LEVEL II SCOUR ANALYSIS FOR BRIDGE 44 (CHESVT00110044) on STATE ROUTE 11, crossing ANDOVER BROOK, CHESTER, VERMONT

U.S. Geological Survey
Open-File Report 97-378

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

LEVEL II SCOUR ANALYSIS FOR BRIDGE 44 (CHESVT00110044) on STATE ROUTE 11, crossing ANDOVER BROOK, CHESTER, VERMONT

By MICHAEL A. IVANOFF & ROBERT E. HAMMOND

U.S. Geological Survey
Open-File Report 97-378

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

Pembroke, New Hampshire

1997

U.S. DEPARTMENT OF THE INTERIOR
BRUCE BABBITT, Secretary

U.S. GEOLOGICAL SURVEY
Gordon P. Eaton, Director

For additional information
write to:

District Chief
U.S. Geological Survey
361 Commerce Way
Pembroke, NH 03275-3718

Copies of this report may be
purchased from:

U.S. Geological Survey
Branch of Information Services
Open-File Reports Unit
Box 25286
Denver, CO 80225-0286

CONTENTS

FIGURES

TABLES

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 44 (CHESVT00110044) ON STATE ROUTE 11, CROSSING ANDOVER BROOK, CHESTER, VERMONT

By **Michael A. Ivanoff and Robert E. Hammond**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CHESVT00110044 on State Route 11 crossing Andover Brook, Chester, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in southeastern Vermont. The 12.6-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture with dense woody vegetation on the immediate banks except the downstream left bank of the bridge which is forested.

In the study area, Andover Brook has an incised, meandering channel with a slope of approximately 0.02 ft/ft, an average channel top width of 74 ft and an average bank height of 8 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 83.6 mm (0.274 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 11, 1996, indicated that the reach was stable.

The State Route 11 crossing of Andover Brook is a 58-ft-long, two-lane bridge consisting of one 56-foot concrete T-beam span (Vermont Agency of Transportation, written communication, March 29, 1995). The opening length of the structure parallel to the bridge face is 52.9 ft.The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 35 degrees to the opening while the opening-skew-to-roadway is 45 degrees.

A scour hole 1.8 ft deeper than the mean thalweg depth was observed along the upstream left wingwall and left abutment during the Level I assessment. The scour protection measures at the site included type-4 stone fill (less than 60 inches diameter) along the upstream left bank between the wingwall and a concrete wall. There was type-2 stone fill (less than 36 inches diameter) along the entire base of the upstream left wingwall, and the downstream end of the downstream right wingwall. There was type-1 stone fill (less than 12 inches diameter) at the downstream end of the downstream left wingwall. There was also a concrete wall along the upstream left bank from 18 to 50 ft upstream of the bridge. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.0 to 1.2 ft. The worst-case contraction scour occurred at the incipient-overtopping discharge. The incipient-overtopping discharge is 520 cfs less than the 100-year discharge. Left abutment scour ranged from 16.4 to 20.9 ft. The worst-case left abutment scour occurred at the 500-year discharge. Right abutment scour ranged from 8.4 to 9.4 ft. The worst-case right abutment scour occurred at both the 100-year and 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 CHESVT00110044 ***Stream*** Andover Brook

County Windsor ***Road*** VT 11 ***District*** 2

Description of Bridge

Bridge length 58 ***ft*** ***Bridge width*** 32.3 ***ft*** ***Max span length*** 56 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 09/11/96

Description of stone fill Type-2, along the upstream left wingwall, and the downstream end of the downstream right wingwall. Type-1, at the downstream end of the downstream left wingwall. There was also a concrete wall along the upstream left bank at the channel bend.

Abutments and wingwalls are concrete. There is a two foot deep scour hole in front of the upstream left wingwall and left abutment.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 35

There is a severe channel bend in the upstream reach. The scour hole has developed in the location where the bend impacts the upstream left wingwall and left abutment.

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	09/11/96	0	0
Level II	09/11/96	0	0

Potential for debris Moderate. There are trees leaning over the channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) There was a point bar along the right bank through the bridge as of 09/11/96.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley with narrow flood plains and steep valley walls on both sides.

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

Date of inspection 09/11/96

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

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

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

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

Description of the Channel

Average top width 74 ***ft*** ***Average depth*** 8 ***ft***

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

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

Vegetative co

09/11/96

DS left: Trees and brush.

DS right: Trees and brush.

US left: Trees and brush.

US right: Trees and brush.

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

Describe any obstructions in channel and date of observation.

The assessment of 09/11/96 noted a point bar on the right bank side of the channel through the bridge.

Hydrology

Drainage area 12.6 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/ New England Upland	65
New England/ Green Mountain	35

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: None

Is there a USGS gage on the stream of interest? Yes

USGS gage description Williams River at Brockways Mills, VT

USGS gage number 01153500

Gage drainage area 103 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 3,350 ***ft³/s*** ***Q500*** 4,910 ***ft³/s***

The 100- and 500-year discharges are based on the discharge values for the mouth of Andover Brook presented in the Flood Insurance Study for Chester, VT (Federal Emergency Management Agency, February 1982). The drainage area at the mouth of Andover Brook is 12.6 square miles. These values are within a range defined by several empirical flood frequency curves (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 359.1 feet to the USGS arbitrary survey datum to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a U.S. Geodetic Survey tablet stamped 1942 532 on top of the upstream end of the right abutment (elev. 501.03 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the right abutment (elev. 501.30 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-42	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	75	2	Modelled Approach section (Templated from APTEM)
APTEM	111	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. The channel "n" value for the reach was 0.045, and overbank "n" values ranged from 0.035 to 0.045.

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 0.0177 ft/ft which was estimated from the 100-year discharge slope downstream of the bridge in the Flood Insurance Study for Chester, VT (Federal Emergency Management Agency, February, 1982).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.00866 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.

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

Bridge Hydraulics Summary

Average bridge embankment elevation 501.3 ***ft***
Average low steel elevation 496.9 ***ft***

100-year discharge 3,350 ***ft^3/s***
Water-surface elevation in bridge opening 496.9 ***ft***
Road overtopping? Yes ***Discharge over road*** 243 ***ft^3/s***
Area of flow in bridge opening 342 ***ft^2***
Average velocity in bridge opening 9.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.7 ***ft/s***

Water-surface elevation at Approach section with bridge 499.3
Water-surface elevation at Approach section without bridge 495.6
Amount of backwater caused by bridge 3.7 ***ft***

500-year discharge 4,910 ***ft^3/s***
Water-surface elevation in bridge opening 496.9 ***ft***
Road overtopping? Yes ***Discharge over road*** 1,312 ***ft^3/s***
Area of flow in bridge opening 342 ***ft^2***
Average velocity in bridge opening 10.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 14.4 ***ft/s***

Water-surface elevation at Approach section with bridge 500.6
Water-surface elevation at Approach section without bridge 496.4
Amount of backwater caused by bridge 4.2 ***ft***

Incipient overtopping discharge 2,830 ***ft^3/s***
Water-surface elevation in bridge opening 493.2 ***ft***
Area of flow in bridge opening 211 ***ft^2***
Average velocity in bridge opening 13.4 ***ft/s***
Maximum WSPRO tube velocity at bridge 16.5 ***ft/s***

Water-surface elevation at Approach section with bridge 497.1
Water-surface elevation at Approach section without bridge 494.7
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 others, 1995). Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

Contraction scour for the incipient-overtopping discharge was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 100-year and 500-year discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). Results of this analysis are presented in figure 8 and tables 1 and 2. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

