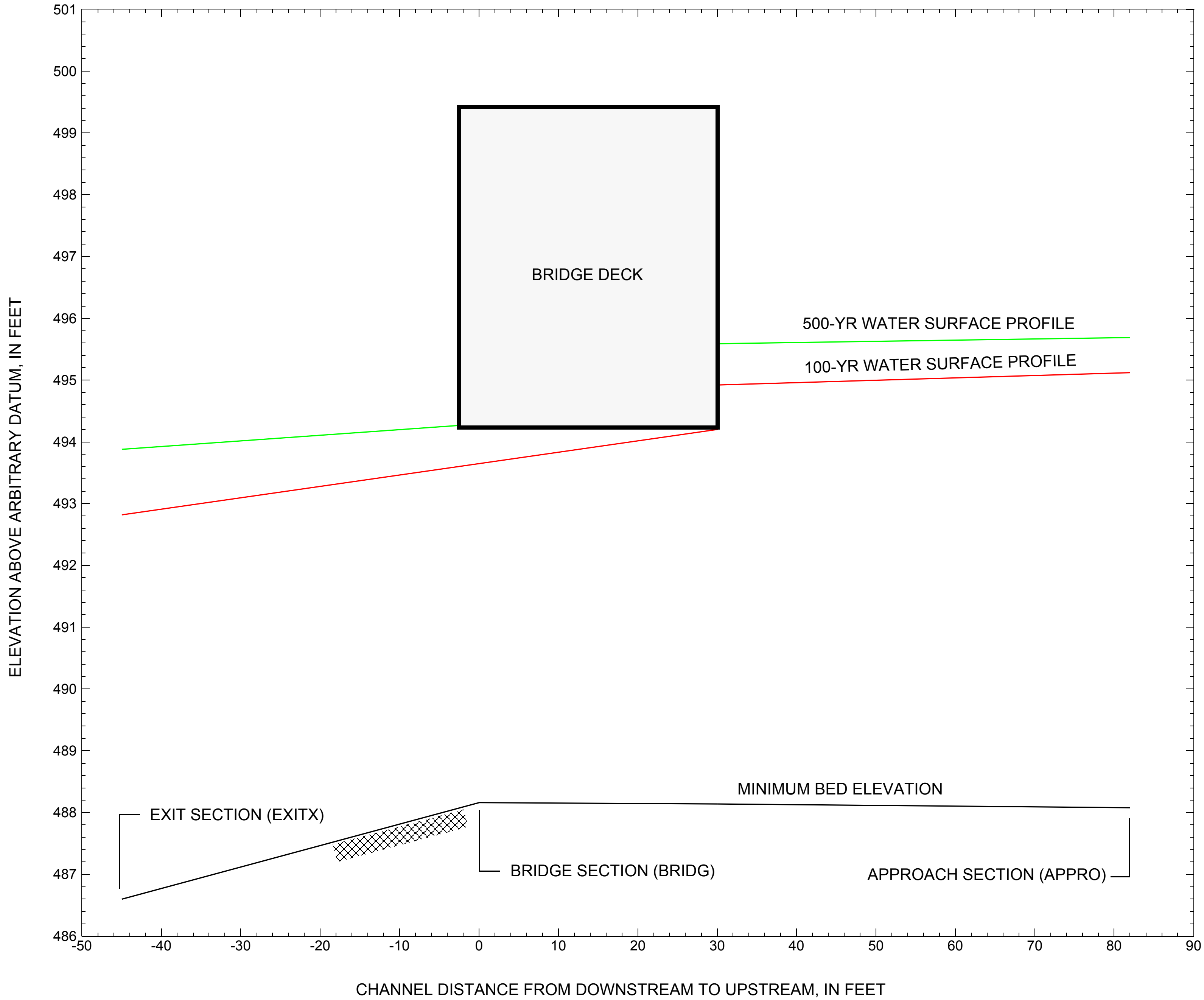

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure ANDOTH00010008 on Town Highway 1, crossing the Andover Branch, Andover, Vermont.

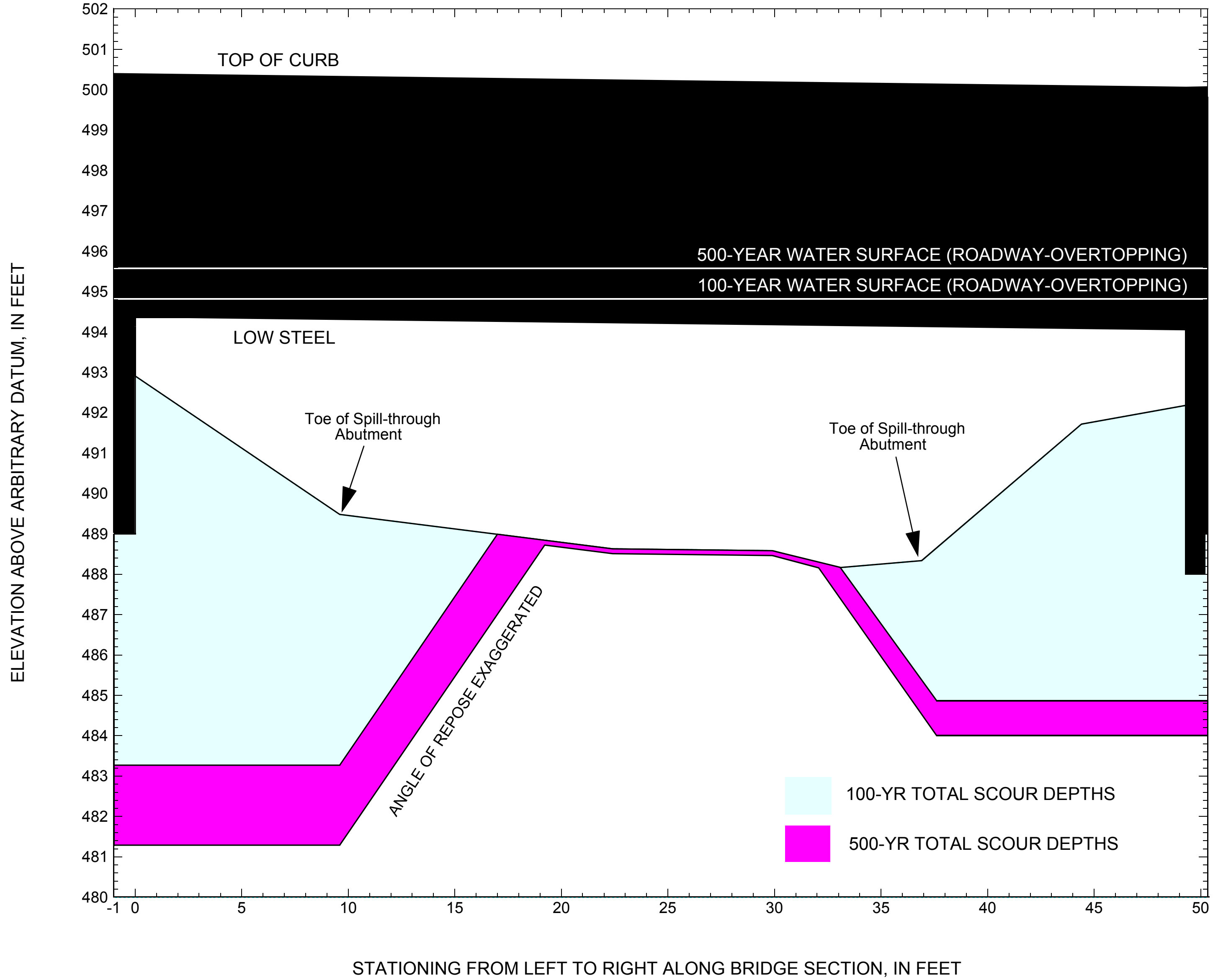

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure ANDOTH00010008 on Town Highway 1, crossing the Andover Branch, Andover, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ANDOTH00010008 on Town Highway 1, crossing the Andover Branch, Andover, Vermont.

