LEVEL II SCOUR ANALYSIS FOR BRIDGE 43 (CHESVT00110043) on STATE ROUTE 11, crossing the MIDDLE BRANCH WILLIAMS RIVER, CHESTER, VERMONT

U.S. Geological Survey
Open-File Report 97-342

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

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By Lora K. Striker and Ronda L. Burns

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Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
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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 43 (CHESVT00110043) ON STATE ROUTE 11, CROSSING THE MIDDLE BRANCH WILLIAMS RIVER, CHESTER, VERMONT

By **Lora K. Striker 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 CHESVT00110043 on State Route 11 crossing the Middle Branch of 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 principally in the Green Mountain section of the New England physiographic province in southeastern Vermont. The 13.7-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is predominantly forest except for the area downstream and right of the bridge which is pasture.

In the study area, the Middle Branch of the Williams River has a sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 77 ft and an average bank height of 8 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 76.6 mm (0.251 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 11, 1996, indicated that the reach was laterally unstable. Lateral instability was evident from the several point bars and cut banks located through the study reach.

The State Route 11 crossing of the Middle Branch of the Williams River is a 76-ft-long, two-lane bridge consisting of two 37-foot concrete Tee-beam spans (Vermont Agency of Transportation, written communication, March 29, 1995). The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 35 degrees to the opening. The computed opening-skew-to-roadway was 30 degrees but the historical records indicate this angle is 25 degrees.

Scour protection measures at the site consist of type-1 stone fill (less than 12 inches diameter) along the downstream banks and the upstream right wing wall. Type-2 (less than 36 inches diameter) stone fill protection is noted on the upstream and downstream left wingwalls and upstream along the left bank. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.0 to 1.5 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 7.2 to 10.7 ft. The worst-case abutment scour occurred at the 500-year discharge for the right abutment. Pier scour ranged from 7.3 to 8.6 ft. 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.

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

NORTH

Figure 1. Location of study area on USGS 1:24,000 scale map.

Figure 2. Location of study area on Vermont Agency of Transportation town highway map.

LEVEL II SUMMARY

Structure Number CHESVT00110043 ***Stream*** Middle Branch Williams River

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

Description of Bridge

Bridge length 76 ***ft*** ***Bridge width*** 32.8 ***ft*** ***Max span length*** 37 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 9/11/96

Description of stone fill Type-2, around the upstream end of the upstream left wingwall and downstream end of the downstream left wingwall and upstream left bank. Type-1, along entire base length of the upstream right wingwall and downstream banks.

Brief description of piers/abutments Abutments and wingwalls are concrete. The pier is a 3 foot wide 37 foot long square nosed concrete pier.

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

There is a mild channel bend at the bridge. A point bar has developed under the right span of the bridge forcing the flow under the left span.

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	9/11/96	0	0
Level II	9/11/96	0	0

Potential for debris Moderate. There is some debris noted in the channel at the right cut-bank and along the left bank at the landslide.

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

There is a significant buildup of sediment under the right span of the bridge which will force flows with water surface elevations below 486.2 at the approach under the left span of the bridge as of 9/11/96 (Figure 8).

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley with narrow flood plains, steep valley walls on the left, and moderately sloping valley walls on right.

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

Date of inspection 9/11/96

DS left: Moderately sloped overbank to narrow flood plain

DS right: Steep bank to narrow flood plain

US left: Moderately sloping channel bank to valley wall

US right: Moderately sloping bank to narrow overbank

Description of the Channel

Average top width 77 *ft* ***Average depth*** 8 *ft*

Predominant bed material Cobble/Boulder ***Bank material*** Cobble/Boulder

Sinuous, equiwidth, and laterally unstable with non-alluvial channel boundaries.

9/11/96

Vegetative co Trees and brush

DS left: Trees

DS right: Trees and brush

US left: Small trees and brush

US right: No

Do banks appear stable? ***If not, describe location and type of instability and date of observation.*** Lateral instability is indicated at the site due to point bars and cut banks throughout the reach. There is also a large landslide located on the left bank upstream.

The assessment of 9/11/96 noted a point bar along the right bank that blocks half the bridge opening on the right side up to a water surface elevation of 486.2 (figure 8).