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

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

Scour Results

Contraction scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.7	1.2
Depth to armoring	29.2	9.9	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	*100-yr discharge*	*500-yr discharge*	*Incipient overtopping discharge*
Abutment scour			
Left abutment	18.7	20.9	16.4
Right abutment	9.4	9.4	8.4
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	2.6	2.7	2.4
Right abutment	2.6	2.7	2.4
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

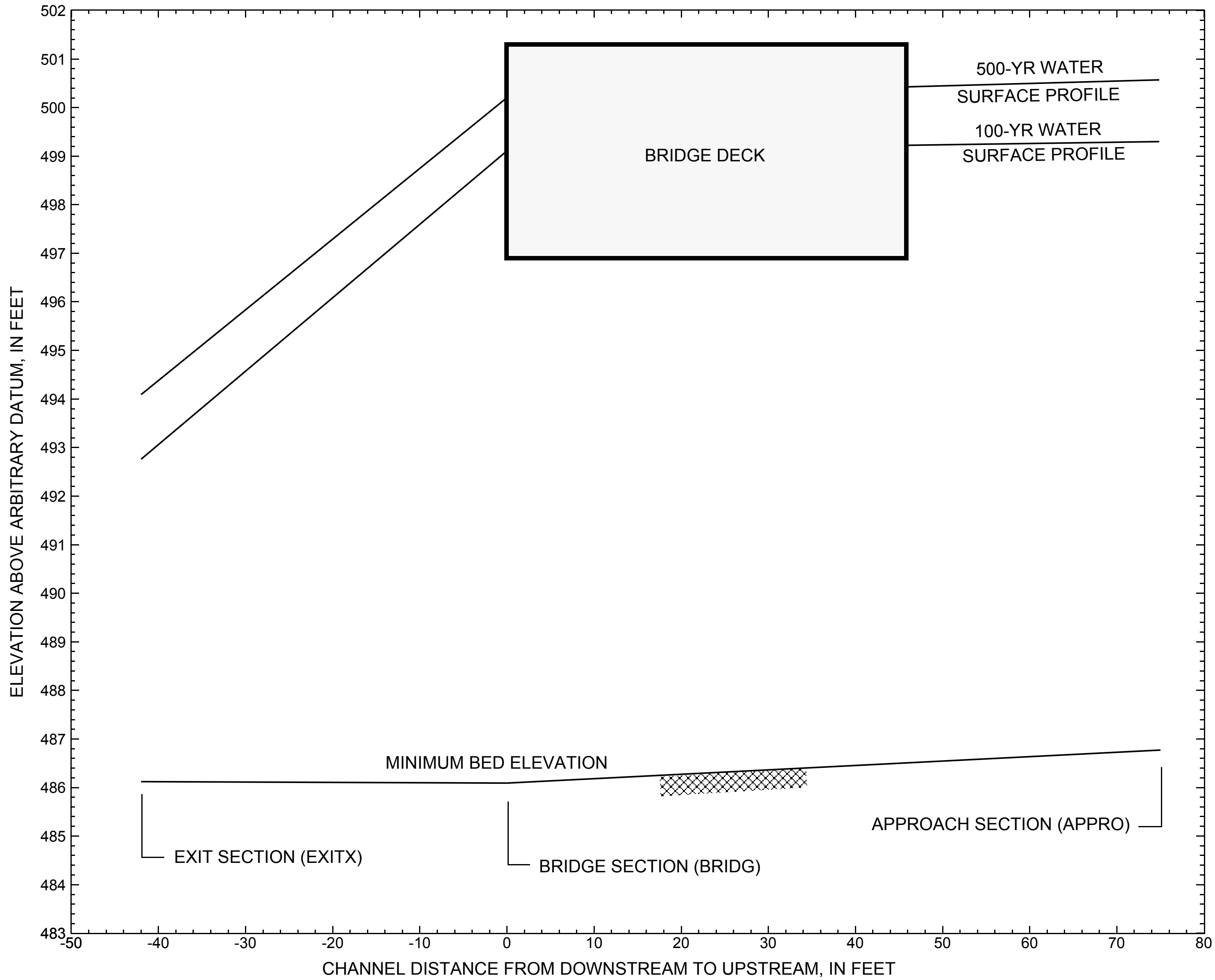


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CHESVT00110044 on State Route 11, crossing Andover Brook, Chester, Vermont.

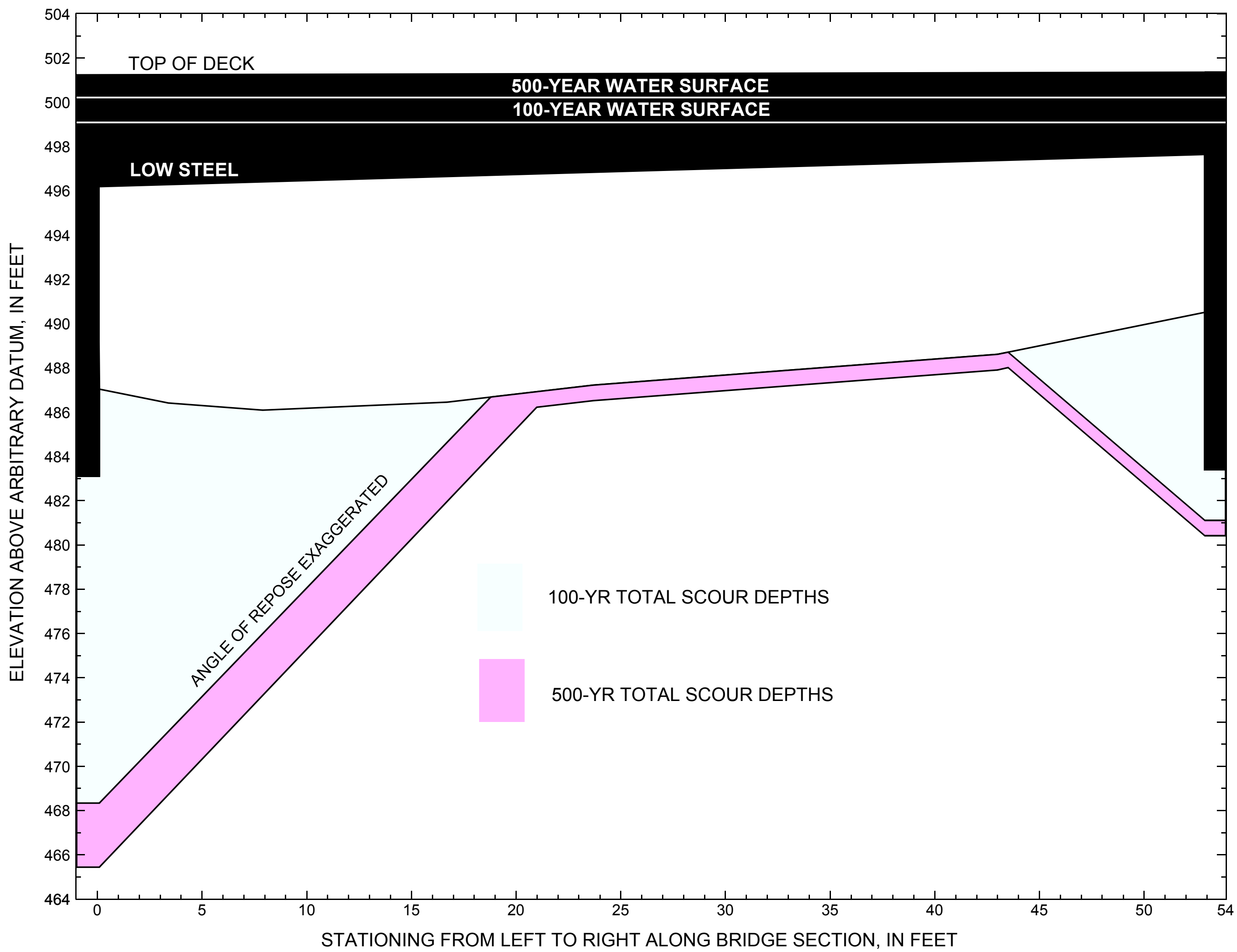


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CHESVT00110044 on State Route 11, crossing Andover Brook, Chester, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CHESVT00110044 on State Route 11, crossing Andover Brook, Chester, 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 3,350 cubic-feet per second											
Left abutment	0.0	856.0	496.2	483.1	487.0	0.0	18.7	--	18.7	468.3	-14.8
Right abutment	52.9	856.0	497.6	483.4	490.5	0.0	9.4	--	9.4	481.1	-2.3