[VTAOT, Vermont Agency of Transportation; --,no data]

Description	Station[1]	VTAOT minimum bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 1,450 cubic-feet per second											
Left abutment	0.0	495.3	494.4	489	492.9	0.0	--	--	--	--	-6
Toe of Labut	9.6	--	--	--	489.5	0.0	6.2	--	6.2	483.3	--
Toe of Rabut	37.6	--	--	--	488.7	0.0	3.8	--	3.8	484.9	--
Right abutment	49.3	495.0	494.0	488	492.2	0.0	--	--	--	--	-3

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 ANDOTH00010008 on Town Highway 1, crossing the Andover Branch, Andover, Vermont.

[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum bridge seat elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 2,150 cubic-feet per second											
Left abutment	0.0	495.3	494.4	489	492.9	0.1	--	--	--	--	-8
Toe of Labut	9.6	--	--	--	489.5	0.1	8.1	--	8.2	481.3	--
Toe of Rabut	37.6	--	--	--	488.7	0.1	4.6	--	4.7	484.0	--
Right abutment	49.3	495.0	494.0	488	492.2	0.1	--	--	--	--	-4

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

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. Department of Transportation, 1993, Stream stability and scour at highway bridges, Participant Workbook: Federal Highway Administration Publication FHWA HI-91-011.

U.S. Geological Survey, 1971, Andover, 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 ando008.wsp
T2        Hydraulic analysis for structure ANDOTH00010008   Date: 12-FEB-97
T3        Bridge 8 over Andover Brook in Andover, Vt. RF
J1         * * 0.002
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1450.0   2150.0   410.0
SK          0.012    0.012    0.012
*
XS   EXTX2   -198       0.
GR         -139.9, 503.52   -123.8, 494.10    -90.3, 492.41      0.0, 491.09
GR           11.0, 485.93     18.2, 485.81     23.6, 484.76     28.1, 485.27
GR           30.9, 485.77     32.0, 486.49     40.7, 488.89     58.3, 490.70
GR           71.9, 492.56     90.3, 495.80    119.9, 495.80    170.0, 495.80
GR          178.6, 498.63
N           0.125       0.050        0.100
SA                 0.0         40.7
*
XS   EXITX    -45        0.
GR         -139.9, 505.36   -123.8, 495.94    -90.3, 494.25      0.0, 492.93
GR           11.0, 487.77     18.2, 487.65     23.6, 486.60     28.1, 487.11
GR           30.9, 487.61     40.7, 490.73     58.3, 492.54     71.9, 494.40
GR           90.3, 497.64    119.9, 497.64    145.0, 491.49     170.0, 497.64
GR          178.6, 500.47
*
N           0.125       0.050        0.100
SA                 0.0         40.7
*
XS   FULLV      0 * * *  0.019
*
*           SRD     LSEL    XSSKEW
BR   BRIDG     0    494.20      30.0
GR            0.0, 494.36      0.1, 494.14      0.1, 492.91      9.6, 489.48
GR           22.4, 488.63     29.9, 488.58     32.9, 488.16     36.9, 488.34
GR           37.6, 488.66     44.4, 491.72     49.2, 492.18     49.2, 493.67
GR           49.3, 494.04      0.0, 494.36
N            0.045
CD           3      39.2     4.8    500.2
*
*           SRD    EMBWID   IPAVE
XR   RDWAY     20      29.6     1
GR         -207.0, 525.00   -206.8, 500.19   -144.7, 497.97     -2.3, 499.55
GR           -2.0, 500.48      0.0, 500.39     49.5, 500.06     51.2, 500.14
GR           51.5, 499.27     88.6, 498.14    113.6, 491.49    138.6, 498.14
GR          146.0, 500.50
*
XT   APTEM     89
GR         -218.0, 520.00   -217.4, 497.81    -94.9, 494.82    -16.6, 494.22
GR            0.0, 492.21      6.8, 489.54     12.7, 489.18     14.8, 488.77
GR           18.6, 488.55     21.6, 488.17     24.1, 488.51     25.1, 489.16
GR           27.6, 491.56     47.6, 494.63     75.5, 498.34    103.2, 507.93
*
AS   APPRO    82 * * * 0.013
GT
N           0.090     0.048      0.090
SA               0.0         27.6
*
HP 1 BRIDG   494.20 1 494.20
HP 2 BRIDG   494.20 * * 1158
HP 2 RDWAY   494.92 * * 292
HP 1 APPRO   495.12 1 495.12
HP 2 APPRO   495.12 * * 1450
*
HP 1 BRIDG   494.29 1 494.29
HP 2 BRIDG   494.29 * * 1691
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V090192             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ando008.wsp
        Hydraulic analysis for structure ANDOTH00010008   Date: 12-FEB-97
        Bridge 8 over Andover Brook in Andover, Vt. RF
           *** RUN DATE & TIME: 03-03-97  09:48
    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     189.   12250.    21.    69.                        3186.
   494.20          189.   12250.    21.    69.  1.00     0.    49.   3186.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.20     0.1    49.3   188.6   12250.    1158.   6.14

X STA.         0.1        6.2        8.8       10.7       12.4       14.1
  A(I)            12.5        9.0        7.8        7.2        7.2
  V(I)            4.62       6.46       7.42       7.99       8.05

X STA.        14.1       15.7       17.3       18.8       20.3       21.8
  A(I)             6.9        7.0        6.9        7.0        7.1
  V(I)            8.33       8.27       8.38       8.32       8.17

X STA.        21.8       23.3       24.9       27.0       29.2       31.2
  A(I)             7.3        7.8       10.3       10.4       10.1
  V(I)            7.94       7.43       5.60       5.59       5.71

X STA.        31.2       33.3       35.3       37.6       40.9       49.3
  A(I)            10.6       10.3       11.4       13.4       18.3
  V(I)            5.46       5.61       5.07       4.32       3.16


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = RDWAY;  SRD =      20.

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.92   100.7   126.5    44.2     923.     292.   6.60

X STA.       100.7      106.2      107.9      109.0      109.9      110.7
  A(I)             4.1        2.7        2.4        2.1        2.0
  V(I)            3.58       5.38       6.08       6.86       7.38

X STA.       110.7      111.4      112.0      112.6      113.1      113.6
  A(I)             1.9        1.8        1.7        1.7        1.7
  V(I)            7.70       8.05       8.51       8.54       8.72

X STA.       113.6      114.1      114.6      115.2      115.8      116.5
  A(I)             1.7        1.7        1.7        1.8        1.9
  V(I)            8.72       8.54       8.51       8.05       7.70

X STA.       116.5      117.3      118.2      119.3      121.0      126.5
  A(I)             2.0        2.1        2.4        2.7        4.1
  V(I)            7.38       6.86       6.08       5.38       3.58


    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      82.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      90.    1304.   111.   111.                         463.
             2     158.   15095.    28.    29.                        2150.
             3      44.    1056.    24.    25.                         331.
   495.12          292.   17455.   163.   165.  2.22  -111.    52.   1490.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      82.

