LEVEL II SCOUR ANALYSIS FOR BRIDGE 12 (CHESVT01030012) on STATE ROUTE 103, crossing the WILLIAMS RIVER, CHESTER, VERMONT

U.S. Geological Survey
Open-File Report 97-364

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 12 (CHESVT01030012) on STATE ROUTE 103, crossing the WILLIAMS RIVER, CHESTER, VERMONT

By ROBERT H. FLYNN and RONDA L. BURNS

U.S. Geological Survey
Open-File Report 97-364

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 12 (CHESVT01030012) ON STATE ROUTE 103, CROSSING THE WILLIAMS RIVER, CHESTER, VERMONT

By **Robert H. Flynn and Ronda L. Burns**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CHESVT01030012 on State Route 103 crossing the Williams River, 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 eastern Vermont. The 23.9-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture on the downstream right and upstream left overbank areas and short grass on the downstream left and upstream right overbank areas. The surface cover along the upstream and downstream immediate banks consists of trees and brush.

In the study area, the the Williams River has an incised, sinuous channel with a slope of approximately 0.0054 ft/ft, an average channel top width of 75 ft and an average bank height of 4 ft. The predominant channel bed material is gravel with a median grain size (D_{50}) of 52.4 mm (0.172 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 18, 1996, indicated that the reach was laterally unstable.

The State Route 103 crossing of the Williams River is a 99-ft-long, two-lane bridge consisting of three concrete T-beam spans (Vermont Agency of Transportation, written communication, March 29, 1995). The bridge is supported by two piers and vertical, concrete abutments with wingwalls and spill-through slopes. The channel is skewed approximately 20 degrees to the opening while the opening-skew-to-roadway is 0 degrees. Downstream of the bridge are the remains of a dam which is acting as a drop structure.

A scour hole, approximately 3 ft deeper than the mean thalweg depth, was observed along the upstream left bank extending from 78 ft upstream of the upstream bridge face to 25 ft downstream of the downstream bridge face during the Level I assessment. Lateral migration of the channel has resulted in flow being directed at an angle to the piers, which has resulted in increased local scour at the bridge. The scour protection measures at the site included type-2 stone fill (less than 36 inches diameter) under the bridge along the entire base length of the left and right spill-through slopes and extending up to the abutments. Type-2 stone fill (less than 36 inches diameter) scour protection was also found along the upstream left bank from the bridge to 46 ft upstream and along the downstream right bank from the bridge to 70 ft downstream. Rock walls were found along the left bank from 88 ft to 200 ft downstream and along the right bank from 124 ft to 224 ft downstream. There are two wood pile drop structures located at 47 ft and 61 ft downstream 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 0.2 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 4.0 to 12.4 ft along the right spill-through abutment and from 8.4 to 10.7 ft along the left spill-through abutment. The worst-case abutment scour occurred at the 500-year discharge. Pier scour ranged from 7.1 to 8.9 ft along Pier 1 (northerly pier) and from 13.5 to 17.1 ft along Pier 2 (southerly pier). The worst case pier 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.

Chester, VT. Quadrangle, 1:24,000, 1972

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 CHESVT01030012 ***Stream*** Williams River

County Windsor ***Road*** VT 103 ***District*** 2

Description of Bridge

Bridge length 99 ***ft*** ***Bridge width*** 28 ***ft*** ***Max span length*** 31 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 9/18/96

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

Brief description of piers/abutments Piers, abutments and wingwalls are concrete. Scouring is evident at the piers.

Is bridge skewed to flood flow according to No ***survey?*** Y ***Angle*** 20

There is a moderate channel bend in the upstream and downstream reach. The scour hole has developed in the location where the bend impacts the upstream left bank and piers.

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	9/18/96	0	0
Level II	9/18/96	0	0

Potential for debris Moderate. There is some debris caught on the front and right of Pier 2 (southerly pier).

Describe any features near or at the bridge that may affect flow (include observation date) There is a point bar along the upstream right bank and two drop structures located approximately 47 ft and 61 ft downstream of the downstream bridge face as of 9/18/96.

Description of the Geomorphic Setting

General topography The channel is located within a wide, flat to slightly irregular flood plain.

9/18/96

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

Date of inspection Steep channel

bank to a narrow flood plain

DS left:

Steep channel bank to a wide flood plain

DS right:

Steep channel bank to flood plain

US left:

Steep channel bank to a wide flood plain

US right:

Description of the Channel

75.0 4

Average top width ft ***Average depth*** ft

Gravel Sand / Gravel

Predominant bed material ***Bank material*** Sinuous and laterally

unstable with semi-alluvial channel boundaries.

9/18/96

Vegetative co TH 9 and grass on overbank with trees and brush along banks

DS left: Grass on overbank with trees and brush along banks

DS right: VT 103 and grass on overbank with trees and brush along banks

US left: Grass on overbank with trees and brush along banks.

US right: No

Do banks appear stable? Type-2 bank protection was found along the upstream left bank and is ***If not, describe location and type of instability and***

stabilizing the impact zone immediately upstream of the bridge but farther upstream, a point bar ***date of observation.***

along the upstream right bank and a cutbank along the upstream left bank indicate lateral

migration of the upstream channel. In addition, the upstream and downstream bank material is

primarily sand. Observed 9/18/96.

Flow conditions up to

bank-full level are influenced by a point bar on the right bank side of the upstream channel. In

Describe any obstructions in channel and date of observation.

addition, some debris is caught on Pier 2.

Hydrology

Drainage area 23.9 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization:*** There are houses along the left overbank area

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

USGS gage description Williams River at Brockways Mills

USGS gage number 01153500

Gage drainage area 103 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 5,200 ***ft³/s*** ***Q500*** 7,620 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(23.9/25.1)exp 0.75] with the Williams River above Trebo Brook in Chester which has flood frequency estimates available from the Flood Insurance Study for Chester (Federal Emergency Management Agency, 1982).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the right abutment (elev. 497.52 ft, arbitrary survey datum). RM2 is the bottom center of the letter "M" in the word "Vermont" on a brass tablet (VT bridge marker #T25B) on the upstream left end of the bridge rail (elev. 501.75 ft, arbitrary survey datum).

[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 0.035 to 0.065, and overbank "n" values ranged from 0.032 to 0.090.

Normal depth at the exit section (EXTDS) of the downstream bridge (CHESTH00090063) 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 0.0054 ft/ft which was estimated from the topographic map (U.S. Geological Survey, 1972).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.002 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 499.1 ***ft***
Average low steel elevation 496.0 ***ft***

100-year discharge 5,200 ***ft³/s***
Water-surface elevation in bridge opening 491.2 ***ft***
Road overtopping? Y ***Discharge over road*** 313 ***ft³/s***
Area of flow in bridge opening 620 ***ft²***
Average velocity in bridge opening 7.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.9 ***ft/s***

Water-surface elevation at Approach section with bridge 493.1
Water-surface elevation at Approach section without bridge 491.9
Amount of backwater caused by bridge 1.2 ***ft***

500-year discharge 7,620 ***ft³/s***
Water-surface elevation in bridge opening 492.2 ***ft***
Road overtopping? Y ***Discharge over road*** 1,246 ***ft³/s***
Area of flow in bridge opening 710 ***ft²***
Average velocity in bridge opening 9.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 11.5 ***/s***

Water-surface elevation at Approach section with bridge 494.8
Water-surface elevation at Approach section without bridge 492.9
Amount of backwater caused by bridge 1.9 ***ft***

Incipient overtopping discharge 3,050 ***ft³/s***
Water-surface elevation in bridge opening 490.3 ***ft***
Area of flow in bridge opening 552 ***ft²***
Average velocity in bridge opening 5.5 ***ft/s***
Maximum WSPRO tube velocity at bridge 7.0 ***ft/s***

Water-surface elevation at Approach section with bridge 491.2
Water-surface elevation at Approach section without bridge 490.8
Amount of backwater caused by bridge 0.4 ***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. 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 was computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). In this case, the 500-year discharge model resulted in the worst case contraction scour with a scour depth of 0.2 ft. The computed depths to streambed armoring suggest armoring will not limit the depth of contraction scour.

Abutment scour for the left abutment was computed by use of the Froehlich equation (Richardson and others, 1995, p. 48, equation 28). Variables for the Froehlich equation include the Froude number of the flow approaching the embankments, the length of the embankment blocking flow, and the depth of flow approaching the embankment less any roadway overtopping. 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 at the right abutment was computed by use of the HIRE equation (Richardson and others, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. The variables used by the HIRE abutment-scour equation are defined the same as those defined for the Froehlich abutment-scour equation.

Scour at the piers (piers 1 and 2) was computed by use of the Colorado State University (CSU) pier scour equation (Richardson and others, 1995, p. 36, equation 21). The variables used by the CSU equation include pier dimensions, flow approach depth and velocity, Froude number, and multiplicative factors for pier shape, attack angle, bed conditions, and armoring (see appendix F).

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	0.2	0.0
Depth to armoring	1.0 2.8	0.0	--
Left overbank	--	--	--
Right overbank	--	--	9.4

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	10.7	8.4	8.6
Right abutment	12.4–	4.0-	8.3-
Pier scour			
Pier 1	8.9	7.1	15.8
Pier 2	17.1	13.5	--
Pier 3	--	--	1.6

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	2.1	0.7	1.6
Right abutment	2.1	0.7	0.9
Piers:			
Pier 1	1.1	0.4	0.9
Pier 2	1.1	0.4	--
	--	--	