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 CHESVT00110044 on State Route 11, crossing Andover Brook, Chester, 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 4,910 cubic-feet per second											
Left abutment	0.0	856.0	496.2	483.1	487.0	0.7	20.9	--	21.6	465.4	-17.7
Right abutment	52.9	856.0	497.6	483.4	490.5	0.7	9.4	--	10.1	480.4	-3.0

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

Federal Emergency Management Agency, 1982, Flood Insurance Study, Town of Chester, Windsor County, Vermont: Washington, D.C., February 1982.

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 ches044.wsp
T2        Hydraulic analysis for structure CHESVT00110044   Date: 24-FEB-97
T3        Bridge # 44 on VT 11 over Andover Brook in Chester, VT  by MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3350.0   4910.0   2830.0
SK          0.0177   0.0177   0.0177
*
XS   EXITX    -42
GR         -278.3, 504.89    -58.1, 496.64    -39.3, 495.79     -6.4, 493.92
GR            0.0, 489.10     10.7, 486.87     18.1, 486.50     21.7, 486.77
GR           24.6, 486.82     30.7, 486.12     33.5, 486.58     37.7, 486.85
GR           42.9, 487.35     48.1, 489.60     54.7, 491.43     88.1, 494.74
GR          392.4, 499.75    737.2, 507.75
N          0.045     0.045        0.040
SA              -6.4         88.1
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.92      45.0
GR            0.0, 496.19      0.0, 487.04      3.4, 486.41      7.9, 486.09
GR            7.9, 486.09     16.7, 486.45     23.7, 487.22     43.0, 488.61
GR           52.9, 490.51     52.9, 497.64      0.0, 496.19
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      47.0      1.9    501.3     74.3
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     20      32.3     1
GR         -265.8, 515.88   -176.9, 502.38    -91.6, 497.42    -53.7, 499.29
GR            0.0, 501.24     22.0, 501.56     53.7, 501.36
GR          226.4, 499.35    463.2, 502.73    733.4, 508.58
*
XT   APTEM    111
GR         -154.6, 514.02    -95.1, 493.86    -37.7, 495.39    -21.8, 495.04
GR            0.0, 494.30      6.0, 488.16      6.9, 487.86      9.3, 487.47
GR           12.0, 487.08     15.9, 487.77     22.6, 487.55     24.9, 487.27
GR           28.7, 487.88     40.0, 492.29     52.7, 500.58    172.8, 499.17
GR          298.1, 500.03    515.7, 504.75    689.2, 508.51
*
* For the 100-yr discharge the section was ended at station 52.7 to prevent right overbank flow.
* This was necessary because there was no road overflow on the right side of the bridge and any
* water on the right overbank of the approach could only go over the road.
AS   APPRO     75    * * * 0.00866
GT
N           0.035        0.045        0.035
SA                  0.0         52.7
*
HP 1 BRIDG   496.92 1 496.92
HP 2 BRIDG   496.92 * * 3162
HP 1 BRIDG   494.15 1 494.15
HP 2 RDWAY   499.10 * * 243
HP 1 APPRO   499.28 1 499.28
HP 2 APPRO   499.28 * * 3350
*
HP 1 BRIDG   496.92 1 496.92
HP 2 BRIDG   496.92 * * 3606
HP 1 BRIDG   495.65 1 495.65
HP 2 RDWAY   500.21 * * 1312
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File ches044.wsp
        Hydraulic analysis for structure CHESVT00110044   Date: 24-FEB-97
        Bridge # 44 on VT 11 over Andover Brook in Chester, VT  by MAI
           *** RUN DATE & TIME: 05-01-97  11:56
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     342.  31939.    19.    72.                         8335.
   496.92          342.  31939.    19.    72.  1.00     0.    53.   8335.

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

         WSEL     LEW     REW    AREA         K        Q    VEL
       496.92     0.0    52.9   342.2   31939.    3162.   9.24

X STA.         0.0        4.7        7.6       10.2       12.6       15.1
  A(I)             32.2       20.4       19.3       17.6       18.0
  V(I)             4.91       7.75       8.21       8.97       8.76

X STA.        15.1       17.5       20.0       22.5       25.2       27.5
  A(I)             17.4       17.6       17.4       17.9       15.6
  V(I)             9.10       8.98       9.10       8.84      10.15

X STA.        27.5       29.5       31.4       33.4       35.4       37.5
  A(I)             13.0       12.8       12.8       12.5       13.1
  V(I)            12.14      12.32      12.37      12.67      12.05

X STA.        37.5       39.7       42.0       44.5       47.5       52.9
  A(I)             13.4       13.5       14.7       16.7       26.3
  V(I)            11.81      11.68      10.75       9.46       6.02

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     245.  23908.    37.    49.                         3568.
   494.15          245.  23908.    37.    49.  1.00     0.    53.   3568.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      20.

         WSEL     LEW     REW    AREA         K        Q    VEL
       499.10  -120.5   -57.6    52.9    1557.     243.   4.60

X STA.      -120.5     -107.7     -103.9     -101.3      -99.2      -97.4
  A(I)              4.8        3.2        2.7        2.6        2.3
  V(I)             2.54       3.81       4.50       4.74       5.22

X STA.       -97.4      -95.8      -94.4      -93.0      -91.8      -90.6
  A(I)              2.2        2.1        2.1        2.0        2.0
  V(I)             5.53       5.83       5.92       6.04       6.13

X STA.       -90.6      -89.4      -88.0      -86.6      -85.0      -83.2
  A(I)              2.0        2.1        2.1        2.2        2.3
  V(I)             6.01       5.88       5.85       5.54       5.18

X STA.       -83.2      -81.3      -78.9      -76.0      -71.8      -57.6
  A(I)              2.4        2.6        2.9        3.4        5.0
  V(I)             5.05       4.69       4.16       3.60       2.44

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      75.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     510.  59384.   112.   113.                         6183.
             2     472.  63917.    51.    57.                         8128.
   499.28          982. 123302.   163.   170.  1.02  -112.    51.  13557.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      75.