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.12  -110.9    52.0   292.2   17455.    1450.   4.96

X STA.      -110.9       -8.3        2.0        4.6        6.6        8.2
  A(I)            69.7       27.5       11.3       10.3        9.2
  V(I)            1.04       2.64       6.43       7.02       7.85

X STA.         8.2        9.8       11.3       12.7       14.1       15.4
  A(I)             9.1        8.8        8.7        8.5        8.3
  V(I)            7.93       8.23       8.34       8.51       8.71

X STA.        15.4       16.7       17.9       19.1       20.3       21.5
  A(I)             8.3        8.1        8.1        8.1        8.1
  V(I)            8.77       8.95       8.91       8.96       8.98

X STA.        21.5       22.6       23.9       25.4       29.1       52.0
  A(I)             8.1        8.6        9.6       15.6       38.2
  V(I)            8.98       8.45       7.53       4.66       1.90
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        U.S. Geological Survey WSPRO Input File ando008.wsp
        Hydraulic analysis for structure ANDOTH00010008   Date: 12-FEB-97
        Bridge 8 over Andover Brook in Andover, Vt. RF
           *** RUN DATE & TIME: 03-03-97  09:48
    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     190.   11127.     9.    81.                       4870.
   494.29          190.   11127.     9.    81.  1.00     0.    49.   4870.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       494.29     0.0    49.3   190.0   11127.    1691.   8.90

X STA.         0.0        5.7        8.1       10.0       11.9       14.0
  A(I)            11.6        8.1        7.4        8.0        9.0
  V(I)            7.28      10.47      11.42      10.52       9.35

X STA.        14.0       16.0       18.0       19.9       21.7       23.5
  A(I)             9.1        8.9        8.8        8.7        8.6
  V(I)            9.31       9.51       9.60       9.70       9.85

X STA.        23.5       25.3       27.1       28.9       30.7       32.5
  A(I)             8.8        8.8        8.9        8.8        8.9
  V(I)            9.64       9.64       9.53       9.55       9.49

X STA.        32.5       34.2       36.1       38.3       41.3       49.3
  A(I)             8.9        9.5       10.3       11.8       16.9
  V(I)            9.50       8.86       8.17       7.14       5.00


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = RDWAY;  SRD =      20.

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.59    98.2   129.0    63.2    1485.     456.   7.22

X STA.        98.2      104.8      106.7      108.1      109.2      110.1
  A(I)             5.8        3.9        3.4        3.0        2.8
  V(I)            3.91       5.88       6.65       7.50       8.07

X STA.       110.1      111.0      111.7      112.4      113.0      113.6
  A(I)             2.7        2.6        2.5        2.4        2.4
  V(I)            8.41       8.80       9.30       9.34       9.54

X STA.       113.6      114.2      114.8      115.5      116.2      117.1
  A(I)             2.4        2.4        2.5        2.6        2.7
  V(I)            9.54       9.34       9.30       8.80       8.41

X STA.       117.1      118.0      119.1      120.5      122.4      129.0
  A(I)             2.8        3.0        3.4        3.9        5.8
  V(I)            8.07       7.50       6.65       5.88       3.91


    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      82.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     160.    2983.   134.   134.                        993.
             2     174.   17679.    28.    29.                       2478.
             3      59.    1556.    29.    29.                        477.
   495.69          393.   22218.   191.   193.  2.60  -134.    56.   1986.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      82.

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.69  -134.3    56.3   392.9   22218.    2150.   5.47

X STA.      -134.3      -45.9      -10.0        1.3        4.3        6.4
  A(I)            75.2       55.4       34.7       14.0       12.0
  V(I)            1.43       1.94       3.10       7.68       8.94

X STA.         6.4        8.2        9.8       11.5       13.1       14.5
  A(I)            11.1       10.4       10.7       10.4       10.1
  V(I)            9.67      10.31      10.03      10.38      10.67

X STA.        14.5       16.0       17.3       18.7       20.0       21.3
  A(I)            10.0        9.8        9.8        9.8        9.5
  V(I)           10.75      10.96      10.92      11.02      11.31

X STA.        21.3       22.6       24.0       25.8       30.8       56.3
  A(I)            10.0       10.1       12.1       22.0       45.9
  V(I)           10.72      10.65       8.88       4.89       2.34
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        U.S. Geological Survey WSPRO Input File ando008.wsp
        Hydraulic analysis for structure ANDOTH00010008   Date: 12-FEB-97
        Bridge 8 over Andover Brook in Andover, Vt. RF
           *** RUN DATE & TIME: 03-03-97  09:48
    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1      55.    2584.    31.    32.                         411.
   490.74           55.    2584.    31.    32.  1.00     6.    42.    411.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

         WSEL     LEW     REW    AREA        K        Q    VEL
       490.74     6.1    42.2    54.8    2584.     410.   7.49

X STA.        6.1       11.8       14.4       16.5       18.4       20.0
  A(I)            4.4        3.4        3.0        2.9        2.7
  V(I)           4.61       6.10       6.83       7.10       7.47

X STA.       20.0       21.5       22.9       24.3       25.6       26.9
  A(I)            2.6        2.5        2.5        2.4        2.4
  V(I)           7.86       8.17       8.34       8.41       8.37

X STA.       26.9       28.2       29.5       30.8       31.9       32.9
  A(I)            2.4        2.4        2.4        2.3        2.3
  V(I)           8.57       8.53       8.55       8.93       8.91

X STA.       32.9       34.0       35.0       36.2       37.6       42.2
  A(I)            2.2        2.3        2.5        2.8        4.2
  V(I)           9.11       8.76       8.31       7.39       4.84


    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      82.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1       8.     107.    12.    12.                          39.
             2     114.    8785.    28.    29.                        1321.
             3      14.     232.    13.    14.                          80.
   493.53          136.    9124.    53.    55.  1.27   -12.    41.   1104.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      82.