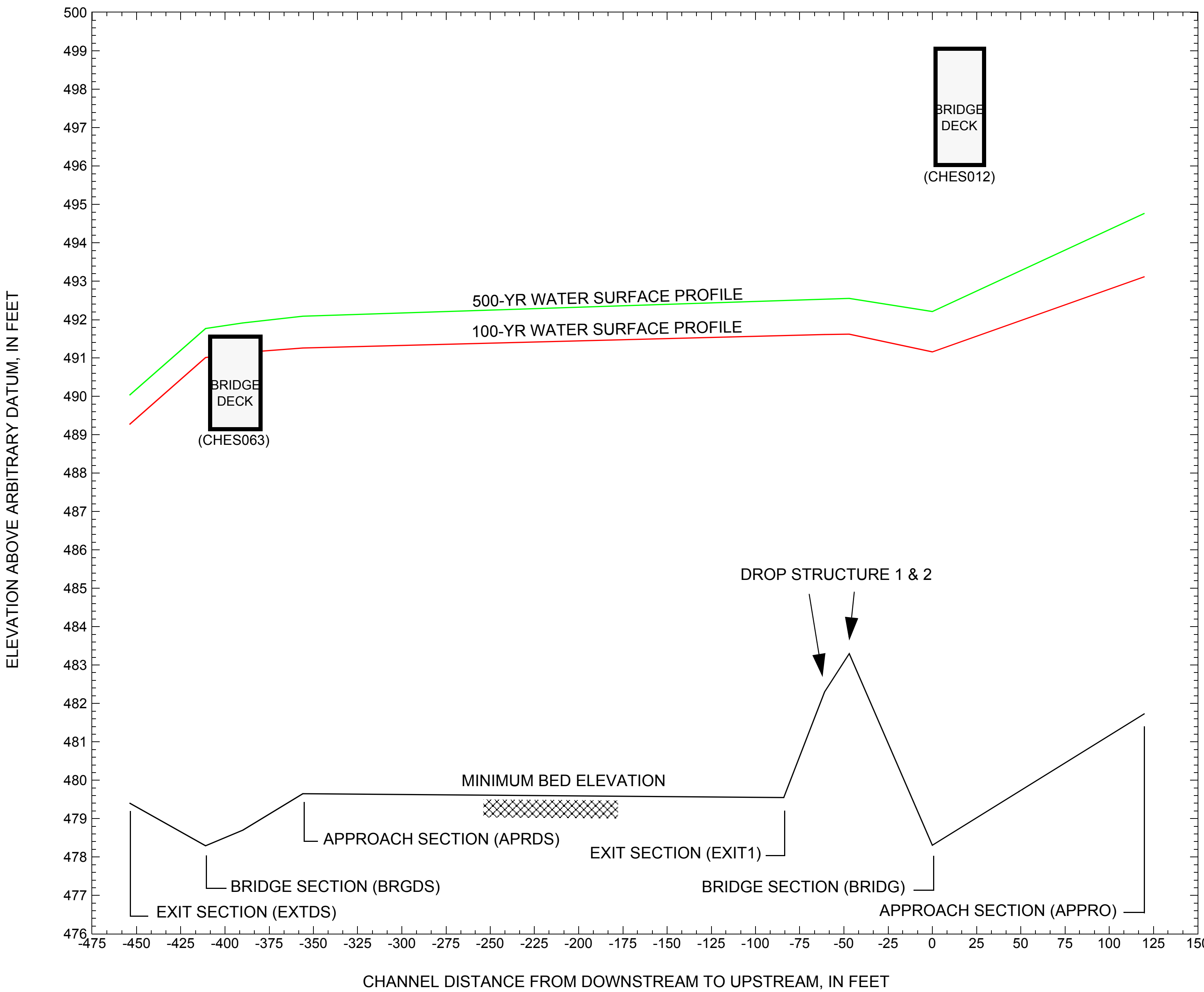


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CHESVT01030012 on State Route 103, crossing the Williams River, Chester, Vermont.

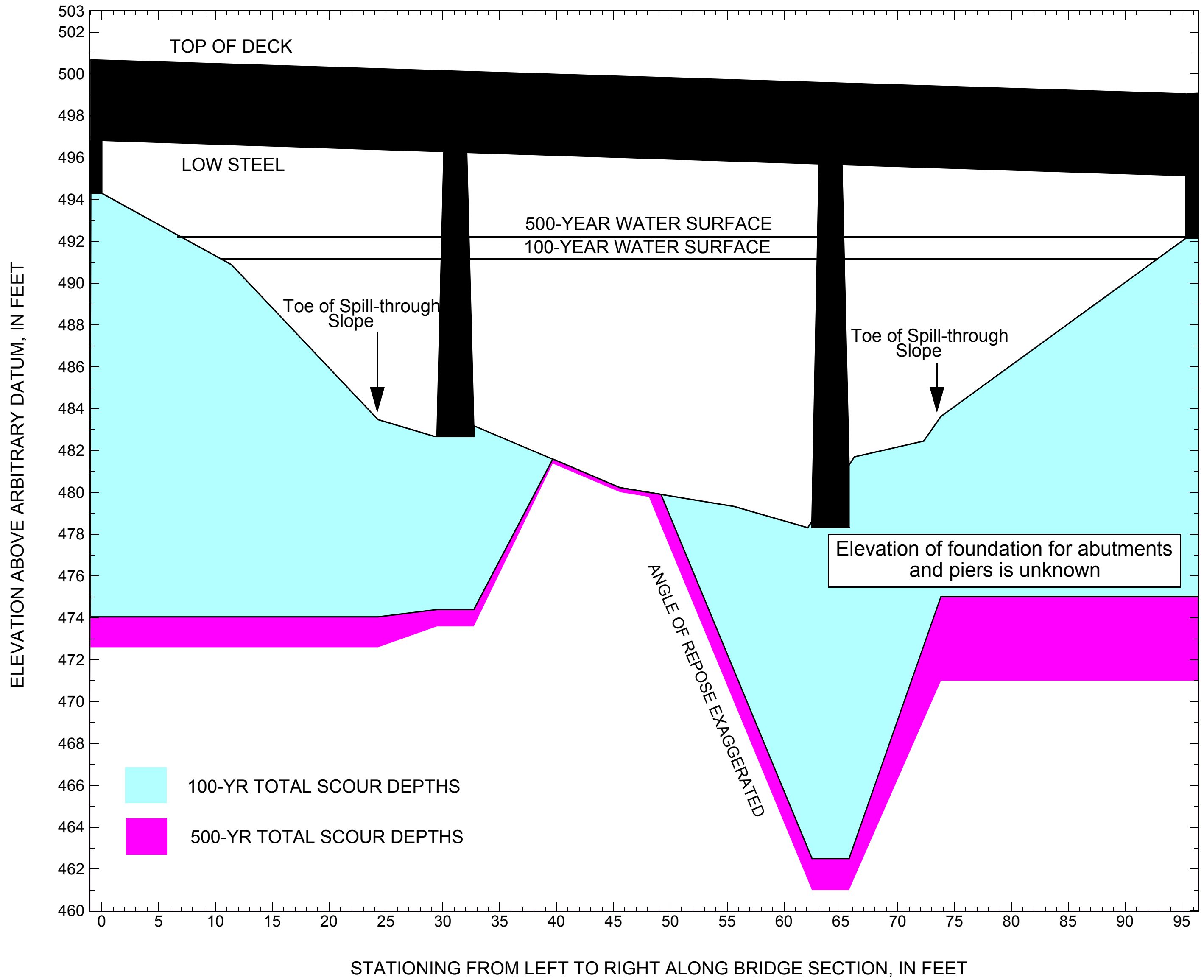


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CHESVT01030012 on State Route 103, crossing the Williams River, Chester, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CHESVT01030012 on State Route 103, crossing the Williams River, Chester, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing 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 5,200 cubic-feet per second											
Left abutment	0.0	-	496.8	-	494.3	0.0	-	--	-	-	-
Toe of LABUT	24.3	-	-	-	483.5	0.0	9.4	-	9.4	474.1	-
Pier 1	31.1	-	496.1	-	482.7	0.0	-	8.3	8.3	474.4	-
Pier 2	64.1	-	495.8	-	478.3	0.0	-	15.8	15.8	462.5	-
Toe of RABUT	73.8	-	-	-	483.6	0.0	8.6	-	8.6	475.0	-
Right abutment	95.4	-	495.1	-	492.2	0.0	-	--	-	-	-

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure CHESVT01030012 on State Route 103, crossing the Williams River, Chester, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing 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 7,620 cubic-feet per second											
Left abutment	0.0	-	496.8	-	494.3	0.2	-	--	-	-	-
Toe of LABUT	24.3	-	-	-	483.5	0.2	10.7	-	10.9	472.6	-
Pier 1	31.1	-	496.1	-	482.7	0.2	-	8.9	9.1	473.6	-
Pier 2	64.1	-	495.8	-	478.3	0.2	-	17.1	17.3	461.0	-
Toe of RABUT	73.8	-	-	-	483.6	0.2	12.4	-	12.6	471.0	-
Right abutment	95.4	-	495.1	-	492.2	0.2	-	--	-	-	-

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

SELECTED REFERENCES

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

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

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

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

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

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

Federal Emergency Management Agency, 1982, Flood Insurance Study, Town of Chester, Windsor County, Vermont: Washington, D.C., Febrary 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, 1972, Chester, 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 ches012.wsp
T2        Hydraulic analysis for structure CHESVT01030012   Date: 13-MAR-97
T3        Bridge #12 over the Williams River, Chester, Vt.   RHF
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
*           The following bridge is Bridge #63 just downstream of
*           the bridge of interest.
*
Q           5210.0   7640.0  3110
SK          0.0054   0.0054 0.0054
*
XS   EXTDS    -454           0.
GR         -229.7, 518.86   -223.3, 510.97    -83.2, 493.31    -47.4, 491.62
GR          -25.1, 491.35    -12.1, 488.58     -9.4, 485.22     -4.1, 482.05
GR            0.0, 480.81      2.8, 479.52     14.7, 479.73     15.8, 479.41
GR           19.7, 480.19     20.4, 480.82     23.2, 481.58
GR           28.3, 484.16     32.9, 485.94     43.2, 486.94    348.7, 487.75
GR          354.8, 489.33    395.2, 491.03    521.8, 494.81    683.6, 501.47
N           0.037        0.055        0.035
SA                 -25.1         43.2
*
XS   FLVDS   -411
*
BR   BRGDS   -411    489.05      0.0
GR            0.0, 489.19      1.8, 480.80      2.0, 478.55      6.4, 478.33
GR           11.0, 478.29     19.4, 479.18     25.0, 480.14     27.6, 480.83
GR           28.4, 481.80     32.4, 482.73     33.3, 488.91      0.0, 489.19
CD           1      28.9 * *     44.4      5.6
N           0.035
*
XR   RWYDS   -400      14.7     1
GR         -164.3, 501.81   -131.5, 498.29    -67.7, 493.28    -22.2, 491.89
GR           -4.9, 491.60      0.0, 491.70     32.1, 491.35     53.9, 490.74
GR          130.9, 488.88    257.9, 489.00    336.2, 490.45    368.2, 490.60
GR          391.2, 491.44    459.6, 493.89    556.1, 496.77    662.7, 501.59
*
XT   ATMDS    -351
GR         -196.9, 506.93   -185.0, 500.04   -163.1, 495.00    -50.1, 492.00
GR          -18.0, 490.51    -13.2, 489.02     -7.5, 484.98     -3.9, 482.64
GR            0.0, 480.85      0.8, 480.48      5.2, 479.67     13.5, 480.06
GR           23.9, 480.12     27.4, 480.86     30.4, 482.02     37.4, 484.82
GR           42.2, 487.07    287.4, 487.99    297.3, 492.23    432.3, 492.57
GR          642.4, 501.37
*
AS   APRDS    -356 * * * 0.0037
GT
N           0.042        0.045        0.032
SA                 -18.0         42.2
*
*            The following reach includes Bridge #12. Discharge is decreased
*            due to a slight change in the drainage area.
*
XS   EXIT1    -84
GR         -184.6, 513.04   -136.9, 496.94      0.0, 495.61      8.2, 494.69
GR           18.4, 485.69     33.4, 482.73     36.2, 481.16
GR           54.4, 480.63     62.5, 480.91     71.3, 481.48     76.4, 482.75
GR           87.8, 484.97    108.3, 486.57    118.1, 489.10    323.4, 488.13
GR          346.9, 489.78    487.2, 499.57
N           0.050        0.055        0.035
SA                 8.2         87.8
*
```

WSPRO INPUT FILE (continued)