         WSEL     LEW     REW    AREA         K        Q    VEL
       499.28  -112.0    51.2   982.3  123302.    3350.   3.41

X STA.      -112.0      -91.7      -82.7      -73.3      -63.4      -52.6
  A(I)             67.9       49.4       49.9       49.8       50.9
  V(I)             2.47       3.39       3.36       3.36       3.29

X STA.       -52.6      -40.5      -27.7      -16.2       -5.9        3.7
  A(I)             53.7       54.9       52.7       50.4       57.4
  V(I)             3.12       3.05       3.18       3.32       2.92

X STA.         3.7        7.8       11.0       14.1       17.2       20.4
  A(I)             45.3       38.0       38.0       37.8       38.2
  V(I)             3.70       4.41       4.40       4.43       4.39

X STA.        20.4       23.7       27.0       30.8       36.0       51.2
  A(I)             39.6       39.9       44.0       51.1       73.4
  V(I)             4.23       4.19       3.80       3.28       2.28
```

```
        U.S. Geological Survey WSPRO Input File ches044.wsp
        Hydraulic analysis for structure CHESVT00110044   Date: 24-FEB-97
        Bridge # 44 on VT 11 over Andover Brook in Chester, VT  by MAI
           *** RUN DATE & TIME: 05-01-97  11:56
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     342.  31939.    19.    72.                         8335.
   496.92          342.  31939.    19.    72.  1.00     0.    53.   8335.

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

         WSEL     LEW     REW    AREA         K        Q    VEL
       496.92     0.0    52.9   342.2   31939.    3606.  10.54

X STA.         0.0        4.7        7.6       10.2       12.6       15.1
  A(I)             32.2       20.4       19.3       17.6       18.0
  V(I)             5.60       8.84       9.36      10.22       9.99

X STA.        15.1       17.5       20.0       22.5       25.2       27.5
  A(I)             17.4       17.6       17.4       17.9       15.6
  V(I)            10.37      10.24      10.37      10.08      11.57

X STA.        27.5       29.5       31.4       33.4       35.4       37.5
  A(I)             13.0       12.8       12.8       12.5       13.1
  V(I)            13.84      14.05      14.11      14.45      13.74

X STA.        37.5       39.7       42.0       44.5       47.5       52.9
  A(I)             13.4       13.5       14.7       16.7       26.3
  V(I)            13.47      13.31      12.26      10.79       6.87

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     302.  32377.    37.    52.                         4859.
   495.65          302.  32377.    37.    52.  1.00     0.    53.   4859.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      20.

         WSEL     LEW     REW    AREA         K        Q    VEL
       500.21  -139.6   286.6   206.6    7207.    1312.   6.35

X STA.      -139.6     -116.8     -110.4     -105.7     -101.9      -98.7
  A(I)             15.1        9.8        8.5        8.0        7.3
  V(I)             4.35       6.72       7.71       8.20       9.05

X STA.       -98.7      -95.8      -93.2      -90.8      -88.3      -85.6
  A(I)              7.0        6.9        6.7        6.7        6.8
  V(I)             9.32       9.51       9.81       9.78       9.64

X STA.       -85.6      -82.7      -79.4      -75.7      -71.2      -65.6
  A(I)              7.0        7.5        7.8        8.5        9.3
  V(I)             9.32       8.78       8.41       7.68       7.07

X STA.       -65.6      -56.8      198.5      218.7      235.0      286.6
  A(I)             11.3       27.0       13.2       13.1       19.0
  V(I)             5.79       2.43       4.97       5.00       3.45

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      75.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     660.  88936.   116.   117.                         8932.
             2     540.  78419.    53.    59.                         9812.
             3     304.  13487.   286.   286.                         1779.
   500.59         1504. 180842.   454.   462.  1.26  -116.   338.  13832.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      75.
         WSEL     LEW     REW    AREA         K        Q    VEL
       500.59  -115.9   338.3  1503.8  180842.    4910.   3.27

X STA.      -115.9      -92.8      -83.2      -73.9      -63.8      -53.0
  A(I)             89.0       66.1       61.6       64.0       65.5
  V(I)             2.76       3.72       3.99       3.84       3.75

X STA.       -53.0      -41.8      -29.4      -18.4       -8.0        2.1
  A(I)             64.5       69.0       64.6       63.9       67.6
  V(I)             3.80       3.56       3.80       3.84       3.63

X STA.         2.1        7.8       11.6       15.5       19.4       23.4
  A(I)             65.7       51.2       52.5       51.8       53.3
  V(I)             3.74       4.79       4.68       4.74       4.61

X STA.        23.4       27.5       32.3       39.3      164.9      338.3
  A(I)             54.8       60.6       71.5      172.8      193.9
  V(I)             4.48       4.05       3.43       1.42       1.27
```

```
        U.S. Geological Survey WSPRO Input File ches044.wsp
        Hydraulic analysis for structure CHESVT00110044   Date: 24-FEB-97
        Bridge # 44 on VT 11 over Andover Brook in Chester, VT  by MAI
           *** RUN DATE & TIME: 05-01-97  11:56
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     211.   19020.    37.    47.                        2837.
   493.22          211.   19020.    37.    47.  1.00     0.    53.   2837.



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

         WSEL     LEW     REW    AREA        K        Q    VEL
       493.22     0.0    52.9   210.7   19020.    2830.  13.43

X STA.         0.0        4.0        6.3        8.3       10.1       11.9
  A(I)            18.7       11.1        9.9        9.3        8.9
  V(I)            7.56      12.71      14.36      15.23      15.85

X STA.        11.9       13.7       15.5       17.3       19.2       21.1
  A(I)             8.8        8.7        8.6        8.6        8.9
  V(I)           16.10      16.30      16.46      16.44      15.95

X STA.        21.1       23.2       25.4       27.7       30.1       32.6
  A(I)             8.9        9.2        9.4        9.8        9.7
  V(I)           15.83      15.39      15.05      14.49      14.61

X STA.        32.6       35.4       38.4       41.7       45.6       52.9
  A(I)            10.4       10.6       11.2       12.4       17.7
  V(I)           13.65      13.37      12.61      11.45       8.01



    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      75.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     273.   21845.   106.   106.                        2495.
             2     364.   43508.    48.    53.                        5694.
   497.10          637.   65354.   153.   159.  1.11  -106.    48.   7000.



    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      75.

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.10  -105.6    47.8   637.1   65354.    2830.   4.44

X STA.      -105.6      -88.2      -76.8      -63.7      -46.6      -24.7
  A(I)            42.6       36.4       38.0       42.5       47.2
  V(I)            3.32       3.89       3.72       3.33       3.00

X STA.       -24.7       -8.7        3.4        7.1        9.5       11.8
  A(I)            40.7       42.7       30.6       23.6       23.0
  V(I)            3.48       3.32       4.63       5.99       6.15

X STA.        11.8       14.0       16.3       18.7       21.1       23.5
  A(I)            22.5       23.0       23.1       23.1       23.4
  V(I)            6.30       6.16       6.11       6.13       6.05

X STA.        23.5       25.8       28.4       31.5       35.6       47.8
  A(I)            23.7       25.4       27.9       31.3       46.5
  V(I)            5.96       5.56       5.08       4.52       3.04
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File ches044.wsp
        Hydraulic analysis for structure CHESVT00110044   Date: 24-FEB-97
        Bridge # 44 on VT 11 over Andover Brook in Chester, VT  by MAI
           *** RUN DATE & TIME: 05-01-97  11:56

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

EXITX:XS   ******    -5.     302.  1.92 *****  494.68  492.64   3350.  492.76
      -42. ******    68.   25166.  1.00 ***** *******    0.96   11.11

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "FULLV"     KRATIO =  1.49

FULLV:FV      42.   -10.     414.  1.02  0.50  495.17 *******   3350.  494.15
        0.    42.    82.   37533.  1.00  0.00   -0.01    0.67    8.08
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     1.37     493.98     495.58
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.65     513.71    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.65     513.71     495.58
 ===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 =   495.58     513.71     495.58