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.53   -11.7    41.0   136.4    9124.     410.   3.01

X STA.      -11.7        3.5        5.8        7.5        8.9       10.3
  A(I)           15.7        7.5        6.5        6.1        5.9
  V(I)           1.31       2.74       3.14       3.39       3.47

X STA.       10.3       11.7       12.9       14.2       15.3       16.3
  A(I)            5.8        5.7        5.6        5.3        5.3
  V(I)           3.53       3.63       3.64       3.85       3.90

X STA.       16.3       17.4       18.4       19.4       20.4       21.3
  A(I)            5.2        5.2        5.0        5.1        5.1
  V(I)           3.96       3.91       4.09       4.00       4.00

X STA.       21.3       22.3       23.3       24.4       26.0       41.0
  A(I)            5.0        5.3        5.6        7.0       18.4
  V(I)           4.09       3.87       3.64       2.92       1.11
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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V090192            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ando008.wsp
        Hydraulic analysis for structure ANDOTH00010008   Date: 12-FEB-97
        Bridge 8 over Andover Brook in Andover, Vt. RF
           *** RUN DATE & TIME: 03-03-97  09:48

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

EXTX2:XS   ******     0.     192.  1.04 *****  492.02  490.18   1450.  490.98
     -198. ******    60.   13228.  1.17 ***** *******    0.81    7.56

 ===125 FR# EXCEEDS FNTEST AT SECID “EXITX”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.84     492.82     491.95
 ===110 WSEL NOT FOUND AT SECID “EXITX”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   490.48     505.36    0.50
 ===115 WSEL NOT FOUND AT SECID “EXITX”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   490.48     505.36     491.95

EXITX:XS     153.     0.     201.  1.01  1.80  493.82  491.95   1450.  492.82
      -45.   153.   150.   13521.  1.24  0.00    0.00    0.84    7.23
 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.95     493.32     492.81
 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.32     506.21    0.50
 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.32     506.21     492.81

FULLV:FV      45.     1.     176.  1.24  0.60  494.55  492.81   1450.  493.31
        0.    45.   149.   11716.  1.18  0.12    0.01    0.95    8.23
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
 ===125 FR# EXCEEDS FNTEST AT SECID “APPRO”:  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.19     494.37     493.95
 ===110 WSEL NOT FOUND AT SECID “APPRO”:  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   492.81     519.91    0.50
 ===115 WSEL NOT FOUND AT SECID “APPRO”:  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   492.81     519.91     493.95

APPRO:AS      82.   -48.     190.  1.41  1.15  495.79  493.95   1450.  494.37
       82.    82.    47.   12798.  1.56  0.09    0.00    1.19    7.64
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>
 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   495.87       0.00     493.04     491.49
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   499.25         1.      1449.
 ===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      45.     0.     189.  0.59 *****  494.79  492.54   1158.  494.20
        0. ******    49.   12250.  1.00 ***** *******    0.55    6.14

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       3. ****    5.  0.420  0.000  494.20 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.    52.  0.36  0.85  495.61    0.00    292.  494.92

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     0.   136.  -177.   -41.   1.1   0.6   6.6  16.1   2.1   3.0
   RT:   292.    26.   101.   126.   3.4   1.7   7.1   6.6   2.4   3.0

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

APPRO:AS      43.  -111.     292.  0.85  0.36  495.97  493.95   1450.  495.12
       82.    45.    52.   17428.  2.22  0.00    0.00    0.98    4.97

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

                          <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V090192            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS
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        U.S. Geological Survey WSPRO Input File ando008.wsp
        Hydraulic analysis for structure ANDOTH00010008   Date: 12-FEB-97
        Bridge 8 over Andover Brook in Andover, Vt. RF
           *** RUN DATE & TIME: 03-03-97  09:48
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXTX2:XS    -198.     0.    60.   1450.   13228.     192.    7.56  490.98
   EXITX:XS     -45.     0.   150.   1450.   13521.     201.    7.23  492.82
   FULLV:FV       0.     1.   149.   1450.   11716.     176.    8.23  493.31
   BRIDG:BR       0.     0.    49.   1158.   12250.     189.    6.14  494.20
   RDWAY:RG      20.*******     0.    292.       0.*********    1.00  494.92
   APPRO:AS      82.  -111.    52.   1450.   17428.     292.    4.97  495.12

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ando008.wsp
        Hydraulic analysis for structure ANDOTH00010008   Date: 12-FEB-97
        Bridge 8 over Andover Brook in Andover, Vt. RF
           *** RUN DATE & TIME: 03-03-97  09:48
  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXTX2:XS    490.18    0.81  484.76  503.52************  1.04  492.02  490.98
   EXITX:XS    491.95    0.84  486.60  505.36  1.80  0.00  1.01  493.82  492.82
   FULLV:FV    492.81    0.95  487.46  506.21  0.60  0.12  1.24  494.55  493.31
   BRIDG:BR    492.54    0.55  488.16  494.36************  0.59  494.79  494.20
   RDWAY:RG  ****************  491.49  525.00  0.36******  0.85  495.61  494.92
   APPRO:AS    493.95    0.98  488.08  519.91  0.36  0.00  0.85  495.97  495.12
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ando008.wsp
        Hydraulic analysis for structure ANDOTH00010008   Date: 12-FEB-97
        Bridge 8 over Andover Brook in Andover, Vt. RF
           *** RUN DATE & TIME: 03-03-97  09:48

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

 EXTX2:XS   ******   -62.     286.  1.34 *****  493.34  491.31   2150.  492.00
      -198. ******    68.   19617.  1.52 ***** *******    1.10    7.52
  ===125 FR# EXCEEDS FNTEST AT SECID "EXITX":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.09     493.88     493.16
  ===110 WSEL NOT FOUND AT SECID "EXITX":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   491.50     505.36    0.50
  ===115 WSEL NOT FOUND AT SECID "EXITX":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   491.50     505.36     493.16

 EXITX:XS     153.   -65.     316.  1.22  1.76  495.10  493.16   2150.  493.88
       -45.   153.   155.   20542.  1.70  0.00    0.01    1.09    6.80

  ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.19     494.28     494.02
  ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.38     506.21    0.50
  ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.38     506.21     494.02

 FULLV:FV      45.   -34.     256.  1.57  0.59  495.86  494.02   2150.  494.29
         0.    45.   153.   17288.  1.44  0.18    0.00    1.19    8.40
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    1.14     495.59     495.59
  ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.79     519.91    0.50
  ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.79     519.91     495.59

 APPRO:AS      82.  -130.     375.  1.30  1.03  496.90  495.59   2150.  495.59
        82.    82.    56.   21347.  2.55  0.00    0.01    1.14    5.74
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   494.29     494.20