```
Q             5200  7620   3050
*
XS   DROP2    -61
GR         -184.6, 513.04   -136.9, 496.94      0.0, 495.61      8.2, 494.69
GR           18.4, 485.69     33.4, 482.73     40.1, 482.36     50.2, 482.30
GR           51.0, 481.59     77.6, 482.59     87.8, 484.97    108.3, 486.57
GR          118.1, 489.10    323.4, 488.13    346.9, 489.78    487.2, 499.57
N           0.050        0.055        0.035
SA                8.2         87.8
*
XS   DROP1    -47
GR         -184.6, 513.04   -136.9, 496.94      0.0, 495.61      8.2, 494.69
GR           18.4, 485.69     33.4, 482.73     40.0, 482.99     60.7, 483.30
GR           82.7, 483.76     87.8, 484.97    108.3, 486.57    118.1, 489.10
GR          323.4, 488.13    346.9, 489.78    487.2, 499.57
N           0.050        0.055        0.035
SA                8.2         87.8
*
XS   FULLV      0
*
BR   BRIDG     0    495.98      0.0
GR            0.0, 496.82      0.3, 494.30     11.4, 490.89     24.3, 483.48
GR           29.3, 482.67     32.8, 483.17     45.6, 480.23     55.6, 479.33
GR           62.1, 478.31     66.2, 481.70     72.3, 482.45     73.8, 483.63
GR           95.2, 492.17     95.4, 495.14      0.0, 496.82
CD           3      33.4    1.39    499.1
N           0.055
*
PW          480.29, 3.25     483.20, 3.25     483.20, 6.50     495.81, 4.00
PW          496.13, 4.00     496.13, 2.00     496.82, 2.00     496.82, 0.00
*
XR   RDWAY     17      28.0     1
GR         -555.0, 501.88   -417.2, 503.64   -297.2, 504.83     -1.7, 499.96
GR           -1.5, 500.66      0.0, 500.65     91.1, 499.05     92.2, 498.96
GR           92.3, 498.23    203.4, 495.23    341.3, 490.85    371.9, 499.56
*
*
XT   APTEM    144           0.
GR          -17.0, 501.51     10.7, 491.29     14.5, 485.41     20.0, 483.78
GR           20.8, 482.59     24.0, 481.79     29.9, 482.31     49.2, 483.03
GR           51.7, 483.61     70.6, 486.63     87.4, 485.62    121.0, 487.04
GR          128.1, 489.64    136.6, 489.84    144.8, 492.47    157.2, 488.49
GR          180.3, 488.54    189.2, 492.88    195.0, 490.70    404.2, 490.06
GR          522.3, 498.83
*
AS   APPRO    120  * * *  0.002
GT
N           0.065        0.090     0.035
SA               70.6         195
*
HP 1 BRIDG  491.16 1 491.16
HP 2 BRIDG  491.16 * * 4887
HP 2 RDWAY  492.76 * * 313
HP 1 APPRO  493.12 1 493.12
HP 2 APPRO  493.12 * * 5200
*
HP 1 BRIDG  492.21 1 492.21
HP 2 BRIDG  492.21 * * 6374
HP 2 RDWAY  494.16 * * 1246
HP 1 APPRO  494.77 1 494.77
HP 2 APPRO  494.77 * * 7620
*
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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

        U.S. Geological Survey WSPRO Input File ches012.wsp
        Hydraulic analysis for structure CHESVT01030012   Date: 13-MAR-97
        Bridge #12 over the Williams River, Chester, Vt.   RHF
           *** RUN DATE & TIME: 03-28-97  11:24
    CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     620.  61826.    82.    88.                         9668.
   491.16          620.  61826.    82.    88.  1.00    11.    93.   9668.

    VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       491.16    10.5    92.7   620.1   61826.    4887.   7.88

X STA.        10.5        24.5        28.9        32.8        36.4        39.6
  A(I)            52.8        35.9        32.2        30.2        28.9
  V(I)            4.63        6.81        7.59        8.09        8.47

X STA.        39.6        42.3        44.9        47.2        49.4        51.6
  A(I)            27.4        26.5        25.3        25.1        24.7
  V(I)            8.93        9.21        9.65        9.75        9.89

X STA.        51.6        53.7        55.8        57.9        59.9        62.0
  A(I)            24.6        25.0        25.0        25.0        25.7
  V(I)            9.94        9.78        9.79        9.79        9.52

X STA.        62.0        64.4        67.5        71.0        76.0        92.7
  A(I)            28.6        31.3        31.7        38.8        55.6
  V(I)            8.53        7.80        7.71        6.29        4.40


    VELOCITY DISTRIBUTION:  ISEQ = 11;  SECID = RDWAY;  SRD =      17.
         WSEL     LEW     REW    AREA        K        Q    VEL
       492.76   281.2   348.0    63.8    2628.     313.   4.90

X STA.       281.2       302.2       308.6       313.1       316.6       319.6
  A(I)             7.1         4.9         4.3         3.7         3.5
  V(I)            2.22        3.21        3.63        4.21        4.48

X STA.       319.6       322.2       324.5       326.6       328.5       330.2
  A(I)             3.3         3.1         2.9         2.8         2.7
  V(I)            4.74        5.04        5.42        5.65        5.79

X STA.       330.2       331.9       333.4       334.8       336.2       337.5
  A(I)             2.6         2.5         2.4         2.3         2.4
  V(I)            6.06        6.25        6.47        6.73        6.62

X STA.       337.5       338.8       340.0       341.3       342.8       348.0
  A(I)             2.3         2.3         2.4         2.6         3.9
  V(I)            6.81        6.92        6.63        5.94        4.05


    CROSS-SECTION PROPERTIES:  ISEQ = 12;  SECID = APPRO;  SRD =     120.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     558.  51166.    65.    70.                         9285.
             2     599.  27814.   124.   127.                         7453.
             3     648.  51930.   251.   251.                         5911.
   493.12         1805. 130910.   440.   448.  1.20     6.   446.  18968.

    VELOCITY DISTRIBUTION:  ISEQ = 12;  SECID = APPRO;  SRD =     120.
         WSEL     LEW     REW    AREA        K        Q    VEL
       493.12     5.6   446.1  1805.3  130910.    5200.   2.88

X STA.         5.6        23.1        29.3        35.2        41.2        47.2
  A(I)           102.9        69.6        63.7        63.2        61.7
  V(I)            2.53        3.73        4.08        4.11        4.21

X STA.        47.2        53.7        61.7        73.9        89.2       105.0
  A(I)            64.2        68.8        86.1       109.9       112.6
  V(I)            4.05        3.78        3.02        2.37        2.31

X STA.       105.0       126.0       179.7       226.0       256.9       286.7
  A(I)           129.7       191.9       110.8        80.5        80.6
  V(I)            2.01        1.35        2.35        3.23        3.23

X STA.       286.7       314.5       341.3       366.9       392.8       446.1
  A(I)            77.7        77.0        75.6        78.4       100.4
  V(I)            3.35        3.38        3.44        3.31        2.59
```

```
       U.S. Geological Survey WSPRO Input File ches012.wsp
       Hydraulic analysis for structure CHESVT01030012   Date: 13-MAR-97
       Bridge #12 over the Williams River, Chester, Vt.   RHF
          *** RUN DATE & TIME: 03-28-97  11:24
   CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     710.  73875.    88.    94.                       11427.
  492.21          710.  73875.    88.    94.  1.00     7.    95.  11427.

   VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = BRIDG;  SRD =       0.
        WSEL     LEW     REW    AREA        K        Q    VEL
      492.21     7.1    95.2   709.6   73875.    6374.   8.98

X STA.         7.1       23.8       28.3       32.2       36.0       39.2
  A(I)            63.6       40.2       36.8       34.9       32.4
  V(I)            5.01       7.93       8.65       9.14       9.83

X STA.        39.2       42.1       44.7       47.1       49.4       51.7
  A(I)            31.9       29.7       28.9       28.6       28.2
  V(I)            9.99      10.72      11.02      11.15      11.31

X STA.        51.7       53.9       56.1       58.3       60.4       62.5
  A(I)            27.8       28.3       28.3       28.2       29.6
  V(I)           11.46      11.28      11.28      11.30      10.76

X STA.        62.5       65.2       68.5       72.2       77.4       95.2
  A(I)            33.4       34.5       36.7       43.2       64.2
  V(I)            9.53       9.23       8.67       7.37       4.97


   VELOCITY DISTRIBUTION:  ISEQ = 11;  SECID = RDWAY;  SRD =      17.
        WSEL     LEW     REW    AREA        K        Q    VEL
      494.16   237.1   352.9   191.7   11386.    1246.   6.50

X STA.       237.1      273.6      284.6      292.5      298.5      303.7
  A(I)            21.2       14.7       12.9       11.2       10.5
  V(I)            2.94       4.25       4.82       5.59       5.94

X STA.       303.7      308.2      312.2      315.8      319.0      322.1
  A(I)             9.9        9.3        8.7        8.3        8.1
  V(I)            6.28       6.68       7.19       7.49       7.67

X STA.       322.1      324.9      327.6      330.1      332.4      334.7
  A(I)             7.8        7.5        7.3        7.0        7.1
  V(I)            8.03       8.28       8.58       8.92       8.77

X STA.       334.7      336.9      339.1      341.2      343.9      352.9
  A(I)             6.9        6.8        7.1        7.9       11.6
  V(I)            9.02       9.18       8.79       7.87       5.37


   CROSS-SECTION PROPERTIES:  ISEQ = 12;  SECID = APPRO;  SRD =     120.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1     669.  66227.    69.    75.                       11787.
            2     804.  45461.   124.   127.                       11597.
            3    1081. 115030.   273.   273.                       12198.
  494.77         2554. 226719.   467.   475.  1.17     1.   468.  31280.

   VELOCITY DISTRIBUTION:  ISEQ = 12;  SECID = APPRO;  SRD =     120.
        WSEL     LEW     REW    AREA        K        Q    VEL
      494.77     1.1   468.3  2554.0  226719.    7620.   2.98

X STA.         1.1       25.1       33.5       41.8       50.0       59.9
  A(I)           161.1      106.8      100.5       98.5      105.6
  V(I)            2.36       3.57       3.79       3.87       3.61

X STA.        59.9       74.0       92.3      112.2      156.8      198.7
  A(I)           124.9      162.1      171.0      240.4      217.4
  V(I)            3.05       2.35       2.23       1.58       1.75

X STA.       198.7      223.2      247.7      270.7      293.8      316.3
  A(I)           102.1      103.9       99.6      101.0      100.3
  V(I)            3.73       3.67       3.83       3.77       3.80

X STA.       316.3      338.1      360.1      381.6      404.0      468.3
  A(I)            98.5      101.3       99.8      106.1      153.2
  V(I)            3.87       3.76       3.82       3.59       2.49
```

```
        U.S. Geological Survey WSPRO Input File ches012.wsp
        Hydraulic analysis for structure CHESVT01030012   Date: 13-MAR-97
        Bridge #12 over the Williams River, Chester, Vt.   RHF
           *** RUN DATE & TIME: 03-28-97  11:24
    CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     552.  52711.    78.    83.                         8329.
   490.31          552.  52711.    78.    83.  1.00    12.    91.   8329.

    VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       490.31    12.4    90.5   552.1   52711.    3050.   5.52

X STA.        12.4       25.1       29.4       33.4       37.0       40.0
  A(I)             46.4       31.1       29.5       27.4       25.7
  V(I)             3.29       4.91       5.18       5.56       5.93

X STA.        40.0       42.7       45.1       47.4       49.5       51.7
  A(I)             24.5       23.8       22.7       22.1       22.5
  V(I)             6.23       6.41       6.71       6.90       6.77

X STA.        51.7       53.7       55.7       57.7       59.7       61.6
  A(I)             21.9       22.2       22.2       22.3       22.9
  V(I)             6.97       6.86       6.86       6.85       6.66

X STA.        61.6       63.8       66.8       70.2       74.7       90.5
  A(I)             25.0       27.7       29.0       33.5       49.8
  V(I)             6.11       5.50       5.26       4.55       3.06


    CROSS-SECTION PROPERTIES:  ISEQ = 12;  SECID = APPRO;  SRD =     120.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     441.  36436.    60.    64.                         6788.
             2     375.  13948.   110.   111.                         3940.
             3     200.   7860.   226.   226.                         1069.
   491.24         1016.  58244.   395.   402.  1.46    11.   421.   7640.

    VELOCITY DISTRIBUTION:  ISEQ = 12;  SECID = APPRO;  SRD =     120.
         WSEL     LEW     REW    AREA        K        Q    VEL
       491.24    10.7   420.7  1016.1   58244.    3050.   3.00

X STA.        10.7       20.5       24.6       28.1       31.5       35.0
  A(I)             52.2       37.0       32.1       31.2       31.2
  V(I)             2.92       4.12       4.75       4.89       4.88

X STA.        35.0       38.6       42.2       45.9       49.8       54.1
  A(I)             31.2       31.2       31.3       31.7       33.2
  V(I)             4.90       4.90       4.87       4.81       4.59

X STA.        54.1       59.3       66.1       77.0       88.6      100.6
  A(I)             36.1       39.9       53.7       62.4       64.3
  V(I)             4.23       3.82       2.84       2.44       2.37

X STA.       100.6      115.4      170.4      279.7      354.9      420.7
  A(I)             71.3      110.6       96.2       72.3       67.0
  V(I)             2.14       1.38       1.58       2.11       2.28
```

```
   *  HP records below are for upstream conditions using
   *  Q100, Q500 and incipient WSEL @ Bridge plus value of Ho at Appro.
   *
     CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1     642.   64672.    84.    89.                      10085.
    491.42          642.   64672.    84.    89.  1.00    10.    93.  10085.

     VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = BRIDG;  SRD =       0.
          WSEL     LEW     REW    AREA        K        Q    VEL
        491.42     9.7    93.3   641.7   64672.    4887.   7.62

 X STA.         9.7       24.4       28.8       32.7       36.3       39.4
   A(I)             56.1       36.2       33.5       31.3       29.3
   V(I)             4.36       6.75       7.29       7.81       8.35

 X STA.        39.4       42.3       44.8       47.2       49.4       51.6
   A(I)             28.9       27.4       26.1       25.8       25.5
   V(I)             8.47       8.93       9.35       9.46       9.59

 X STA.        51.6       53.8       55.9       58.0       60.1       62.1
   A(I)             25.4       25.8       25.8       25.8       26.5
   V(I)             9.62       9.47       9.47       9.47       9.22

 X STA.        62.1       64.6       67.8       71.4       76.4       93.3
   A(I)             30.0       32.3       33.0       39.9       57.3
   V(I)             8.15       7.57       7.41       6.12       4.27


     CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1     735.   77685.    89.    95.                      11988.
    492.50          735.   77685.    89.    95.  1.00     6.    95.  11988.

     VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = BRIDG;  SRD =       0.
          WSEL     LEW     REW    AREA        K        Q    VEL
        492.50     6.2    95.2   735.3   77685.    6374.   8.67

 X STA.         6.2       23.6       28.2       32.1       35.9       39.1
   A(I)             66.8       42.8       37.3       36.3       33.6
   V(I)             4.77       7.45       8.54       8.79       9.48

 X STA.        39.1       42.1       44.7       47.1       49.5       51.8
   A(I)             33.0       31.2       29.8       29.4       29.0
   V(I)             9.65      10.21      10.71      10.84      11.00

 X STA.        51.8       54.0       56.2       58.4       60.5       62.7
   A(I)             29.3       28.9       29.3       29.3       30.6
   V(I)            10.87      11.04      10.87      10.89      10.41

 X STA.        62.7       65.5       68.9       72.5       77.9       95.2
   A(I)             34.9       35.8       37.3       45.3       65.3
   V(I)             9.12       8.91       8.54       7.04       4.88


     CROSS-SECTION PROPERTIES:  ISEQ = 10;  SECID = BRIDG;  SRD =       0.

      WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
              1     564.   54291.    79.    84.                       8562.
    490.46          564.   54291.    79.    84.  1.00    12.    91.   8562.

     VELOCITY DISTRIBUTION:  ISEQ = 10;  SECID = BRIDG;  SRD =       0.
          WSEL     LEW     REW    AREA        K        Q    VEL
        490.46    12.1    90.9   563.9   54291.    3050.   5.41

 X STA.        12.1       25.1       29.3       33.3       36.9       39.9
   A(I)             48.1       30.9       30.3       28.0       25.7
   V(I)             3.17       4.94       5.04       5.44       5.93

 X STA.        39.9       42.6       45.1       47.3       49.5       51.6
   A(I)             25.5       24.2       23.1       22.5       23.0
   V(I)             5.98       6.29       6.59       6.77       6.64

 X STA.        51.6       53.7       55.8       57.8       59.7       61.7
   A(I)             22.3       22.7       22.7       22.7       23.3
   V(I)             6.84       6.73       6.73       6.72       6.54