APPRO:AS      75.  -101.     409.  1.31 *****  496.88  495.58   3350.  495.58
       75.    75.    46.   36805.  1.25 ***** *******    0.97    8.19
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   498.10       0.00     493.88     497.42
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                   WS,QBO,QRD =   501.68         1.      3349.
 ===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      42.     0.     342.  1.33 *****  498.25  493.65   3162.  496.92
        0. ******    53.   31939.  1.00 ***** *******    0.64    9.24

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.483  0.000  496.92 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF    VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.    43.  0.03  0.18  499.43    0.02    243.  499.10

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    243.    63.  -120.   -58.   1.7   0.8   4.9   4.6   1.2   3.0
   RT:      0.    59.   194.   253.   0.4   0.2   3.7   8.4   0.6   3.0

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

APPRO:AS      28.  -112.     982.  0.18  0.08  499.46  495.58   3350.  499.28
       75.    32.    51.  123329.  1.02  0.00    0.02    0.25    3.41

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -42.    -5.    68.   3350.   25166.     302.   11.11  492.76
   FULLV:FV       0.   -10.    82.   3350.   37533.     414.    8.08  494.15
   BRIDG:BR       0.     0.    53.   3162.   31939.     342.    9.24  496.92
   RDWAY:RG      20.*******   243.    243.*********      0.    1.00  499.10
   APPRO:AS      75.  -112.    51.   3350.  123329.     982.    3.41  499.28

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    492.64    0.96  486.12  507.75************  1.92  494.68  492.76
   FULLV:FV  ********    0.67  486.12  507.75  0.50  0.00  1.02  495.17  494.15
   BRIDG:BR    493.65    0.64  486.09  497.64************  1.33  498.25  496.92
   RDWAY:RG  ****************  497.42  515.88  0.03******  0.18  499.43  499.10
   APPRO:AS    495.58    0.25  486.77  513.71  0.08  0.00  0.18  499.46  499.28
```

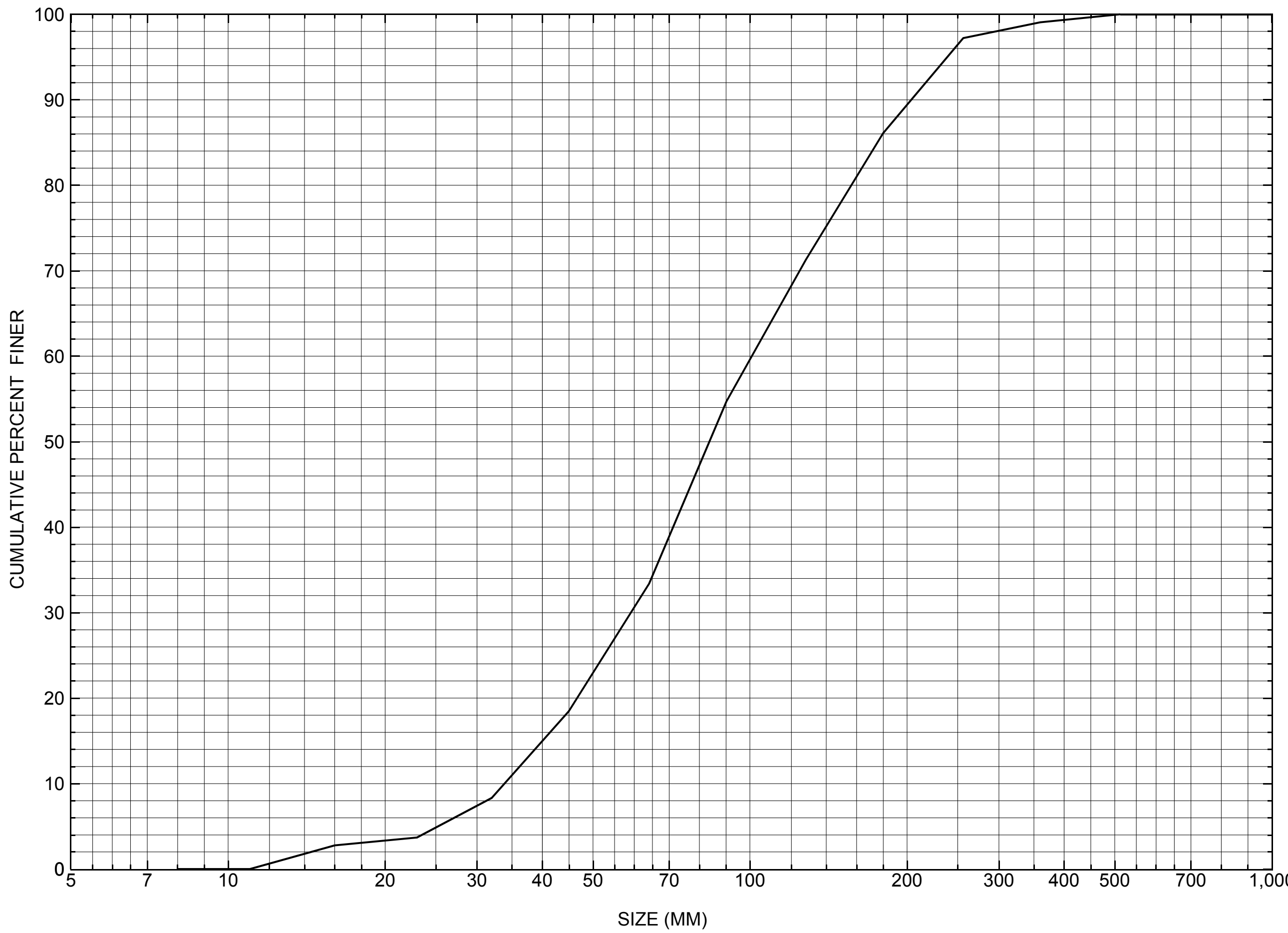
```
       U.S. Geological Survey WSPRO Input File ches044.wsp
       Hydraulic analysis for structure CHESVT00110044   Date: 24-FEB-97
       Bridge # 44 on VT 11 over Andover Brook in Chester, VT  by MAI
          *** RUN DATE & TIME: 05-01-97  11:56

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

EXITX:XS   ******    -9.     409.  2.25 *****  496.34  494.03   4910.  494.09
      -42. ******    82.   36876.  1.00 ***** *******    1.00   12.01

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.83     495.65     494.03
 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   493.59     507.75    0.50
 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   493.59     507.75     494.03
 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "FULLV"     KRATIO =  1.62

FULLV:FV      42.   -37.     605.  1.14  0.46  496.79  494.03   4910.  495.65
        0.    42.   143.   59754.  1.12  0.00    0.00    0.83    8.12
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    1.30     495.74     496.42
 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   495.15     513.71    0.50
 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   495.15     513.71     496.42
 ===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 =   496.42     513.71     496.42

APPRO:AS      75.  -104.     534.  1.54 *****  497.96  496.42   4910.  496.42
       75.    75.    47.   51288.  1.17 ***** *******    0.93    9.20
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
         WS1,WSSD,WS3,RGMIN =   500.79       0.00     495.72     497.42
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===240 NO DISCHARGE BALANCE IN 15 ITERATIONS.
                 WS,QBO,QRD =   502.17         0.      4910.
 ===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      42.     0.     342.  1.73 *****  498.65  494.20   3606.  496.92
        0. ******    53.   31939.  1.00 ***** *******    0.73   10.54
     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****   5.  0.496  0.000  496.92 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      20.    43.  0.03  0.21  500.77    0.00   1312.  500.21

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    910.   111.  -140.   -28.   2.8   1.3   6.5   6.1   1.9   3.1
   RT:    401.   134.   152.   287.   0.9   0.4   4.5   6.9   1.0   3.0