            <<<<<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
```
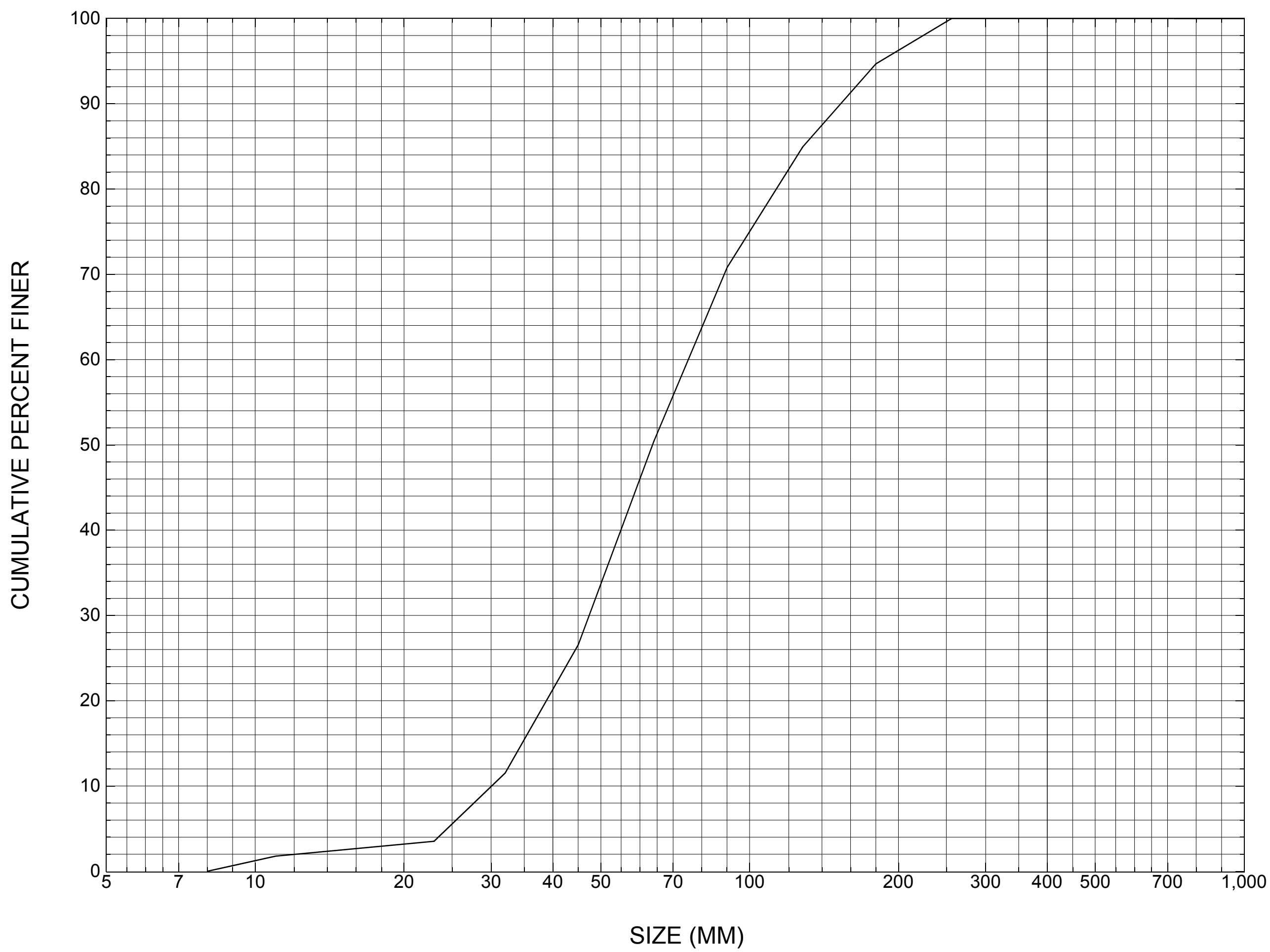

```
 BRIDG:BR      45.     0.     190.  1.23 *****  495.52  493.38   1691.  494.29
        0. ******    49.   11155.  1.00 ***** *******    0.80    8.90

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        3. ****   6.  0.800  0.000  494.20 ****** ****** ******

     XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      20.    52.  0.49  1.21  496.41    0.00    456.  495.59

             Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
    LT:      0.   144.  -179.   -35.   1.2   0.6   6.7  15.7   2.1   3.0
    RT:    456.    31.    98.   129.   4.1   2.0   7.7   7.2   2.9   3.0

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

 APPRO:AS      43.  -134.     393.  1.21  0.69  496.90  495.59   2150.  495.69
       82.    46.    56.   22206.  2.60  0.00    0.00    1.08    5.48

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

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File ando008.wsp
         Hydraulic analysis for structure ANDOTH00010008   Date: 12-FEB-97
         Bridge 8 over Andover Brook in Andover, Vt. RF
            *** RUN DATE & TIME: 03-03-97  09:48
   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q       K     AREA     VEL    WSEL
    EXTX2:XS    -198.   -62.    68.   2150.   19617.     286.    7.52  492.00
    EXITX:XS     -45.   -65.   155.   2150.   20542.     316.    6.80  493.88
    FULLV:FV       0.   -34.   153.   2150.   17288.     256.    8.40  494.29
    BRIDG:BR       0.     0.    49.   1691.   11155.     190.    8.90  494.29
    RDWAY:RG      20.*******     0.    456.       0.*********    1.00  495.59
    APPRO:AS      82.  -134.    56.   2150.   22206.     393.    5.48  495.69

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS  **********************
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File ando008.wsp
         Hydraulic analysis for structure ANDOTH00010008   Date: 12-FEB-97
         Bridge 8 over Andover Brook in Andover, Vt. RF
            *** RUN DATE & TIME: 03-03-97  09:48
  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
    EXTX2:XS    491.31    1.10  484.76  503.52************  1.34  493.34  492.00
    EXITX:XS    493.16    1.09  486.60  505.36  1.76  0.00  1.22  495.10  493.88
    FULLV:FV    494.02    1.19  487.46  506.21  0.59  0.18  1.57  495.86  494.29
    BRIDG:BR    493.38    0.80  488.16  494.36************  1.23  495.52  494.29
    RDWAY:RG    ****************  491.49  525.00  0.49******  1.21  496.41  495.59
    APPRO:AS    495.59    1.08  488.08  519.91  0.69  0.00  1.21  496.90  495.69
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File ando008.wsp
         Hydraulic analysis for structure ANDOTH00010008   Date: 12-FEB-97
         Bridge 8 over Andover Brook in Andover, Vt. RF
            *** RUN DATE & TIME: 03-03-97  09:48

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

 EXTX2:XS   ******     6.      75.  0.47 *****  488.90  487.74    410.  488.43
      -198. ******    39.    3743.  1.00 ***** *******    0.64    5.47

 EXITX:XS     153.     6.      76.  0.45  1.79  490.70 *******    410.  490.25
       -45.   153.    39.    3833.  1.00  0.00    0.01    0.63    5.39

 FULLV:FV      45.     6.      66.  0.59  0.62  491.40 *******    410.  490.81
        0.    45.    38.    3163.  1.00  0.07    0.01    0.75    6.17
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 APPRO:AS      82.     0.      72.  0.51  1.07  492.49 *******    410.  491.98
       82.    82.    31.    4061.  1.02  0.00    0.01    0.66    5.66
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
```

```
 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   493.53       0.00     490.74     491.49
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                  WS,QBO,QRD =   496.19         0.       410.
 ===280 REJECTED FLOW CLASS 4 SOLUTION.
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
 ===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                       YU/Z,WSIU,WS = 1.01     494.24     494.27
 ===270 REJECTED 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      45.     6.      55.  0.87  0.76  491.61  488.36    410.  490.74
        0.    45.    42.    2583.  1.00  0.07    0.00    1.00    7.49

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  1.000 ******  494.20 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.        <<<<<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      43.   -12.     137.  0.18  0.31  493.71  491.19    410.  493.53
       82.    43.    41.    9133.  1.27  1.79    0.00    0.37    3.00

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.000  0.007    9063.    -4.    33.   493.43

                    <<<<<END OF BRIDGE COMPUTATIONS>>>>>
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ando008.wsp
        Hydraulic analysis for structure ANDOTH00010008   Date: 12-FEB-97
        Bridge 8 over Andover Brook in Andover, Vt. RF
           *** RUN DATE & TIME: 03-03-97  09:48
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXTX2:XS    -198.     6.    39.    410.    3743.      75.    5.47  488.43
   EXITX:XS     -45.     6.    39.    410.    3833.      76.    5.39  490.25
   FULLV:FV       0.     6.    38.    410.    3163.      66.    6.17  490.81
   BRIDG:BR       0.     6.    42.    410.    2583.      55.    7.49  490.74
   RDWAY:RG      20.**************      0.       0.*********    1.00********
   APPRO:AS      82.   -12.    41.    410.    9133.     137.    3.00  493.53