 X STA.        61.7       63.9       66.9       70.4       75.0       90.9
   A(I)             26.0       28.2       29.8       34.2       50.8
   V(I)             5.87       5.41       5.13       4.46       3.00
```

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

        U.S. Geological Survey WSPRO Input File ches012.wsp
        Hydraulic analysis for structure CHESVT01030012   Date: 13-MAR-97
        Bridge #12 over the Williams River, Chester, Vt.   RHF
           *** RUN DATE & TIME: 03-28-97  11:24

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

EXTDS:XS   ******   -15.     959.  0.49 *****  489.76  488.76   5210.  489.27
     -454. ******   355.   70897.  1.07 ***** *******    0.61    5.43

FLVDS:FV      43.   -17.    1072.  0.38  0.20  489.95 *******   5210.  489.57
     -411.    43.   361.   83270.  1.04  0.00    0.00    0.52    4.86
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APRDS:AS      55.   -15.     958.  0.52  0.20  490.22 *******   5210.  489.69
     -356.    55.   291.   91729.  1.14  0.07    0.00    0.58    5.44
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =   489.57     489.05

            <<<<<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

BRGDS:BR      43.     0.     303.  1.14 *****  490.33  485.53   2591.  489.19
     -411. ******    33.   30937.  1.00 ***** *******    0.50    8.55

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  489.05 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RWYDS:RG    -400.    40.  0.04  0.21  491.43    0.01   2654.  491.01

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     0.    77.   -62.    15.   1.6   1.0   6.3   7.8   1.9   3.1
   RT:  2654.   335.    44.   379.   2.1   1.4   6.5   5.6   1.8   3.2

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

APRDS:AS      26.   -35.    1452.  0.21  0.12  491.47  488.98   5210.  491.26
     -356.    44.   295.  171391.  1.03  0.00    0.01    0.31    3.59

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

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

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

EXIT1:XS     272.    12.    1514.  0.19  0.29  491.77 *******   5200.  491.57
      -84.   272.   373.  149136.  1.04  0.00    0.01    0.30    3.43

DROP2:XS      23.    12.    1482.  0.20  0.03  491.80 *******   5200.  491.61
      -61.    23.   373.  143059.  1.03  0.00    0.00    0.31    3.51
1
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V090192             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ches012.wsp
        Hydraulic analysis for structure CHESVT01030012   Date: 13-MAR-97
        Bridge #12 over the Williams River, Chester, Vt.   RHF
           *** RUN DATE & TIME: 03-28-97  11:24

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

DROP1:XS      14.    12.    1442.  0.21  0.02  491.83 *******   5200.  491.62
      -47.    14.   373.  135960.  1.02  0.00    0.00    0.32    3.61

FULLV:FV      47.    12.    1404.  0.22  0.07  491.91 *******   5200.  491.69
        0.    47.   372.  130637.  1.02  0.01    0.00    0.33    3.70
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              "APPRO"     KRATIO =  0.62

APPRO:AS     120.     9.    1299.  0.33  0.31  492.27 *******   5200.  491.94
      120.   120.   430.   80429.  1.31  0.05   -0.01    0.46    4.00
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>
```

```
 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
          WS1,WSSD,WS3,RGMIN =   493.28       0.00     490.99     490.85
 ===260 ATTEMPTING FLOW CLASS 4 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      47.    11.     620.  1.49  0.15  492.66  488.29   4887.  491.16
        0.    47.    93.   61868.  1.55  0.68    0.00    0.63    7.88

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   4.  0.804  0.089  495.98 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      17.    92.  0.14  0.15  493.14    0.00    313.  492.76

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
    LT:     0. ****** ****** ****** ***** ***** ***** ***** ***** *****
   RT:    313.    67.   281.   348.   1.9   1.0   5.3   4.9   1.3   3.0

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

APPRO:AS      87.     6.    1807.  0.15  0.36  493.28  489.57   5200.  493.12
      120.   111.   446.  131102.  1.20  0.26    0.00    0.27    2.88

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.798  0.547   59505.    26.   108. ********

                    <<<<<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 ches012.wsp
        Hydraulic analysis for structure CHESVT01030012   Date: 13-MAR-97
        Bridge #12 over the Williams River, Chester, Vt.   RHF
           *** RUN DATE & TIME: 03-28-97  11:24
   FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXTDS:XS    -454.   -15.   355.   5210.   70897.     959.    5.43  489.27
   FLVDS:FV    -411.   -17.   361.   5210.   83270.    1072.    4.86  489.57
   BRGDS:BR    -411.     0.    33.   2591.   30937.     303.    8.55  489.19
   RWYDS:RG    -400.*******     0.   2654.       0.*********    1.00  491.01
   APRDS:AS    -356.   -35.   295.   5210.  171391.    1452.    3.59  491.26

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

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -84.    12.   373.   5200.  149136.    1514.    3.43  491.57
   DROP2:XS     -61.    12.   373.   5200.  143059.    1482.    3.51  491.61
   DROP1:XS     -47.    12.   373.   5200.  135960.    1442.    3.61  491.62
   FULLV:FV       0.    12.   372.   5200.  130637.    1404.    3.70  491.69
   BRIDG:BR       0.    11.    93.   4887.   61868.     620.    7.88  491.16
   RDWAY:RG      17.*******     0.    313.       0.*********    1.00  492.76
   APPRO:AS     120.     6.   446.   5200.  131102.    1807.    2.88  493.12

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      26.   108.   59505.

 SECOND USER DEFINED TABLE.
    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXTDS:XS    488.76    0.61  479.41  518.86************  0.49  489.76  489.27
   FLVDS:FV  ********    0.52  479.41  518.86  0.20  0.00  0.38  489.95  489.57
   BRGDS:BR    485.53    0.50  478.29  489.19************  1.14  490.33  489.19
   RWYDS:RG  ****************  488.88  501.81  0.04******  0.21  491.43  491.01
   APRDS:AS    488.98    0.31  479.65  506.91  0.12  0.00  0.21  491.47  491.26
   EXIT1:XS  ********    0.30  480.63  513.04  0.29  0.00  0.19  491.77  491.57
   DROP2:XS  ********    0.31  481.59  513.04  0.03  0.00  0.20  491.80  491.61
   DROP1:XS  ********    0.32  482.73  513.04  0.02  0.00  0.21  491.83  491.62
   FULLV:FV  ********    0.33  482.90  513.21  0.07  0.01  0.22  491.91  491.69
   BRIDG:BR    488.29    0.63  478.31  496.82  0.15  0.68  1.49  492.66  491.16
   RDWAY:RG  ****************  490.85  504.83  0.14******  0.15  493.14  492.76
   APPRO:AS    489.57    0.27  481.74  501.46  0.36  0.26  0.15  493.28  493.12
```

```
        U.S. Geological Survey WSPRO Input File ches012.wsp
        Hydraulic analysis for structure CHESVT01030012   Date: 13-MAR-97
        Bridge #12 over the Williams River, Chester, Vt.   RHF
           *** RUN DATE & TIME: 03-28-97  11:24

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

EXTDS:XS   ******   -19.    1247.  0.59 *****  490.62  489.23   7640.  490.03
     -454. ******   371.  103894.  1.01 ***** *******    0.61    6.12

FLVDS:FV      43.   -20.    1370.  0.49  0.20  490.82 *******   7640.  490.34
     -411.    43.   379.  119272.  1.01  0.00    0.00    0.53    5.58
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APRDS:AS      55.   -18.    1194.  0.67  0.21  491.13 *******   7640.  490.46
     -356.    55.   293.  126554.  1.05  0.09    0.00    0.59    6.40
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                       WS3N,LSEL =   490.34     489.05

            <<<<<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

BRGDS:BR      43.     0.     303.  1.20 *****  490.39  485.66   2665.  489.19
     -411. ******    33.   30937.  1.00 ***** *******    0.51    8.80

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.089  489.05 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RWYDS:RG    -400.    40.  0.05  0.31  492.35    0.00   4994.  491.77

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     54.    30.   -15.    15.   0.2   0.1   3.8  14.2   0.7   3.0
   RT:   4940.   385.    15.   400.   2.9   1.9   7.6   6.6   2.5   3.2

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

APRDS:AS      26.   -54.    1731.  0.31  0.18  492.40  489.57   7640.  492.09
     -356.    48.   297.  223908.  1.03  0.26    0.00    0.36    4.41

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

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

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

EXIT1:XS     272.    11.    1849.  0.27  0.35  492.75 *******   7620.  492.48
      -84.   272.   386.  200985.  1.02  0.00    0.00    0.33    4.12

DROP2:XS      23.    11.    1820.  0.27  0.03  492.80 *******   7620.  492.52
      -61.    23.   386.  195129.  1.01  0.00    0.01    0.34    4.19

        U.S. Geological Survey WSPRO Input File ches012.wsp
        Hydraulic analysis for structure CHESVT01030012   Date: 13-MAR-97
        Bridge #12 over the Williams River, Chester, Vt.   RHF
           *** RUN DATE & TIME: 03-28-97  11:24

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

DROP1:XS      14.    11.    1781.  0.29  0.02  492.83 *******   7620.  492.55
      -47.    14.   387.  187922.  1.00  0.01    0.01    0.35    4.28

FULLV:FV      47.    11.    1746.  0.30  0.08  492.92 *******   7620.  492.63
        0.    47.   385.  182286.  1.00  0.01    0.01    0.36    4.36
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPRO"     KRATIO =  0.66

APPRO:AS     120.     6.    1710.  0.37  0.32  493.28 *******   7620.  492.90
      120.   120.   443.  120294.  1.21  0.04    0.00    0.44    4.46
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   495.60       0.00     491.42     490.85
```

```
 ===260 ATTEMPTING FLOW CLASS 4 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      47.     7.     710.  1.93  0.24  494.14  489.51   6374.  492.21
        0.    47.    95.   73874.  1.53  1.07    0.00    0.69    8.98

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3.   0.   4.  0.807  0.085  495.98 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      17.    92.  0.10  0.16  494.83    0.00   1246.  494.16

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0. ****** ****** ****** ***** ***** ***** ***** ***** *****
   RT:   1246.   116.   237.   353.   3.3   1.7   6.9   6.5   2.3   3.0

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

APPRO:AS      87.     1.    2554.  0.16  0.50  494.93  491.41   7620.  494.77
      120.   121.   468.  226701.  1.17  0.29   -0.01    0.24    2.98

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.795  0.773   51636.    53.   141. ********

                     <<<<<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 ches012.wsp
        Hydraulic analysis for structure CHESVT01030012   Date: 13-MAR-97
        Bridge #12 over the Williams River, Chester, Vt.   RHF
           *** RUN DATE & TIME: 03-28-97  11:24
  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXTDS:XS    -454.   -19.   371.   7640.  103894.    1247.    6.12  490.03
   FLVDS:FV    -411.   -20.   379.   7640.  119272.    1370.    5.58  490.34
   BRGDS:BR    -411.     0.    33.   2665.   30937.     303.    8.80  489.19
   RWYDS:RG    -400.*******    54.   4994.        0.*********    1.00  491.77
   APRDS:AS    -356.   -54.   297.   7640.  223908.    1731.    4.41  492.09

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

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -84.    11.   386.   7620.  200985.    1849.    4.12  492.48
   DROP2:XS     -61.    11.   386.   7620.  195129.    1820.    4.19  492.52
   DROP1:XS     -47.    11.   387.   7620.  187922.    1781.    4.28  492.55
   FULLV:FV       0.    11.   385.   7620.  182286.    1746.    4.36  492.63
   BRIDG:BR       0.     7.    95.   6374.   73874.     710.    8.98  492.21
   RDWAY:RG      17.*******     0.   1246.        0.*********    1.00  494.16
   APPRO:AS     120.     1.   468.   7620.  226701.    2554.    2.98  494.77

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      53.   141.   51636.
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ches012.wsp
        Hydraulic analysis for structure CHESVT01030012   Date: 13-MAR-97
        Bridge #12 over the Williams River, Chester, Vt.   RHF
           *** RUN DATE & TIME: 03-28-97  11:24
 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXTDS:XS    489.23    0.61  479.41  518.86************  0.59  490.62  490.03
   FLVDS:FV  ********    0.53  479.41  518.86  0.20  0.00  0.49  490.82  490.34
   BRGDS:BR    485.66    0.51  478.29  489.19************  1.20  490.39  489.19
   RWYDS:RG  ****************  488.88  501.81  0.05******  0.31  492.35  491.77
   APRDS:AS    489.57    0.36  479.65  506.91  0.18  0.26  0.31  492.40  492.09
   EXIT1:XS  ********    0.33  480.63  513.04  0.35  0.00  0.27  492.75  492.48
   DROP2:XS  ********    0.34  481.59  513.04  0.03  0.00  0.27  492.80  492.52
   DROP1:XS  ********    0.35  482.73  513.04  0.02  0.01  0.29  492.83  492.55
   FULLV:FV  ********    0.36  482.90  513.21  0.08  0.01  0.30  492.92  492.63
   BRIDG:BR    489.51    0.69  478.31  496.82  0.24  1.07  1.93  494.14  492.21
   RDWAY:RG  ****************  490.85  504.83  0.10******  0.16  494.83  494.16
   APPRO:AS    491.41    0.24  481.74  501.46  0.50  0.29  0.16  494.93  494.77
```

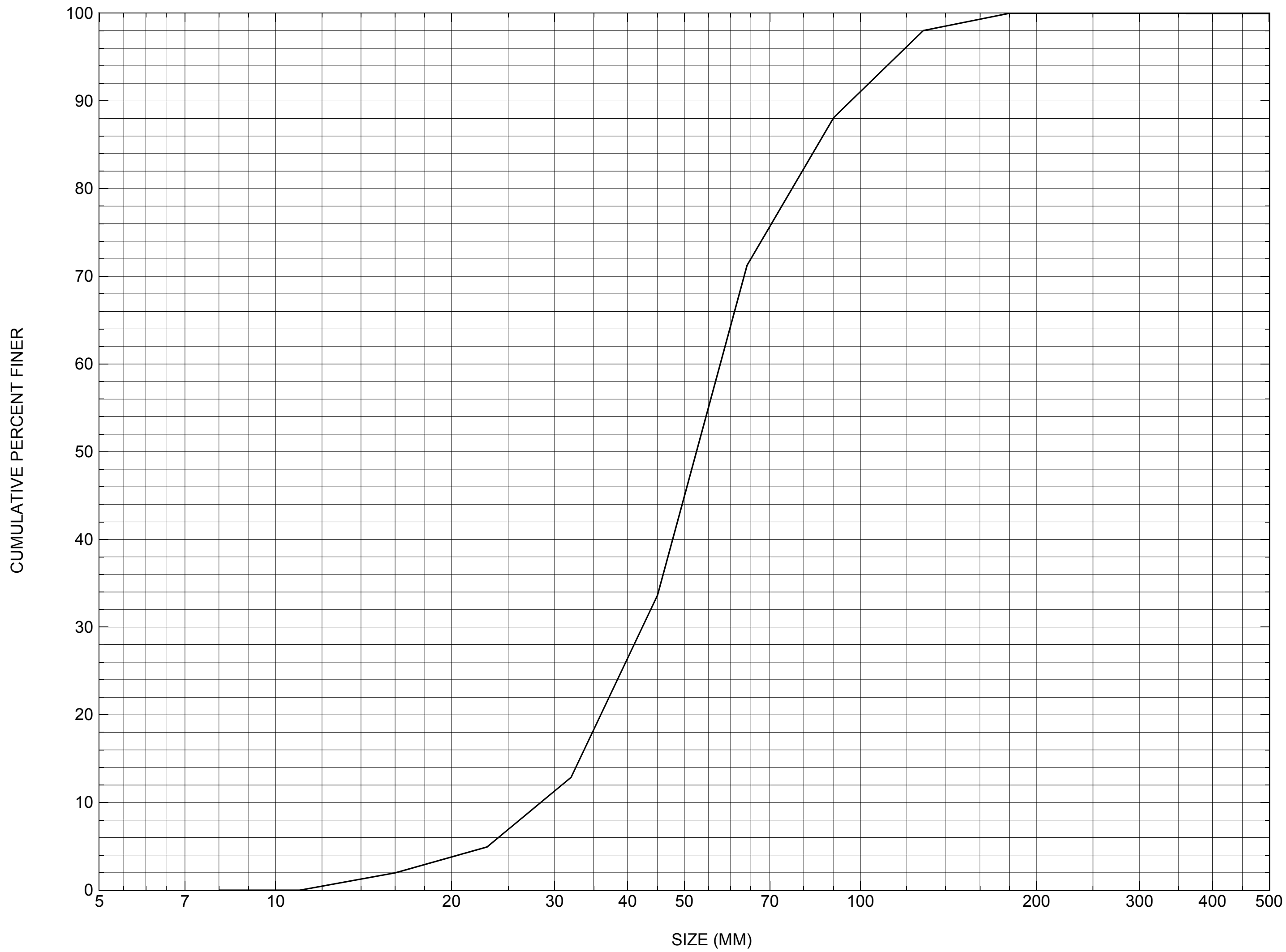
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File ches012.wsp
        Hydraulic analysis for structure CHESVT01030012   Date: 13-MAR-97
        Bridge #12 over the Williams River, Chester, Vt.   RHF
           *** RUN DATE & TIME: 03-28-97  11:24