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

APPRO:AS      28.  -116.    1505.  0.21  0.11  500.80  496.42   4910.  500.59
       75.    34.   338.  180981.  1.26  0.00    0.00    0.35    3.26

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -42.    -9.    82.   4910.   36876.     409.   12.01  494.09
   FULLV:FV       0.   -37.   143.   4910.   59754.     605.    8.12  495.65
   BRIDG:BR       0.     0.    53.   3606.   31939.     342.   10.54  496.92
   RDWAY:RG      20.*******   910.   1312.*********       0.    1.00  500.21
   APPRO:AS      75.  -116.   338.   4910.  180981.    1505.    3.26  500.59

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    494.03    1.00  486.12  507.75************  2.25  496.34  494.09
   FULLV:FV    494.03    0.83  486.12  507.75  0.46  0.00  1.14  496.79  495.65
   BRIDG:BR    494.20    0.73  486.09  497.64************  1.73  498.65  496.92
   RDWAY:RG  ****************  497.42  515.88  0.03******  0.21  500.77  500.21
   APPRO:AS    496.42    0.35  486.77  513.71  0.11  0.00  0.21  500.80  500.59
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File ches044.wsp
        Hydraulic analysis for structure CHESVT00110044   Date: 24-FEB-97
        Bridge # 44 on VT 11 over Andover Brook in Chester, VT  by MAI
           *** RUN DATE & TIME: 05-01-97  11:56

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

EXITX:XS   ******    -4.      263.  1.80 *****  494.01  492.07   2830.  492.21
      -42. ******    63.   21253.  1.00 ***** *******    0.96   10.77

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  1.49

FULLV:FV      42.    -6.      362.  0.95  0.50  494.50 *******   2830.  493.55
        0.    42.    76.   31651.  1.00  0.00   -0.01    0.65    7.81
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.12     493.57     494.72

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.05     513.71    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.05     513.71     494.72

 ===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 =   494.72     513.71     494.72

APPRO:AS      75.   -99.      290.  1.72 *****  496.44  494.72   2830.  494.72
       75.    75.    44.   26360.  1.16 ***** *******    1.16    9.75
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===285 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D !!!!!
                   SECID "BRIDG"     Q,CRWS =   2830.     493.22

            <<<<<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      42.     0.      211.  2.81 *****  496.03  493.22   2830.  493.22
        0.    42.    53.   19015.  1.00 ***** *******    1.00   13.44

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4. ****    1.  1.000 ******  496.92 ****** ****** ******

    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      28.  -106.      636.  0.34  0.19  497.44  494.72   2830.  497.10
       75.    30.    48.   65260.  1.11  1.22    0.01    0.41    4.45

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.629  0.321   44092.    -3.    50.   497.01

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -42.    -4.    63.   2830.   21253.     263.   10.77  492.21
   FULLV:FV       0.    -6.    76.   2830.   31651.     362.    7.81  493.55
   BRIDG:BR       0.     0.    53.   2830.   19015.     211.   13.44  493.22
   RDWAY:RG      20.**************      0.*****************     1.00********
   APPRO:AS      75.  -106.    48.   2830.   65260.     636.    4.45  497.10

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      -3.    50.   44092.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    492.07    0.96  486.12  507.75************  1.80  494.01  492.21
   FULLV:FV  ********    0.65  486.12  507.75  0.50  0.00  0.95  494.50  493.55
   BRIDG:BR    493.22    1.00  486.09  497.64************  2.81  496.03  493.22
   RDWAY:RG  ***************  497.42  515.88**********************************
   APPRO:AS    494.72    0.41  486.77  513.71  0.19  1.22  0.34  497.44  497.10
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CHESVT00110044, in Chester, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CHESVT00110044

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 29 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 13675

Mile marker *(I - 11; nnn.nnn)* 001390

Waterway *(I - 6)* ANDOVER BROOK

Road Name *(I - 7)*: -

Route Number VT 11

Vicinity *(I - 9)* 3.6 MI W JCT. VT.103 N

Topographic Map Andover

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43157

Longitude *(i - 17; nnnnn.n)* 72395

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20001600441407

Maintenance responsibility *(I - 21; nn)* 01

Maximum span length *(I - 48; nnnn)* 0056

Year built *(I - 27; YYYY)* 1933

Structure length *(I - 49; nnnnnn)* 000058

Average daily traffic, ADT *(I - 29; nnnnnn)* 003540

Deck Width *(I - 52; nn.n)* 323

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

Channel & Protection *(I - 61; n)* 7

Opening skew to Roadway *(I - 34; nn)* 45

Waterway adequacy *(I - 71; n)* 5

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

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

Structure type *(I - 43; nnn)* 104

Year Reconstructed *(I - 106)* 1974

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

Clear span (*nnn.n ft*) 88.0

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

Vertical clearance from streambed (*nnn.n ft*) 9.0

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

Waterway of full opening (*nnn.n ft*^{2}) 625

Comments:

The structural inspection report of 11/10/93 indicates the structure is a concrete T-beam type bridge with an asphalt road surface. There is some moderate scaling reported along the flow line of the left abutment. The downstream right wingwall and left abutment wall and the downstream left wingwall consist of newer concrete. The upstream original wingwalls have a few areas of minor to moderate spalling noted. Overall, there is no significant section loss or any reinforcement bar exposed. The footings are not in view. There is an old concrete retaining wall off the upstream end of upstream left wingwall which is just about to fall into the stream in a few locations. **(Continued, page 33)**

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} (*ft^3/ sec*): -

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

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

Highway No. : - Structure No. : - Structure Type: -

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

Downstream distance (*miles*): - Town: - Year Built: -

Highway No. : - Structure No. : - Structure Type: -

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

Comments:

A log mat forms the foundation upon which both abutment walls were built. The waterway makes a moderate to sharp bend into the structure, and there is some minor localized scour at the upstream end of the left abutment. There is a stone and gravel point bar along the right abutment wall.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **12.55** mi^2 Lake and pond area **0.01** mi^2

Watershed storage *(ST)* **0.1** %

Bridge site elevation **860** ft Headwater elevation **2860** ft

Main channel length **6.90** mi

10% channel length elevation **900** ft 85% channel length elevation **1840** ft

Main channel slope *(S)* **181.61** 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):* 05 / 1974

Project Number FAP 100G Minimum channel bed elevation: 847.5

Low superstructure elevation: USLAB 856.0 DSLAB 856.0 USRAB 856.0 DSRAB 856.0

Benchmark location description:

No specific benchmarks are shown on the plans but a couple of points are shown with elevations: 1) on the streamward edge, top of concrete of the downstream right wing wall where the concrete slope begins the decline, elevation 860.5; 2) at the same location as described above on the downstream left wingwall, elevation 859.5

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 2.0 Footing bottom elevation: 842.*

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:

NOTE ON PLANS "FOUNDATION: GRAVEL"

Comments:

***Footing bottom elevations are left: 842.17 and right: 842.53. Plans indicate the bridge was widened on the downstream side using the original bridge abutments and wingwalls. The bottom of the footing given is on the expanded bridge. The bridge was widened over the top of the downstream right wingwall. The footing of the extended downstream right wingwall was set at elevation 846.0. This elevation is shown to be roughly 3.5 feet above the bottom of the existing abutment.**

Cross-sectional Data

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

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

Comments: **The stations and elevations are in feet.**

Station	**313**	**320**	**339**	**368**	-	-	-	-	-	-	-
Feature	**LAB**	-	-	**RAB**	-	-	-	-	-	-	-
Low cord elevation	**856.5**	**856.5**	**856.5**	**856.5**	-	-	-	-	-	-	-
Bed elevation	**845.5**	**845.5**	**847**	**849.5**	-	-	-	-	-	-	-
Low cord to bed length	**11**	**11**	**9.5**	**7**	-	-	-	-	-	-	-

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: **10/02/96**

Computerized by: **RB** Date: **10/02/96**

Reviewd by: **MAI** Date: **04/02/97**

Structure Number **CHESVT00110044**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **R**. **HAMMOND** Date *(MM/DD/YY)* **09** / **11** / 19**96**

2. Highway District Number **02** Mile marker **0013900**

County **WINDSOR (027)** Town **CHESTER (13675)**

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

Route Number **VT11** Hydrologic Unit Code: **01080107**

3. Descriptive comments:

The site is located 3.6 miles west of the junction with VT 103 north and 0.1 miles east of junction with a road leading to the community of Andover.