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -4.    33.    9063.
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ando008.wsp
        Hydraulic analysis for structure ANDOTH00010008   Date: 12-FEB-97
        Bridge 8 over Andover Brook in Andover, Vt. RF
           *** RUN DATE & TIME: 03-03-97  09:48
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXTX2:XS    487.74    0.64  484.76  503.52************  0.47  488.90  488.43
   EXITX:XS  ********    0.63  486.60  505.36  1.79  0.00  0.45  490.70  490.25
   FULLV:FV  ********    0.75  487.46  506.21  0.62  0.07  0.59  491.40  490.81
   BRIDG:BR    488.36    1.00  488.16  494.36  0.76  0.07  0.87  491.61  490.74
   RDWAY:RG  ****************  491.49  525.00************  0.12  494.34********
   APPRO:AS    491.19    0.37  488.08  519.91  0.31  1.79  0.18  493.71  493.53
  ER

1  NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure ANDOTH00010008, in Andover, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ANDOTH00010008

General Location Descriptive

Data collected by *(First Initial, Full last name)* M. IVANOFF

Date *(MM/DD/YY)* 03 / 28 / 95

Highway District Number *(I - 2; nn)* 02

County *(FIPS county code; I - 3; nnn)* 027

Town *(FIPS place code; I - 4; nnnnn)* 01300

Mile marker *(I - 11; nnn.nnn)* 003710

Waterway *(I - 6)* ANDOVER BRANCH

Road Name *(I - 7):* -

Route Number TH01

Vicinity *(I - 9)* 3.0 MI N JCT. VT.11

Topographic Map Andover

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43169

Longitude *(i - 17; nnnnn.n)* 72425

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20013200081401

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

Maximum span length *(I - 48; nnnn)* 0051

Year built *(I - 27; YYYY)* 1993

Structure length *(I - 49; nnnnnn)* 000054

Average daily traffic, ADT *(I - 29; nnnnnn)* 000750

Deck Width *(I - 52; nn.n)* 296

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

Channel & Protection *(I - 61; n)* 8

Opening skew to Roadway *(I - 34; nn)* 30

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 42

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

Vertical clearance from streambed (*nnn.n ft*) 6.0

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

Waterway of full opening (*nnn.n ft*^{2}) 200

Comments:

The structural inspection report of 8/3/94 indicates the structure is a single span, steel stringer type bridge with an asphalt road surface. The bridge is part of the Federal Aid System listed under the route number, FAS 132. Both abutments are well protected with stone fill. The waterway has a moderate turn just upstream. The stream bed consists of stone and gravel with a few random boulders.

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: **5.3**

Terrain character: **Rolling hills, mountainous**

Stream character & type: **Straight**

Streambed material: **gravel and cobbles**

Discharge Data *(cfs)*: $Q_{2.33}$ **350** Q_{10} **750** Q_{25} **1000**

Q_{50} **1200** Q_{100} **1450** Q_{500} ____

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

Estimated Discharge *(cfs)*: **1000** Velocity at Q **25** *(ft/s)*: **6.8**

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

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: **According to the VTAOT files:**
Not affected by downstream conditions. Estimated scour of 4 feet calculated at the southerly abutment (right abutment), live bed scour with abutments set at edge of channel.

Watershed storage area (*in percent*): **1** %

The watershed storage area is: **2** (*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*)	**491.8**	**494.0**	**494.4**	**494.9**	**495.4**
Velocity (*ft / sec*)	**7.2**	**8.4**	**9.2**	**7.5**	**8.1**

Long term stream bed changes: -

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): **Y** Frequency: **Q 4***

Relief Elevation (*ft*): **493.0** Discharge over roadway at Q_{100} (*ft³/ sec*): -

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

Upstream distance (*miles*): **2000'** Town: **ANDOVER** Year Built: -

Highway No. : **TH0001** Structure No. : **005** Structure Type: -

Clear span (*ft*): **19** Clear Height (*ft*): **8** Full Waterway (*ft²*): -

Downstream distance (*miles*): 3500' Town: ANDOVER Year Built: -

Highway No. : TH023 Structure No. : 025 Structure Type: -

Clear span (*ft*): 23 Clear Height (*ft*): 12 Full Waterway (ft^2): -

Comments:

*** Flow jumps bank at right abutment, then flows along side of highway until it overtops highway at about 300 feet from the bridge.**

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 5.30 mi^2

Lake and pond area 0.01 mi^2

Watershed storage *(ST)* 0.1 %

Bridge site elevation 1180 ft

Headwater elevation 2220 ft

Main channel length 3.616 mi

10% channel length elevation 1320 ft

85% channel length elevation 2220 ft

Main channel slope *(S)* 331.85 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)*: **10** / **1991**

Project Number **BHS 0132(5)** Minimum channel bed elevation: **488.0**

Low superstructure elevation: USLAB **495.30** DSLAB **495.30** USRAB **495.00** DSRAB **495.00**

Benchmark location description:

Roadway to the temporary bridge is shown over the area where BM's were originally established so they probably don't exist now. BM#1 is a spike in trunk of an 18" ash tree about 243 feet left bankward on the roadway from the left abutment and about 20 feet perpendicular from the roadway center line in a downstream direction, elevation 500.0.

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 **2.5** Footing bottom elevation: **489.0***

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:

***The base of footing elevations are left: 489.0 and right: 487.8. The plans show only rehabilitation construction, which seems to leave the cross sections pending, as a channel base line for the measuring of section location from the bridge is shown on the plans but, sections are not attached (yet). Flows(Q), drainage area, and outlet velocity at Q25 are printed on plans.**

Cross-sectional Data

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

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

Comments: -

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

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

Comments: -

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **09/24/96**

Computerized by: **RB** Date: **09/25/96**

Reviewd by: **RF** Date: **02/21/97**

Structure Number **ANDOTH00010008**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E**. **WILD** Date *(MM/DD/YY)* **08** / **27** / 19**96**

2. Highway District Number **02** Mile marker **003710**

County **027 WINDSOR** Town **01300 ANDOVER**

Waterway *(I - 6)* **ANDOVER BRANCH** Road Name **-**

Route Number **TH01** Hydrologic Unit Code: **01080107**

3. Descriptive comments:

Located 3.0 miles north of the junction with VT 11.