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

EXTDS:XS   ******   -12.     662.  0.43 *****  488.89  488.19   3110.  488.46
     -454. ******   351.   42291.  1.26 ***** *******    0.69    4.70

FLVDS:FV      43.   -13.     776.  0.29  0.19  489.06 *******   3110.  488.77
     -411.    43.   353.   52355.  1.17  0.00   -0.02    0.52    4.01
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

APRDS:AS      55.   -13.     712.  0.39  0.16  489.28 *******   3110.  488.89
     -356.    55.   290.   61728.  1.31  0.05    0.00    0.57    4.37
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   490.15       0.00     487.73     488.88

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   488.22     489.71     489.80     489.05

 ===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

BRGDS:BR      43.     0.     303.  0.87 *****  490.06  485.04   2272.  489.19
     -411. ******    33.   30937.  1.00 ***** *******    0.44    7.50

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.390  0.085  489.05 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RWYDS:RG    -400.    40.  0.03  0.13  490.30    0.00    843.  490.06

             Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.    66.   -51.    15.   1.2   0.8   5.8   7.6   1.6   3.1
   RT:    843.   234.    82.   315.   1.2   0.9   4.9   4.2   1.1   3.1

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

APRDS:AS      26.   -17.    1114.  0.13  0.08  490.33  486.55   3110.  490.20
     -356.    38.   293.  114205.  1.08  0.14    0.00    0.27    2.79

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

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

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

EXIT1:XS     272.    13.    1116.  0.13  0.23  490.57 *******   3050.  490.44
      -84.   272.   356.   96221.  1.13  0.00    0.01    0.28    2.73

DROP2:XS      23.    13.    1081.  0.14  0.02  490.60 *******   3050.  490.47
      -61.    23.   357.   90079.  1.10  0.00    0.00    0.29    2.82

        U.S. Geological Survey WSPRO Input File ches012.wsp
        Hydraulic analysis for structure CHESVT01030012   Date: 13-MAR-97
        Bridge #12 over the Williams River, Chester, Vt.   RHF
           *** RUN DATE & TIME: 03-28-97  11:24

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

DROP1:XS      14.    13.    1039.  0.14  0.02  490.63 *******   3050.  490.48
      -47.    14.   357.   83237.  1.08  0.00    0.00    0.31    2.94

FULLV:FV      47.    13.    1001.  0.16  0.07  490.70 *******   3050.  490.54
        0.    47.   355.   78793.  1.09  0.01    0.00    0.33    3.05
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                              “APPRO”     KRATIO =  0.59
```

```
 APPRO:AS     120.    11.     831.  0.32  0.31  491.09 *******   3050.  490.77
       120.   120.   414.   46424.  1.54  0.08    0.00    0.54    3.67
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

  ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
            WS1,WSSD,WS3,RGMIN =   491.24       0.00     490.31     490.85

  ===260 ATTEMPTING FLOW CLASS 4 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      47.    12.     552.  0.63  0.13  490.93  486.46   3050.  490.31
         0.    47.    91.   52690.  1.32  0.18   -0.01    0.42    5.53

      TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
        3.   0.   4.  0.872  0.092  495.98 ****** ****** ******

     XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
    RDWAY:RG      17.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

 APPRO:AS      87.    11.    1018.  0.20  0.37  491.45  488.03   3050.  491.24
       120.    94.   421.   58364.  1.46  0.15    0.01    0.40    3.00

        M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
       0.804  0.298   40776.    10.    88. ********

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

         U.S. Geological Survey WSPRO Input File ches012.wsp
         Hydraulic analysis for structure CHESVT01030012   Date: 13-MAR-97
         Bridge #12 over the Williams River, Chester, Vt.   RHF
            *** RUN DATE & TIME: 03-28-97  11:24
   FIRST USER DEFINED TABLE.

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXTDS:XS    -454.   -12.   351.   3110.   42291.     662.    4.70  488.46
    FLVDS:FV    -411.   -13.   353.   3110.   52355.     776.    4.01  488.77
    BRGDS:BR    -411.     0.    33.   2272.   30937.     303.    7.50  489.19
    RWYDS:RG    -400.*******     0.    843.       0.*********    1.00  490.06
    APRDS:AS    -356.   -17.   293.   3110.  114205.    1114.    2.79  490.20

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

     XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
    EXIT1:XS     -84.    13.   356.   3050.   96221.    1116.    2.73  490.44
    DROP2:XS     -61.    13.   357.   3050.   90079.    1081.    2.82  490.47
    DROP1:XS     -47.    13.   357.   3050.   83237.    1039.    2.94  490.48
    FULLV:FV       0.    13.   355.   3050.   78793.    1001.    3.05  490.54
    BRIDG:BR       0.    12.    91.   3050.   52690.     552.    5.53  490.31
    RDWAY:RG      17.**************      0.       0.       0.    1.00********
    APPRO:AS     120.    11.   421.   3050.   58364.    1018.    3.00  491.24

     XSID:CODE   XLKQ   XRKQ       KQ
    APPRO:AS      10.    88.   40776.
1
 WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
 V090192           MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

         U.S. Geological Survey WSPRO Input File ches012.wsp
         Hydraulic analysis for structure CHESVT01030012   Date: 13-MAR-97
         Bridge #12 over the Williams River, Chester, Vt.   RHF
            *** RUN DATE & TIME: 03-28-97  11:24
  SECOND USER DEFINED TABLE.

     XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL     WSEL
    EXTDS:XS    488.19    0.69  479.41  518.86************  0.43  488.89  488.46
    FLVDS:FV  ********    0.52  479.41  518.86  0.19  0.00  0.29  489.06  488.77
    BRGDS:BR    485.04    0.44  478.29  489.19************  0.87  490.06  489.19
    RWYDS:RG  ****************  488.88  501.81  0.03******  0.13  490.30  490.06
    APRDS:AS    486.55    0.27  479.65  506.91  0.08  0.14  0.13  490.33  490.20
    EXIT1:XS  ********    0.28  480.63  513.04  0.23  0.00  0.13  490.57  490.44
    DROP2:XS  ********    0.29  481.59  513.04  0.02  0.00  0.14  490.60  490.47
    DROP1:XS  ********    0.31  482.73  513.04  0.02  0.00  0.14  490.63  490.48
    FULLV:FV  ********    0.33  482.90  513.21  0.07  0.01  0.16  490.70  490.54
    BRIDG:BR    486.46    0.42  478.31  496.82  0.13  0.18  0.63  490.93  490.31
    RDWAY:RG  ****************  490.85  504.83  0.25******  0.20  491.20********
    APPRO:AS    488.03    0.40  481.74  501.46  0.37  0.15  0.20  491.45  491.24
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CHESVT01030012, in Chester, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CHESVT01030012

General Location Descriptive

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

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)* 13600

Mile marker *(I - 11; nnn.nnn)* 003830

Waterway *(I - 6)* WILLIAMS RIVER

Road Name *(I - 7):* -

Route Number VT103

Vicinity *(I - 9)* 0.8 MI N JCT. VT.11 W

Topographic Map Chester

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43163

Longitude *(i - 17; nnnnn.n)* 72354

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20002500121407

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

Maximum span length *(I - 48; nnnn)* 0031

Year built *(I - 27; YYYY)* 1931

Structure length *(I - 49; nnnnnn)* 000099

Average daily traffic, ADT *(I - 29; nnnnnn)* 003443

Deck Width *(I - 52; nn.n)* 280

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

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

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

Waterway adequacy *(I - 71; n)* 4

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 87.0

Number of spans *(I - 45; nnn)* 003

Vertical clearance from streambed (*nnn.n ft*) 13.5

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

Waterway of full opening (*nnn.n* ft^2) 680.0

Comments:

The structural inspection report of 11/18/93 indicates the structure is a three span, concrete T-beam type bridge. The report refers to a proposal to repair or replace the existing bridge. The latest memorandum for action is dated 03/08/94. The wingwalls are short extensions of the abutment walls. Both piers are solid concrete and have some spalling at their ends. There is some minor reinforcement bar exposed in a few locations. The footings are not in view. The water is noted as quite deep along pier 1 on the north side. The waterway makes a sharp turn into the structure. The streambed consists of sand and gravel. The banks in front of the abutments are well protected with stone fill. **(Continued, page 38)**

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: **27.0**

Terrain character: -

Stream character & type: -

Streambed material: **SAND AND GRAVEL**

Discharge Data *(cfs)*: $Q_{2.33}$ **1200** Q_{10} **3000** Q_{25} **4000**

Q_{50} **4800** Q_{100} **5600** 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: **Downstream is a dam and grist mill.**

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*)	**586.6**	**589.5**	**590.7**	**591.6**	**593.5**
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -

Is the roadway overtopped below the Q_{100}? (*Yes, No, Unknown*): **Y** Frequency: **Q10**

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

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

Upstream distance (*miles*): **3000'** Town: **CHESTER** Year Built: **1940**

Highway No. : **TH005** Structure No. : **11** Structure Type: **2 SPAN I-BEAM**

Clear span (*ft*): **110** Clear Height (*ft*): **14.0** Full Waterway (*ft^2*): -

Downstream distance (*miles*): **400'** Town: **CHESTER** Year Built: **-**

Highway No. : **TH 009** Structure No. : **63** Structure Type: **STEEL BEAM**

Clear span (*ft*): **31.0** Clear Height (*ft*): **8.6** Full Waterway (ft^2): ________