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 13.7 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/New England Upland	30
New England/Green Mountain	70

Is drainage area considered rural or urban? Rural ***Describe any significant urbanization***: -

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/pond that will significantly affect hydrology/hydraulics? No

-

Calculated Discharges

Q100 3570 ***ft³/s*** ***Q500*** 5240 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(13.7/14.8)exp 0.67] with bridge number 46 in Chester. Bridge number 46 crosses the Middle Branch Williams River downstream of this site and has flood frequency estimates available from the VTAOT database. The drainage area above bridge number 46 is 14.8 square miles. These computed discharges were within a range defined by use of several empirical equations. (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887)

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

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

Datum tie between USGS survey and VTAOT plans Subtract 406 feet from USGS arbitrary survey datum to obtain VTAOT plans datum to the nearest foot.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X in a chiseled square at the upstream end of the right abutment (elev. 499.55 ft, arbitrary survey datum). RM2 is a chiseled X on top of the left abutment concrete at the downstream end (elev. 499.07 ft, arbitrary datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-61	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	14	1	Road Grade section
APPRO	91	2	Modelled Approach section (Templated from APTEM)
APTEM	127	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.065 to 0.070, and overbank "n" values ranged from 0.038 to 0.075.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.0132 ft/ft, which was estimated from the 100-year water surface profile downstream of the site presented in the flood insurance study for the Town of Chester, Vermont (Federal Emergency Management Agency, 1982).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0209 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 section location also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.7 *ft*
Average low steel elevation 495.8 *ft*

100-year discharge 3570 *ft³/s*
Water-surface elevation in bridge opening 491.8 *ft*
Road overtopping? N *Discharge over road* 0 *ft³/s*
Area of flow in bridge opening 375 *ft²*
Average velocity in bridge opening 9.5 *ft/s*
Maximum WSPRO tube velocity at bridge 11.7 *ft/s*

Water-surface elevation at Approach section with bridge 494.0
Water-surface elevation at Approach section without bridge 493.0
Amount of backwater caused by bridge 1.0 *ft*

500-year discharge 5240 *ft³/s*
Water-surface elevation in bridge opening 492.3 *ft*
Road overtopping? N *Discharge over road* 0 *ft³/s*
Area of flow in bridge opening 406 *ft²*
Average velocity in bridge opening 12.9 *ft/s*
Maximum WSPRO tube velocity at bridge 15.9 *ft/s*

Water-surface elevation at Approach section with bridge 496.4
Water-surface elevation at Approach section without bridge 493.7
Amount of backwater caused by bridge 2.7

Incipient overtopping discharge - *ft³/s*
Water-surface elevation in bridge opening - *ft*
Area of flow in bridge opening - *ft²*
Average velocity in bridge opening - *ft/s*
Maximum WSPRO tube velocity at bridge - *ft/s*

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

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the 100- and 500-year discharges were computed by use of the clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour at the 500-year discharge.

Abutment scour for the left and right abutments for the 100- and 500-year discharges 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.

Pier scour for the 100- and 500-year discharges was computed by use of an equation based on the CSU equation (Richardson and others, 1995, p. 36, eq. 21). Variables for the equation include: pier length, pier width, approach velocity and correction factors for pier shape, attack angle, bed condition, and armoring.

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	1.5	-
Depth to armoring	3.6	33.6	-
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	7.2	9.9	-
Right abutment	8.1	10.7	--
Pier scour			
Pier 1	7.3	8.6	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	*500-yr discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	1.8	2.6	-
Right abutment	1.8	2.6	-
Piers:			
Pier 1	2.2	3.5	--
Pier 2	--	--	--
	--	--	--