B. Bridge Deck Observations

4. Surface cover... LBUS **4** 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 **54** *(feet)* Span length **51** *(feet)* Bridge width **29.6** *(feet)*

Road approach to bridge:

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

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

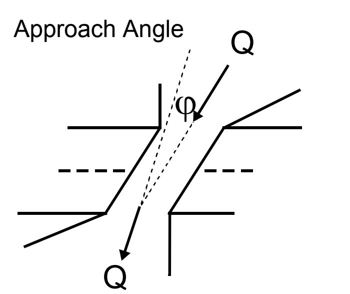
10. Embankment slope (*run / rise in feet / foot*):
US left **-** US right **-**

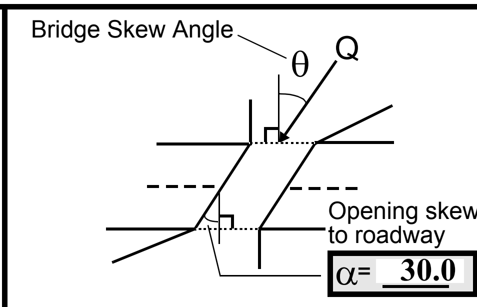
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

*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: **5** 16. Bridge skew: **45**





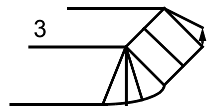
17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **100** feet **US** *(US, UB, DS)* to **67** feet **US**

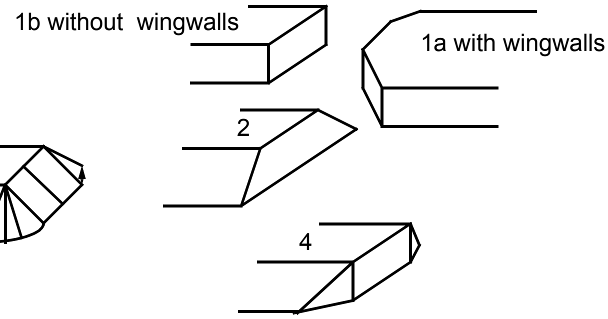
Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **40** feet **DS** *(US, UB, DS)* to **250** feet **DS**

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

18. Bridge Type: **3 / 1a**

1a- Vertical abutments with wingwalls
1b- Vertical abutments without wingwalls
2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face
3- Spill through abutments
4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.





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

4. Surface cover is forest except for 1 bridge length US and DS on both the right and left banks where it is grass. A small brick house is on the DS left bank.
8. and 9. The left and right road approaches are paved until the road dip (where the hills start). Beyond the dip in the road, the road has recently been chip sealed and there is loose rock on the pavement.
7. Values are from the VTAOT files. Measured bridge length is 54 ft., span length is 50 ft. and bridge width is 33 ft.

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
50.5	**2.5**			**2.5**	**1**	**3**	**4352**	**435**	**1**	**2**

23. Bank width **20.0** 24. Channel width **40.0** 25. Thalweg depth **28.0** 29. Bed Material **43**

30 .Bank protection type: LB **1** RB **1** 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.):

26. With the exception of grass on either bank, there is no other vegetation from the US bridge face to one bridge length US. Beyond this point, the banks are tree covered.
30. On the right bank the protection extends from the US bridge face to 47 ft. US. The left bank protection is type 1 from 65 ft. US to 40 ft. US and type 3 from 89 ft. US to 65 ft. US.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 26 35. Mid-bar width: 11

36. Point bar extent: 69 feet US (US, UB) to 26 feet DS (US, UB, DS) positioned 0 %LB to 80 %RB

37. Material: 43

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

Additional alternating side bars are US. From 153 ft. US to 101 ft. US, there is a gravel and cobble bar positioned 40% LB to 100% RB with mid-bar distance at 136 ft. US and a width of 11.5 ft. From 230 ft. US to 167 ft. US, there is another gravel and cobble bar positioned 0% LB to 50% RB with a mid-bar distance at 200 ft. US.

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: 75 42. Cut bank extent: 95 feet US (US, UB) to 71 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) 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
18.5		0.5		2	7	7	-

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

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

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

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

34

The abutment protection (dumped stone) acts like a spill through, but at bank full, the water level is even with the bottom of the abutments.

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 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

69. There is no evidence of ice build up but, the blockage potential is moderate because of the low clearance under the bridge.

66. There is debris both US and DS within one bridge length.

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	0	0	-	-	90.0
RABUT	1	15	90			0	0	42.5

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.):

-

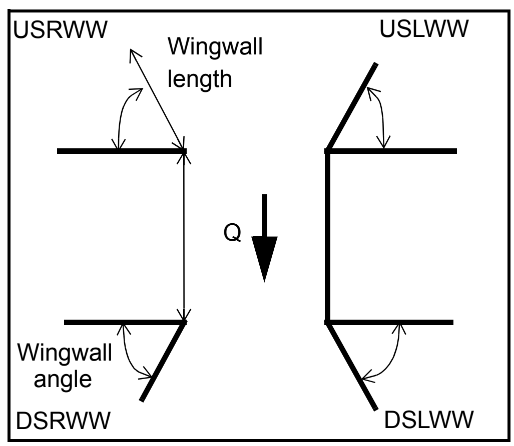
-

1

72. The abutment protection slope is 40 degrees in front of the left and right abutments.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						42.5	
USRWW:	Y		1		0	0.5	
DSLWW:	-		-		Y	39.0	
DSRWW:	1		0		-	39.5	



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

82. **Bank / Bridge Protection**:

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

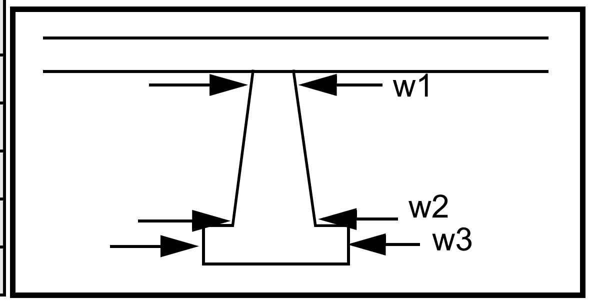
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? **80.** *(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				30.0	12.5	60.0
Pier 2	8.0	6.0		60.0	30.0	10.0
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	-	-	-	-	-

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

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

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

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

NO PIERS

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):

3

106. Point/Side bar present? 3 (Y or N. if N type ctrl-n pb) Mid-bar distance: 123 Mid-bar width: 123

Point bar extent: 1 feet 1 (US, UB, DS) to 435 feet 0 (US, UB, DS) positioned 0 %LB to - %RB

Material: -

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

There is only grass as vegetation along the banks from the DS bridge face to 1 bridge length DS.
On the left bank, about 45 ft. DS, there are boulders along the bank that at one time were protection, but have since failed.
The bed drops about 1 ft. at 43 ft. DS where there is a cluster of boulders in the channel.

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

Cut bank extent: ____ feet ____ (US, UB, DS) to ____ feet ____ (US, UB, DS)

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

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

N

Is channel scour present? - (Y or if N type ctrl-n cs) Mid-scour distance: NO

Scour dimensions: Length DRO Width P Depth: STR Positioned UC %LB to TU %RB

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

RE

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

Confluence 1: Distance Y Enters on 167 (LB or RB) Type 35 (**1**- perennial; **2**- ephemeral)

Confluence 2: Distance 52 Enters on DS (LB or RB) Type 250 (**1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

DS
20

F. Geomorphic Channel Assessment

107. Stage of reach evolution 100

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)*:

435

Refer to the US assessment for the point bar closest to the bridge.