Comments:

There is a small dam and grist mill just downstream. The existing beams are above the Q100, due to the roadway overflow on the south approach at about Q10. The recommendation is for a 90' minimum clear span with the bottom of beams at or above 592.5 (04/22/92). Bridge deck is highly deteriorated and given a rating of 2 out of 10 in the inspector's report. Cross-sections are available from FEMA data. The Vermont Agency of Transportation used WSPRO and the data is in the hydraulic folder. Proposed construction date 1995.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **23.94** mi^2

Lake and pond area **0.08** mi^2

Watershed storage *(ST)* **0.3** %

Bridge site elevation **600** ft

Headwater elevation **2882** ft

Main channel length **14.47** mi

10% channel length elevation **620** ft

85% channel length elevation **1580** ft

Main channel slope *(S)* **88.45** ft / mi

Watershed Precipitation Data

Average site precipitation **-** in

Average headwater precipitation **-** in

Maximum 2yr-24hr precipitation event *(I24,2)* **-** in

Average seasonal snowfall *(Sn)* **-** ft

Bridge Plan Data

Are plans available? N *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: - / -

Project Number - Minimum channel bed elevation: -

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

Benchmark location description:

NO BENCHMARK INFORMATION

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

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

If 1: Footing Thickness ______ Footing bottom elevation: ______

If 2: Pile Type: ____ (*1-Wood; 2-Steel or metal; 3-Concrete*) Approximate pile driven length: ______

If 3: Footing bottom elevation: ______

Is boring information available? N *If no, type ctrl-n bi* Number of borings taken: -

Foundation Material Type: 3 (*1-regolith, 2-bedrock, 3-unknown*)

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

Plans are in production for the proposed structure to replace the current bridge. The new bridge is to be a single span. The bottom of the right abutment is now proposed at 591.75 feet and the left at 594.25 feet.

Cross-sectional Data

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

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

Comments: **The elevation and station measurements are in feet. The data only provides one low cord elevation for the entire bridge opening. Low cord does vary according to the 9/96 survey.**

Station	322	328	335	340	343	352	355	370	385	388	395
Feature	LAB	-	-	-	-	-	-	-	-	-	-
Low cord elevation	595.3	595.3	595.3	595.3	595.3	595.3	595.3	595.3	595.3	595.3	595.3
Bed elevation	592.8	592	589	585	584.2	582.5	582	583.1	583.7	584	583.1
Low cord to bed length	2.5	3.3	6.3	10.3	11.1	12.8	13.3	12.1	11.6	11.3	12.2

Station	403	409	418	-	-	-	-	-	-	-	-
Feature	-	-	RAB	-	-	-	-	-	-	-	-
Low cord elevation	595.3	595.3	595.3	-	-	-	-	-	-	-	-
Bed elevation	582.6	587.9	589.4	-	-	-	-	-	-	-	-
Low cord to bed length	12.7	7.4	5.9	-	-	-	-	-	-	-	-

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: EW Date: 9/23/96
Computerized by: EW Date: 9/23/96
Reviewd by: RF Date: 4/01/97

Structure Number CHESVT01030012

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. BURNS Date *(MM/DD/YY)* 09 / 18 / 1996

2. Highway District Number 02 Mile marker 003830

County WINDSOR 027 Town CHESTER 13600

Waterway *(I - 6)* WILLIAMS RIVER Road Name -

Route Number VT 103 Hydrologic Unit Code: 01080107

3. Descriptive comments:

LOCATED 0.8 MILES NORTH OF JUNCTION WITH VT 11 WEST, AND AT INTERSECTION BETWEEN VT 103 AND GREEN MOUNTAIN TURNPIKE.

B. Bridge Deck Observations

4. Surface cover... LBUS 5 RBUS 5 LBDS 2 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 1 UB 1 DS 1 *(**1**- pool; **2**- riffle)*

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

7. Bridge length 99 *(feet)* Span length 31 *(feet)* Bridge width 28 *(feet)*

Road approach to bridge:

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

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

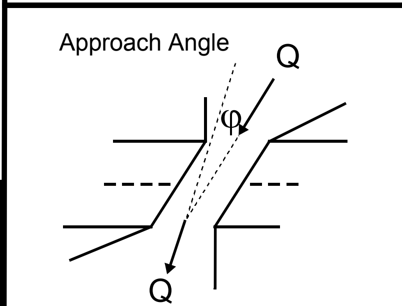
10. Embankment slope (*run / rise in feet / foot*):
US left - US right -

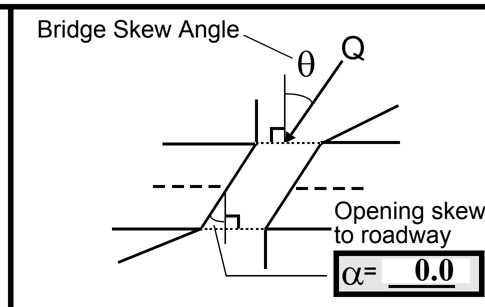
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	0	-	2	1
RBDS	5	1	0	-
LBDS	0	-	0	-

*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: 20





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 100 feet US *(US, UB, DS)* to 10 feet US

Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 180 feet DS *(US, UB, DS)* to 210 feet DS

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

18. Bridge Type: **1b**

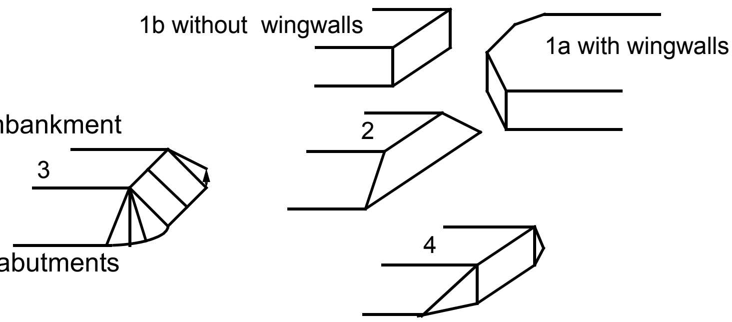
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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 along the banks upstream is forest with lawns or fields beyond two bridge lengths.

#7: Measured bridge length = 99 feet; span length between piers = 33 feet and bridge width = 28 feet.

#11: Road embankment protection on the DSRB is an artificial levee built up from when the drop structure was a dam for the mill.

#13: Road wash erosion may be foot paths under the bridge.

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
118.0	**6.0**			**3.0**	**2**	**3**	**213**	**023**	**2**	**0**

23. Bank width **55.0** 24. Channel width **10.0** 25. Thalweg depth **70.5** 29. Bed Material **324**

30 .Bank protection type: LB **2** RB **0** 31. Bank protection condition: LB **1** 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*

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

#29: From 65 feet upstream to the upstream bridge face , the bed material in the right half of the channel is primarily sand.

#30: The left bank protection extends from the upstream bridge face to 46 feet upstream.

33. Point/Side bar present? **Y** *(Y or N. if N type ctrl-n pb)* 34. Mid-bar distance: **235** 35. Mid-bar width: **32**

36. Point bar extent: **300** feet **US** *(US, UB)* to **36** feet **US** *(US, UB, DS)* positioned **50** %LB to **100** %RB

37. Material: **234**

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

Point bar is completely vegetated with shrubs and brush along the right bank. From 150 feet upstream to 300 feet upstream, the point bar is composed primarily of gravel.

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: **127** 42. Cut bank extent: **199** feet **US** *(US, UB)* to **46** 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.):

Above the cut-bank, there is an old stone wall from 226 feet upstream to 81 feet upstream.

45. Is channel scour present? **Y** *(Y or if N type ctrl-n cs)* 46. Mid-scour distance: **0 US**

47. Scour dimensions: Length **125** Width **35** Depth : **3.25** Position **10** %LB to **90** %RB

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

The scour hole extends from 78 feet upstream along the left bank, then between the piers, and continues to 25 feet downstream. The thalweg depth is assumed to be 2.0 feet.

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
37.0		1.5		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.):

243

The stream channel makes a sharp bend just upstream of the bridge. Most of the flow is between the piers.

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

67. Debris Potential **2** ___ *(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

There is debris caught along the front and right side of the right pier.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		-	90	0	0	-	-	90.0
RABUT	1	45	90			0	0	95.5

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.):

-

-

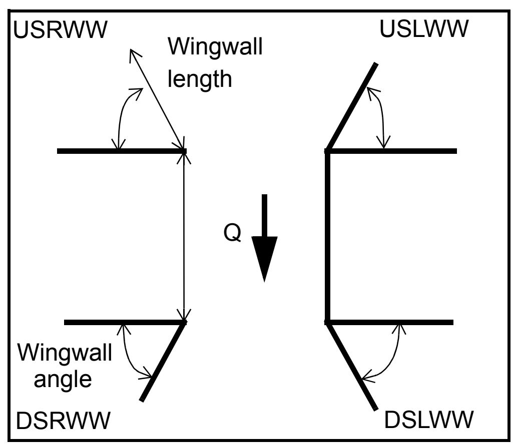
1

Stone fill protection in front of the abutments is similar to a spill-through type. The stone fill along the abutment is at a 35 degree angle. The protection also protrudes into the channel while the concrete part of the abutment is even with the top of bank.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						95.5	
USRWW:	N		-		-	4.0	
DSLWW:	-		-		N	33.5	
DSRWW:	-		-		-	33.5	

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



82. **Bank / Bridge Protection**:

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

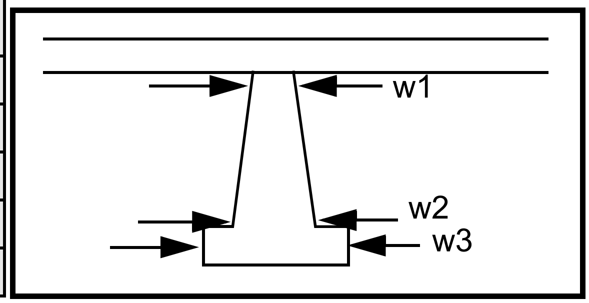
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

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	-	-	-	-	-	-
Pier 2	-	**2.0**	**3.25**	-	**496.13**	**483.20**
Pier 3	-	**2.0**	**3.25**	-	**495.81**	**480.30**
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)		**L**	**MCR**		*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type		**1**	**1**		***1**- Solid pier, **2**- column, **3**- bent*
88. Material		**2**	**2**		***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape		**1**	**1**		***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?		**N**	**N**		*Y- yes; N- no*
91. Attack ∠ (BF)		-	**45**		
92. Pushed		**RB**	**LB**		*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles		**UNK**	**UNK**		
95. Cross-members		**0**	**0**		***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition		**1**	**1**		***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**Y**	**3.25**	**2.0**		
98. Exposure depth	**MC**	**0**	**0**		

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
-	-			-			Scou	r	dep	ths

Bank width (BF) - Channel width (Amb) 31.6 Thalweg depth (Amb) 29.27 Bed Material were

Bank protection type (Qmax): LB mea RB sur Bank protection condition: LB ed at RB upst

*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.):
ream end of piers.