B. Bridge Deck Observations

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

5. Ambient water surface... US **2** UB **1** DS **2** *(**1**- pool; **2**- riffle)*

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

7. Bridge length **58** *(feet)* Span length **56** *(feet)* Bridge width **32.3** *(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)*

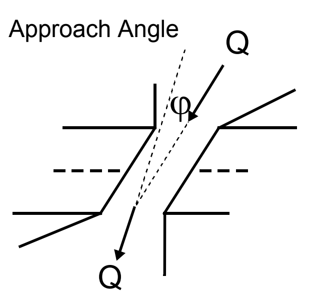
10. Embankment slope (*run / rise in feet / foot*):
US left **2.2:1** US right **1.5:1**

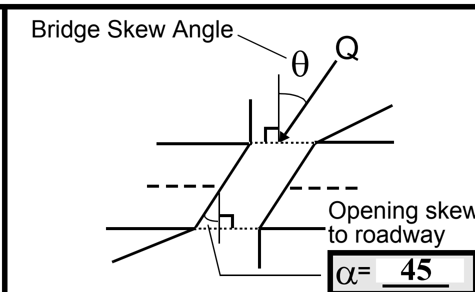
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	0	-	2	1
RBDS	0	-	2	0
LBDS	0	-	2	1

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

Channel approach to bridge (BF):

15. Angle of approach: **35** 16. Bridge skew: **60**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **3**
Range? **100** feet **US** *(US, UB, DS)* to **30** feet **UB**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **40** feet **DS** *(US, UB, DS)* to **150** feet **DS**

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

18. Bridge Type: **4**

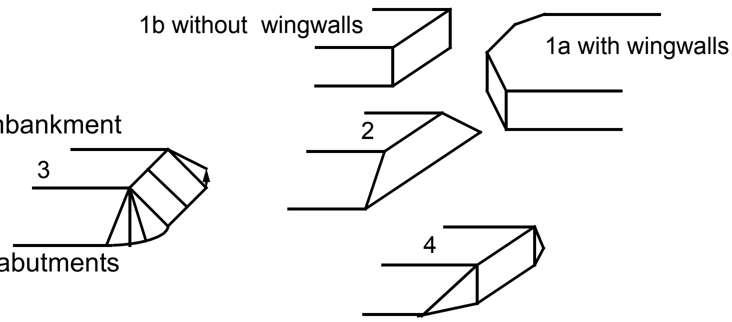
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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. The right bank DS is a large field with a house and driveway and some brush along the banks. There are roads parallel to the stream on both the US left and right banks.
7. The values are from the VT AOT files. The measured bridge length is 55.7 ft US and 63.6 ft DS, span length is 52.7 ft US and 60.3 ft DS, and bridge width is 32.1 ft between the outside edges of the deck. The bridge deck has been widened. At the base of the abutments the opening is 37.4 ft perpendicularly between the abutment faces.
18. The end of the US left wingwall is 5 ft below the low chord and the US right wingwall is 2.5 ft below low chord. The ends of the DS right and left wingwalls are at the low chord elevation.

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
53.0	6.0			12.5	1	1	7	43	2	0

23. Bank width **40.0** 24. Channel width **30.0** 25. Thalweg depth **52.5** 29. Bed Material **345**

30 .Bank protection type: LB **5** 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 left bank protection from 10 ft US to 18 ft US is placed boulders and concrete blocks. From 18 ft US to 50 ft US there is a poured concrete wall, then from 50 ft US to 65 ft US there are more dumped boulders. The right bank protection extends from 105 ft US to 300+ft US and protects the VT 11 embankment where the stream is parallel to the road.
31. The left bank concrete wall is intact but leaning towards the channel.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 30UB 35. Mid-bar width: 27

36. Point bar extent: 45 feet US (US, UB) to 65 feet DS (US, UB, DS) positioned 30 %LB to 100 %RB

37. Material: 342

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

This point bar is comprised of gravel, cobble, and sand.

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

41. Mid-bank distance: 240 42. Cut bank extent: 145 feet US (US, UB) to 300 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? Y (Y or if N type ctrl-n cs) 46. Mid-scour distance: 18UB

47. Scour dimensions: Length 101 Width 9 Depth : 1.8 Position 0 %LB to 30 %RB

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

The average thalweg depth is 0.5 ft. The scour is from 37 ft US to 20 ft DS. There is also scour from 185 ft US to 157 ft that is 1.2 ft deep, 5 ft wide and 28 ft long. It is positioned from 60% LB to 80% RB with mid-scour distance at 180 ft US. There was also some local scour beside and DS of large boulders in the upstream channel.

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
22.5		1.0		2	7	7	0

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

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

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

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

345

The DS right wingwall is 21.3 ft long and joins the abutment underneath the deck of the bridge.

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

The bend in the channel through the bridge could cause jamming of ice and debris.

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		**20**	**90**	**2**	**2**	**1.8**	**0**	**90.0**
RABUT	**1**	**-**	**90**			**2**	**0**	**35.0**

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.):

-

-

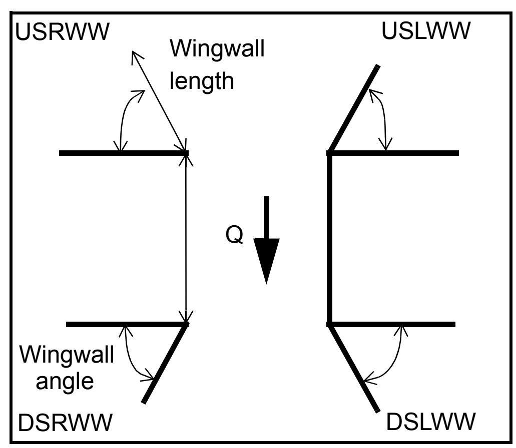
1

75. The top of the US left wingwall and left abutment footing is visible and level with the channel bed.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						**35.0**	**1.0**
USRWW:	**Y**		**1**		**2**	**47.0**	
DSLWW:	**1.8**		**0**		**Y**	**34.0**	
DSRWW:	**1**		**0**		**-**		

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	**-**	**0**	**Y**	**-**	**3**	**-**	**-**	**-**
Condition	**Y**	**-**	**1**	**-**	**1**	**-**	**-**	**-**
Extent	**1**	**-**	**0**	**2**	**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*

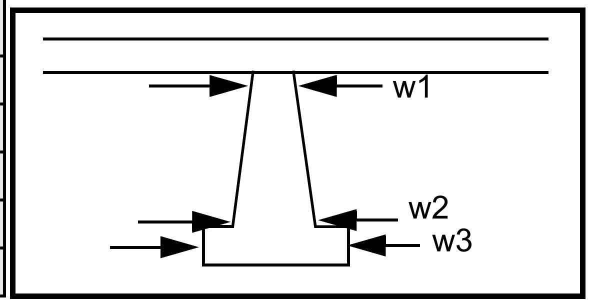
83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):

-
-
-
-
-
1
1
3
2
1
3

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	120.0			11.0	30.0	17.5
Pier 2				30.0	21.0	115.0
Pier 3		-	-	21.5	-	-
Pier 4	-	-	-	-	-	-



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

4
3
43
43
1
1
345
0
4
-
1
There is an old stone wall/pile parallel to the stream on the left bank from 35 ft DS to 130 ft DS. On the right bank there is large stone fill protection from 135 ft DS to 300 ft DS providing protection for the dirt road

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

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

105. Drop structure comments (eg. downstream scour depth):
ankment that is parallel to the stream.

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

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

Material: **NO**

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

DROP 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: **135** feet **15** *(US, UB, DS)* to **20** feet **DS** *(US, UB, DS)*

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

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

DS
0
30
453

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 **255** %RB

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

220
DS
300
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

Some local scour beside and DS of large boulders.