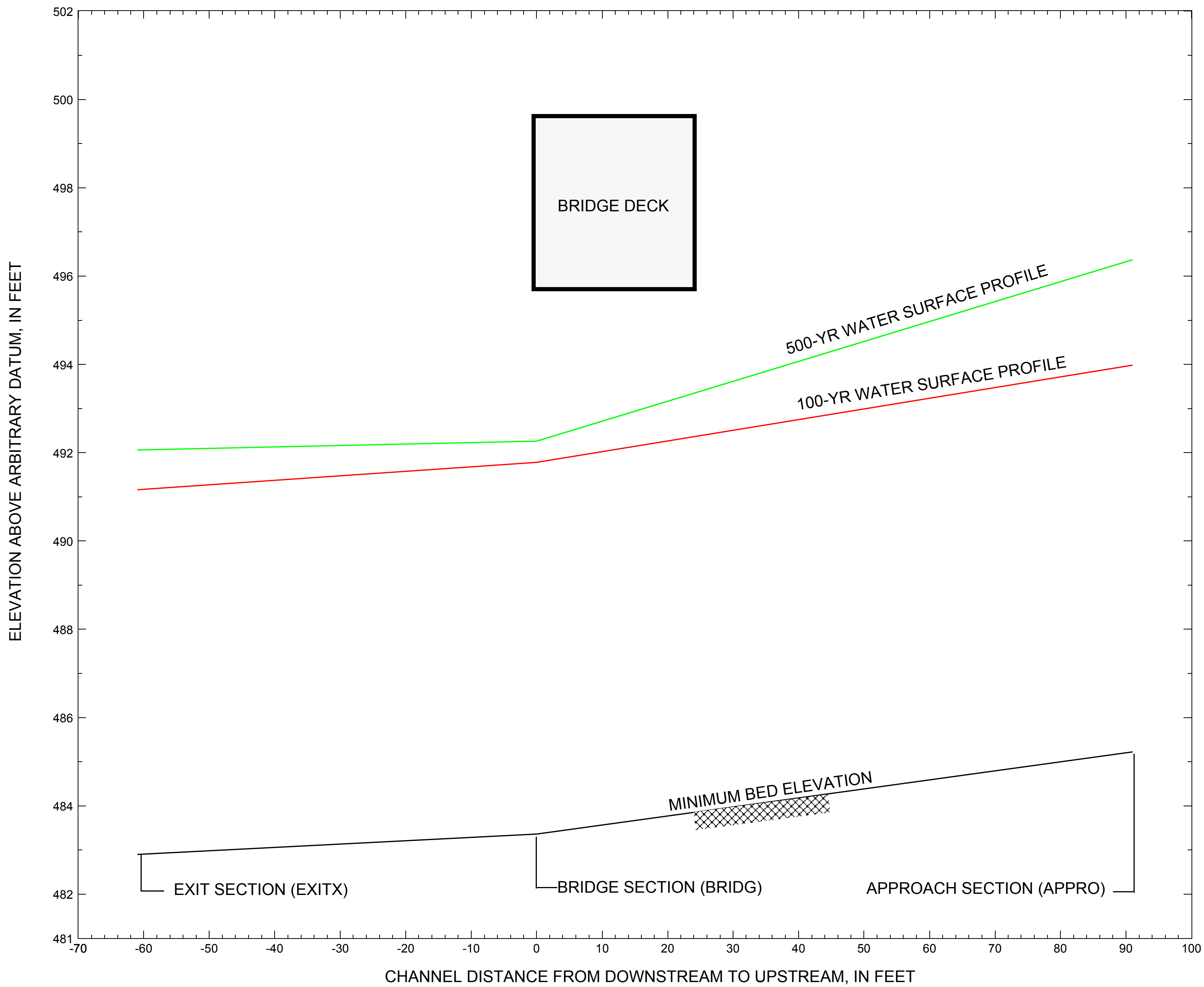

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CHESVT00110043 on State Route 11, crossing the Middle Branch Williams River, Chester, Vermont.