1
1
2
2
0

101. Is a drop structure present? 1 *(Y or N, if N type ctrl-n ds)* 102. Distance: - feet

103. Drop: - feet 104. Structure material: 342 *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

105. Drop structure comments (eg. downstream scour depth):
5
2/ 5
1
1
On the left bank there is a stone wall in-line with the abutment from the bridge face to 88 feet downstream. From 88 ft downstream to 200 feet downstream, the rock wall is along the left edge of water .

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

Point bar extent: **right** feet **ban** *(US, UB, DS)* to **k,** feet **the** *(US, UB, DS)* positioned **pro** %LB to **tec** %RB

Material: **tio**

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

n extends from the bridge face to 70 feet downstream. There is a section of no protection from 70 ft downstream to 124 ft downstream which is then followed by a rock wall extending from 124 feet downstream to 224 feet downstream.

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

Cut bank extent: **brid** feet **ge** *(US, UB, DS)* to **63 is** feet **400** *(US, UB, DS)*

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

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

downstream from this bridge.

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

Scour dimensions: Length ______ Width ______ Depth: **Y** Positioned **2** %LB to **The** %RB

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

drop structure, which is the remnant of an old dam, is located approximately 62 feet downstream.
At approximately 70 feet downstream, there is another drop structure which was the base of the downstream face of the dam. The structure drops 2 feet and the water depth is 0.3 feet over the top of the structure.

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

Confluence 1: Distance **Y** Enters on **197** *(LB or RB)* Type **22** *(**1**- perennial; **2**- ephemeral)*

Confluence 2: Distance **146** Enters on **DS** *(LB or RB)* Type **236** *(**1**- perennial; **2**- ephemeral)*

Confluence comments (eg. confluence name):

DS
10

F. Geomorphic Channel Assessment

107. Stage of reach evolution **80**

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)*:

324

This is a mid-channel bar which is vegetated with grass and some shrubs. The left side of the mid-channel bar is composed primarily of sand, while the right side of the mid-channel bar is composed primarily of gravel.

Y
RB
268
224
DS
312
DS

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: CHESVT01030012 Town: CHESTER
Road Number: VT 103 County: WINDSOR
Stream: WILLIAMS RIVER

Initials RHF Date: 3/26/97 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	5200	7620	3050
Main Channel Area, ft2	558	669	441
Left overbank area, ft2	0	0	0
Right overbank area, ft2	1247	1885	575
Top width main channel, ft	65	69	60
Top width L overbank, ft	0	0	0
Top width R overbank, ft	375	397	336
D50 of channel, ft	0.172	0.172	0.172
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.6	9.7	7.4
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	3.3	4.7	1.7
Total conveyance, approach	130910	226719	58244
Conveyance, main channel	51166	66227	36436
Conveyance, LOB	0	0	0
Conveyance, ROB	79744	160491	21808
Percent discrepancy, conveyance	0.0000	0.0004	0.0000
Qm, discharge, MC, cfs	2032.4	2225.9	1908.0
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	3167.6	5394.1	1142.0
Vm, mean velocity MC, ft/s	3.6	3.3	4.3
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	2.5	2.9	2.0
Vc-m, crit. velocity, MC, ft/s	8.9	9.1	8.7
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

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	4887	6374	3050
Main channel area (DS), ft2	620.1	709.6	552.1

Main channel width (normal), ft	82.2	88.1	78.1
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	82.2	88.1	78.1
D90, ft	0.3157	0.3157	0.3157
D95, ft	0.3772	0.3772	0.3772
Dc, critical grain size, ft	0.1945	0.2470	0.0978
Pc, Decimal percent coarser than Dc	0.369	0.207	0.888
Depth to armoring, ft	1.00	2.84	0.04

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	5200	7620	3050
(Q) discharge thru bridge, cfs	4887	6374	3050
Main channel conveyance	61826	73875	52711
Total conveyance	61826	73875	52711
Q2, bridge MC discharge,cfs	4887	6374	3050
Main channel area, ft2	555	640	492
Main channel width (normal), ft	82.2	88.1	78.1
Cum. width of piers in MC, ft	5.3	5.3	5.3
W, adjusted width, ft	76.95	82.85	72.85
y_bridge (avg. depth at br.), ft	7.21	7.72	6.75
Dm, median (1.25*D50), ft	0.215	0.215	0.215
y2, depth in contraction,ft	6.74	7.94	4.72
ys, scour depth (y2-ybridge), ft	-0.47	0.22	-2.04

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	5200	7620	3050	5200	7620	3050
a', abut.length blocking flow, ft	12	15.6	7.65	305.7	271.05	340
Ae, area of blocked flow ft2	70.56	104.72	40.75	1051.91	1389.59	524.2
Qe, discharge blocked abut.,cfs	178.29	247.65	119.04	2672.55	3898.5	1018.86
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.53	2.36	2.92	2.54	2.81	1.94
ya, depth of f/p flow, ft	5.88	6.71	5.33	3.44	5.13	1.54
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	90	90	90	90	90	90
K2	1.00	1.00	1.00	1.00	1.00	1.00
Fr, froude number f/p flow	0.184	0.161	0.223	0.241	0.218	0.276

ys, scour depth, ft	9.43	10.66	8.44	15.87	19.06	10.47

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)	12	15.6	7.65	305.7	271.05	340
y1 (depth f/p flow, ft)	5.88	6.71	5.33	3.44	5.13	1.54
a'/y1	2.04	2.32	1.44	88.84	52.87	220.53
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.18	0.16	0.22	0.24	0.22	0.28
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	15.66	22.57	7.33
vertical w/ ww's	ERR	ERR	ERR	12.84	18.50	6.01
spill-through	ERR	ERR	ERR	8.61	12.41	4.03

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 (DS)	0.63	0.69	0.42	0.63	0.69	0.42
y, depth of flow in bridge (DS), ft	7.54	8.05	7.07	7.54	8.05	7.07
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.85	2.37	0.77	1.85	2.37	0.77
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR
Fr<=0.8 (spillthrough abut.)	1.62	2.07	0.67	1.62	2.07	0.67
Fr>0.8 (spillthrough abut.)	ERR	ERR	ERR	ERR	ERR	ERR

Pier Scour
ys/y1=2.0*K1*K2*K3*K4*(a/y1)^0.65*Fr1^0.43
(Richardson and others, 1995, p. 36, eq. 21)

K1, corr. factor for pier nose shape
Sharp nose, 0.9; round nose, cylinder, or cylinder grp., 1.0; square nose, 1.1

K2, corr. factor attack angle (see Table 3, p 37)
K2=[cos(attackangle)+L/a*sin(attackangle)]^0.65

K3, corr. factor for bed condition
Clear-water, plane bed, antidune, 1.1; med. dunes, 1.1-1.2 (see Tab.4,p37)

K4, corr. factor for armoring (the following equations are in Si units)
K4=[1-0.89*(1-Vr)^2]^0.5
Vr=(V1-Vi)/(Vc90-Vi)
V1=0.645*((D50/a)^0.053)*Vc50
Vc=6.19*(y^1/6)*(Dc^1/3)

Note for round nose piers:
ys<=2.4 times the pier width (a) for Fr<=0.8
ys<=3.0 times the pier width (a) for Fr>0.8

Pier 1	Q100	Q500	Qother
Pier stationing, ft	31.1	31.1	31.1
Area of WSPRO flow tube, ft2	25.4	28.9	22.3
Skewed width of flow tube, ft	2.2	2.2	2.1
y1, pier approach depth, ft	11.55	13.14	10.62
y1 in meters	3.519	4.004	3.237
V1, pier approach velocity, ft/s	9.62	11.04	6.84
a, pier width, ft	3.25	3.25	3.25
L, pier length, ft	31.6	31.6	31.6
Fr1, Froude number at pier	0.499	0.537	0.370
Pier attack angle, degrees	0	0	0
K1, shape factor	1	1	1
K2, attack factor	1.00	1.00	1.00
K3, bed condition factor	1.1	1.1	1.1
D50, ft	0.172	0.172	0.172
D50, m	0.052423	0.052423	0.052423
D90, ft	0.3157	0.3157	0.3157
D90, m	0.096221	0.096221	0.096221
Vc50,critical velocity(D50),m/s	2.857	2.919	2.818
Vc90,critical velocity(D90),m/s	3.498	3.574	3.450
Vi,incipient velocity,m/s	1.577	1.611	1.555
Vr, velocity ratio	0.705	0.893	0.279
K4, armor factor	0.00	0.00	0.00
ys, scour depth (K4 applicable) ft	ERR	ERR	ERR
ys, scour depth (K4 not applied)ft	8.26	8.92	7.06

Pier 2	Q100	Q500	Qother
Pier stationing, ft	64.1	64.1	64.1
Area of WSPRO flow tube, ft2	25.4	28.9	22.3
Skewed width of flow tube, ft	2.2	2.2	2.1
y1, pier approach depth, ft	11.55	13.14	10.62
y1 in meters	3.519	4.004	3.237
V1, pier approach velocity, ft/s	9.62	11.04	6.84
a, pier width, ft	3.25	3.25	3.25
L, pier length, ft	32.5	32.5	32.5
Fr1, Froude number at pier	0.499	0.537	0.370
Pier attack angle, degrees	10	10	10
K1, shape factor	1	1	1
K2, attack factor	1.92	1.92	1.92
K3, bed condition factor	1.1	1.1	1.1
D50, ft	0.172	0.172	0.172
D50, m	0.052423	0.052423	0.052423
D90, ft	0.3157	0.3157	0.3157
D90, m	0.096221	0.096221	0.096221
Vc50,critical velocity(D50),m/s	2.857	2.919	2.818
Vc90,critical velocity(D90),m/s	3.498	3.574	3.450
Vi,incipient velocity,m/s	1.577	1.611	1.555
Vr, velocity ratio	0.705	0.893	0.279
K4, armor factor	0.00	0.00	0.00
ys, scour depth, (K4 applicable) ft	ERR	ERR	ERR
ys, scour depth, (K4 not applied)ft	15.84	17.10	13.53

Pier rip-rap sizing
D50=0.692(K*V)^2/(Ss-1)*2*g
(Richardson and others, 1995, p.115, eq. 83)

Pier-shape coefficient (K), round nose, 1.5; square nose, 1.7
Characteristic avg. channel velocity, V, (Q/A):

(Mult. by 0.9 for bankward piers in a straight, uniform reach,
up to 1.7 for a pier in main current of flow around a bend)

Pier 1	Q100	Q500	Qother
K, pier shape coeff.	1.5	1.5	1.5
V, velocity on pier, ft/s	7.62	8.67	5.41
D50, median stone diameter, ft	0.85	1.10	0.43

Pier 2			
K, pier shape coeff.	1.5	1.5	1.5
V, velocity on pier, ft/s	7.62	8.67	5.41
D50, median stone diameter, ft	0.85	1.10	0.43