Y

1

500

RB

1

-

-

-

109. G. Plan View Sketch

- A

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: CHESVT00110044 Town: Chester
Road Number: VT 11 County: Windsor
Stream: Andover Brook

Initials MAI Date: 05/01/97 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	3350	4910	2830
Main Channel Area, ft2	472	540	364
Left overbank area, ft2	510	660	273
Right overbank area, ft2	0	304	0
Top width main channel, ft	51	53	48
Top width L overbank, ft	112	116	106
Top width R overbank, ft	0	286	0
D50 of channel, ft	0.274	0.274	0.274
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	9.3	10.2	7.6
y1, average depth, LOB, ft	4.6	5.7	2.6
y1, average depth, ROB, ft	ERR	1.1	ERR
Total conveyance, approach	123302	180842	65354
Conveyance, main channel	63917	78419	43508
Conveyance, LOB	59384	88936	21845
Conveyance, ROB	0	13487	0
Percent discrepancy, conveyance	0.0008	0.0000	0.0015
Qm, discharge, MC, cfs	1736.6	2129.1	1884.0
Ql, discharge, LOB, cfs	1613.4	2414.7	945.9
Qr, discharge, ROB, cfs	0.0	366.2	0.0
Vm, mean velocity MC, ft/s	3.7	3.9	5.2
Vl, mean velocity, LOB, ft/s	3.2	3.7	3.5
Vr, mean velocity, ROB, ft/s	ERR	1.2	ERR
Vc-m, crit. velocity, MC, ft/s	10.5	10.7	10.2
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	3350	4910	2830
(Q) discharge thru bridge, cfs	3162	3606	2830
Main channel conveyance	31939	31939	19020
Total conveyance	31939	31939	19020
Q2, bridge MC discharge,cfs	3162	3606	2830
Main channel area, ft2	342	342	211
Main channel width (normal), ft	37.4	37.4	37.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	37.4	37.4	37.4
y_bridge (avg. depth at br.), ft	9.14	9.15	5.63
Dm, median (1.25*D50), ft	0.3425	0.3425	0.3425
y2, depth in contraction,ft	7.54	8.44	6.86
ys, scour depth (y2-ybridge), ft	-1.60	-0.71	1.22

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	3350	4910	2830
Q, thru bridge MC, cfs	3162	3606	2830
Vc, critical velocity, ft/s	10.55	10.72	10.21
Va, velocity MC approach, ft/s	3.68	3.94	5.18
Main channel width (normal), ft	37.4	37.4	37.4
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	37.4	37.4	37.4
qbr, unit discharge, ft2/s	84.5	96.4	75.7
Area of full opening, ft2	342.2	342.2	210.7
Hb, depth of full opening, ft	9.15	9.15	5.63
Fr, Froude number, bridge MC	0.64	0.73	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	245	302	N/A
**Hb, depth at downstream face, ft	6.55	8.07	N/A
**Fr, Froude number at DS face	0.89	0.74	ERR
**Cf, for downstream face (<=1.0)	1.00	1.00	N/A

Elevation of Low Steel, ft	496.92	496.92	0
Elevation of Bed, ft	487.77	487.77	-5.63
Elevation of Approach, ft	499.28	500.59	0
Friction loss, approach, ft	0.08	0.11	0
Elevation of WS immediately US, ft	499.20	500.48	0.00
ya, depth immediately US, ft	11.43	12.71	5.63
Mean elevation of deck, ft	501.3	501.3	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	0.95	0.92	1.00
**Cc, for downstream face (<=1.0)	0.826245	0.876792	ERR
Ys, scour w/Chang equation, ft	-0.67	0.66	N/A
Ys, scour w/Umbrell equation, ft	-2.48	-1.49	N/A

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

**Ys, scour w/Chang equation, ft	3.15	2.18	N/A
**Ys, scour w/Umbrell equation, ft	0.12	-0.41	ERR

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

y2, from Laursen's equation, ft	7.54	8.44	6.86
WSEL at downstream face, ft	494.15	495.65	--
Depth at downstream face, ft	6.55	8.07	ERR
Ys, depth of scour (Laursen), ft	0.99	0.37	N/A

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	3162	3606	2830
Main channel area (DS), ft2	245	302	210.7
Main channel width (normal), ft	37.4	37.4	37.4
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	37.4	37.4	37.4
D90, ft	0.6680	0.6680	0.6680
D95, ft	0.7828	0.7828	0.7828
Dc, critical grain size, ft	0.7337	0.5765	0.8471
Pc, Decimal percent coarser than Dc	0.070	0.149	0.027
Depth to armoring, ft	29.24	9.88	N/A

Abutment Scour

Froehlich's Abutment Scour

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

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	3350	4910	2830	3350	4910	2830
a', abut.length blocking flow, ft	112	115.9	105.6	13.8	300.9	10.4
Ae, area of blocked flow ft2	462.1	538	278.1	66.6	323.8	39.6
Qe, discharge blocked abut.,cfs	--	--	950.7	152.1	--	120.6

(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)

Ve, (Qe/Ae), ft/s	3.13	3.63	3.42	2.28	1.44	3.05
ya, depth of f/p flow, ft	4.13	4.64	2.63	4.83	1.08	3.81

--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	135	135	135	45	45	45
K2	1.05	1.05	1.05	0.91	0.91	0.91
Fr, froude number f/p flow	0.257	0.268	0.371	0.183	0.225	0.275
ys, scour depth, ft	18.74	20.91	16.44	9.41	9.38	8.35

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)	112	115.9	105.6	13.8	300.9	10.4
y1 (depth f/p flow, ft)	4.13	4.64	2.63	4.83	1.08	3.81
a'/y1	27.15	24.97	40.10	2.86	279.62	2.73
Skew correction (p. 49, fig. 16)	1.10	1.10	1.10	0.80	0.80	0.80
Froude no. f/p flow	0.26	0.27	0.37	0.18	0.23	0.28
Ys w/ corr. factor K1/0.55:						
vertical	21.08	ERR	15.19	ERR	3.83	ERR
vertical w/ ww's	17.29	ERR	12.46	ERR	3.14	ERR
spill-through	11.59	ERR	8.36	ERR	2.10	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)

Downstream bridge face property	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.89	0.74	1	0.89	0.74	1
y, depth of flow in bridge, ft	6.55	8.07	5.63	6.55	8.07	5.63
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	2.73	ERR	ERR	2.73	ERR
Fr>0.8 (vertical abut.)	2.65	ERR	2.35	2.65	ERR	2.35