Y
LB
53
45
US
57
DS
1

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: ANDOTH00010008 Town: Andover
Road Number: TH01 County: Windsor
Stream: Andover Brook

Initials RHF Date: 2/18/97 Checked: SAO

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	1450	2150	410
Main Channel Area, ft2	158	174	114
Left overbank area, ft2	90	160	8
Right overbank area, ft2	44	59	14
Top width main channel, ft	28	28	28
Top width L overbank, ft	111	134	12
Top width R overbank, ft	24	29	13
D50 of channel, ft	0.2086	0.2086	0.2086
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	5.6	6.2	4.1
y1, average depth, LOB, ft	0.8	1.2	0.7
y1, average depth, ROB, ft	1.8	2.0	1.1
Total conveyance, approach	17455	22218	9124
Conveyance, main channel	15095	17679	8785
Conveyance, LOB	1304	2983	107
Conveyance, ROB	1056	1556	232
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1254.0	1710.8	394.8
Ql, discharge, LOB, cfs	108.3	288.7	4.8
Qr, discharge, ROB, cfs	87.7	150.6	10.4
Vm, mean velocity MC, ft/s	7.9	9.8	3.5
Vl, mean velocity, LOB, ft/s	1.2	1.8	0.6
Vr, mean velocity, ROB, ft/s	2.0	2.6	0.7
Vc-m, crit. velocity, MC, ft/s	8.9	9.0	8.4
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	1	0
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

ARMORING

D90	0.50109	0.50109	0.50109
D95	0.60281	0.60281	0.60281
Critical grain size,Dc, ft	0.1603	0.3368	0.3758
Decimal-percent coarser than Dc	0.67869	0.23914	0.19509
Depth to armoring,ft	0.23	3.21	4.65

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour
y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)
ys=y2-y_bridge
(Richardson and others, 1995, p. 30, eq. 17 and 18)

	Approach			Bridge		
Characteristic	100 yr	500 yr	Other Q	100 yr	500 yr	Other Q
Q1, discharge, cfs	1450	2150	410	1158	1691	0
Total conveyance	17455	22218	9124	12250	11127	0
Main channel conveyance	15095	17679	8785	12250	11127	0
Main channel discharge	1254	1711	395	1158	1691	ERR
Area - main channel, ft2	158	174	114	188.6	190	0
(W1) channel width, ft	28	28	28	35.25	35.51	0
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	28	28	28	35.25	35.51	0
D50, ft	0.2086	0.2086	0.2086			
w, fall velocity, ft/s (p. 32)	3.737	3.737	0			
y, ave. depth flow, ft	5.64	6.21	4.07	5.35	5.35	ERR
S1, slope EGL	0.015	0.0127	0			
P, wetted perimeter, MC, ft	29	29	0			
R, hydraulic Radius, ft	5.448	6.000	ERR			
V*, shear velocity, ft/s	1.622	1.566	N/A			
V*/w	0.434	0.419	ERR			
Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)						
k1	0.59	0.59	0			
y2,depth in contraction, ft	4.60	5.35	ERR			
ys, scour depth, ft (y2-y_bridge)	-0.75	-0.00	N/A			

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	158	174	114
Main channel width, ft	28	28	28
y1, main channel depth, ft	5.64	6.21	4.07

Bridge Section

(Q) total discharge, cfs	1450	2150	410
(Q) discharge thru bridge, cfs	1158	1691	410
Main channel conveyance	12250	11127	2584
Total conveyance	12250	11127	2584
Q2, bridge MC discharge,cfs	1158	1691	410
Main channel area, ft2	189	190	55
Main channel width (skewed), ft	35.25	35.51	27.71
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	35.25	35.51	27.71
y_bridge (avg. depth at br.), ft	5.35	5.35	1.98
Dm, median (1.25*D50), ft	0.26075	0.26075	0.26075
y2, depth in contraction,ft	3.62	4.98	1.83
ys, scour depth (y2-ybridge), ft	-1.73	-0.37	-0.15

Pressure Flow Scour (contraction scour for orifice flow conditions)

Hb+Ys=Cq*qbr/Vc   Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)
Chang Equation   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
(Richarson and others, 1995, p. 145-146)

	5	6	1
	Q100	Q500	OtherQ
Q, total, cfs	1450	2150	410
Q, thru bridge, cfs	1158	1691	410
Total Conveyance, bridge	12250	11127	2584
Main channel(MC) conveyance, bridge	12250	11127	2584
Q, thru bridge MC, cfs	1158	1691	410
Vc, critical velocity, ft/s	8.87	9.01	8.40
Vc, critical velocity, m/s	2.70	2.75	2.56
Main channel width (skewed), ft	35.3	35.5	27.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	35.3	35.5	27.7
qbr, unit discharge, ft2/s	32.9	47.6	14.8
qbr, unit discharge, m2/s	3.1	4.4	1.4
Area of full opening, ft2	188.6	190.0	54.8
Hb, depth of full opening, ft	5.35	5.35	1.98
Hb, depth of full opening, m	1.63	1.63	0.60
Fr, Froude number, bridge MC	0.55	0.8	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
Elevation of Low Steel, ft	494.204	494.204	0
Elevation of Bed, ft	488.85	488.85	-1.98
Elevation of Approach, ft	495.12	495.69	0
Friction loss, approach, ft	0.36	0.69	0
Elevation of WS immediately US, ft	494.76	495.00	0.00
ya, depth immediately US, ft	5.91	6.15	1.98
ya, depth immediately US, m	1.80	1.87	0.60
Mean elevation of deck, ft	500.23	500.23	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.98	0.97	1.00
Ys, depth of scour, ft	-1.56	0.12	N/A

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

y2, from Laursen's equation, ft	3.624855	N/A	1.829677
Full valley WSEL, ft	493.31	0	0
Full valley depth, ft	4.456355	0	1.977625
Ys, depth of scour (y2-yfullv), ft	-0.8315	N/A	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)

Characteristic	Left Abutment 100 yr Q	Left Abutment 500 yr Q	Left Abutment Other Q	Right Abutment 100 yr Q	Right Abutment 500 yr Q	Right Abutment Other Q
(Qt), total discharge, cfs	1450	2150	410	1450	2150	410
a', abut.length blocking flow, ft	116.7	139.9	21.7	10.9	15.1	3.3
Ae, area of blocked flow ft2	114.68	186.73	40.44	18.18	27.18	4.05
Qe, discharge blocked abut.,cfs	261	496.55	98.11	34.51	63.66	4.51
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.28	2.66	2.43	1.90	2.34	1.11
ya, depth of f/p flow, ft	0.98	1.33	1.86	1.67	1.80	1.23
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	60	60	60	120	120	120
K2	0.95	0.95	0.95	1.04	1.04	1.04
Fr, froude number f/p flow	0.405	0.406	0.313	0.259	0.308	0.177
ys, scour depth, ft	6.21	8.07	4.99	3.79	4.64	2.07

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)	116.7	139.9	21.7	10.9	15.1	3.3
y1 (depth f/p flow, ft)	0.98	1.33	1.86	1.67	1.80	1.23
a'/y1	118.76	104.81	11.64	6.54	8.39	2.69
Skew correction (p. 49, fig. 16)	0.90	0.90	0.90	1.07	1.07	1.07
Froude no. f/p flow	0.40	0.41	0.31	0.26	0.31	0.18
Ys w/ corr. factor K1/0.55:						
vertical	4.77	6.49	ERR	ERR	ERR	ERR
vertical w/ ww's	3.91	5.32	ERR	ERR	ERR	ERR
spill-through	2.62	3.57	ERR	ERR	ERR	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother	Q100	Q500	Qother
Fr, Froude Number	0.55	0.8	1	0.55	0.8	1
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5.35	5.35	1.98	5.35	5.35	1.98
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.00	2.12	ERR	1.00	2.12	ERR
Fr>0.8 (vertical abut.)	ERR	ERR	0.83	ERR	ERR	0.83
Fr<=0.8 (spillthrough abut.)	0.87	1.85	ERR	0.87	1.85	ERR
Fr>0.8 (spillthrough abut.)	ERR	ERR	0.73	ERR	ERR	0.73