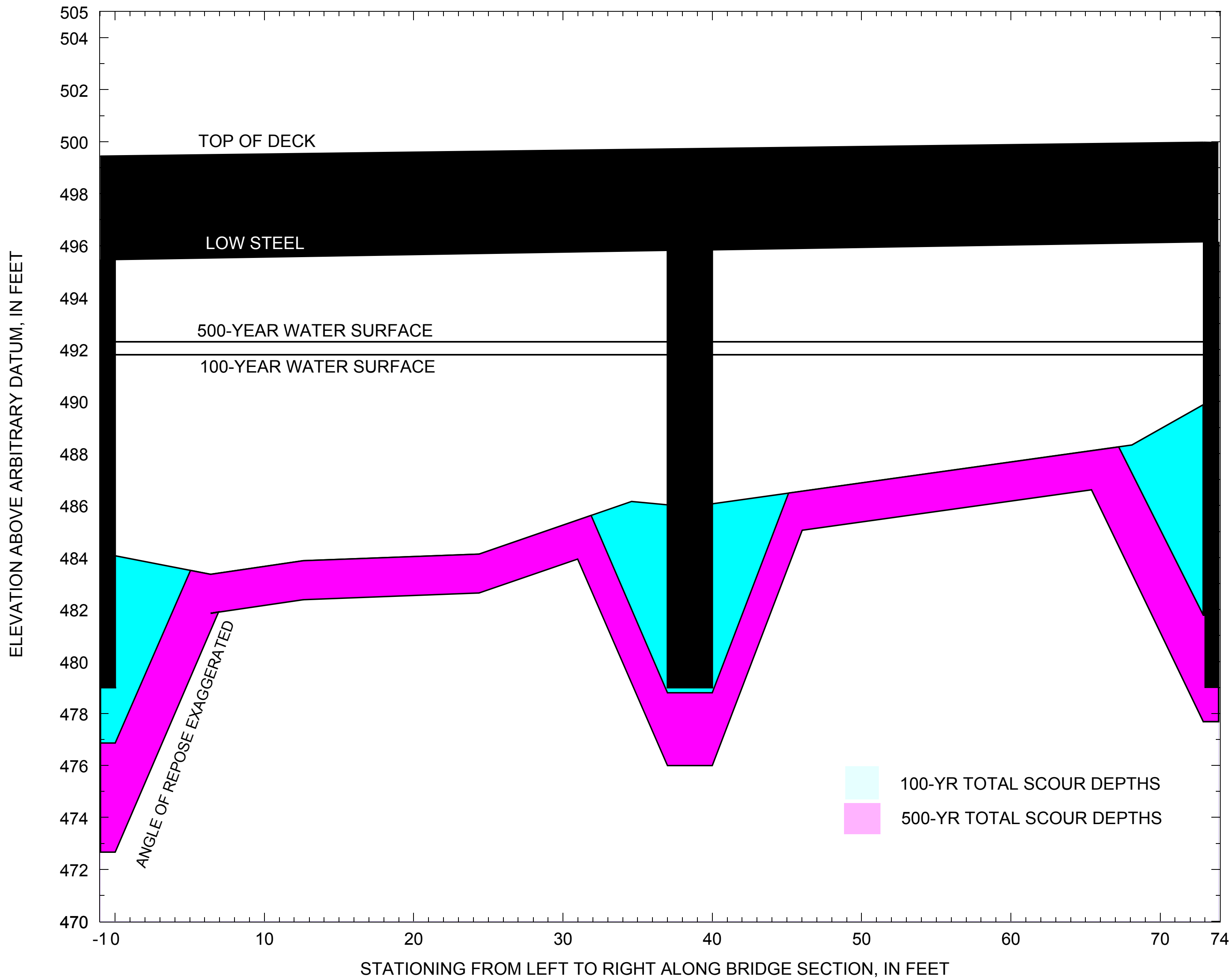

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CHESVT00110043 on State Route 11, crossing Middle Branch Williams River, Chester, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CHESVT00110043 on State Route 11, crossing Middle Branch 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 3570 cubic-feet per second											
Left abutment	0.0	89.8	495.5	479	484.1	0.0	7.2	--	7.2	476.9	-2
Pier	36.5	89.9	495.8	479	486.1	0.0	--	7.3	7.3	478.8	0
Right abutment	73.1	90.0	496.2	479	489.9	0.0	8.1	--	8.1	481.8	3

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure CHESVT00110043 on State Route 11, crossing Middle Branch 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 5240 cubic-feet per second											
Left abutment	0.0	89.8	495.5	479	484.1	1.5	9.9	--	11.4	472.7	-6
Pier	36.5	89.9	495.8	479	486.1	1.5	--	8.6	10.1	476.0	-3
Right abutment	73.1	90.0	496.2	479	489.9	1.5	10.7	--	12.2	477.7	-1

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

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U.S. Geological Survey, 1971, Andover, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

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T1        U.S. Geological Survey WSPRO Input File ches043.wsp
T2        Hydraulic analysis for structure chesvt00110043   Date: 31-JAN-97
T3        Vermont State Route 11 over the Middle Branch of the Williams River
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3570.0   5240.0
SK          0.0132   0.0132
*
XS   EXITX    -61           0.
GR         -279.1, 504.51   -258.0, 494.99   -143.6, 494.82    -77.6, 495.92
GR          -21.0, 494.84      0.0, 488.29     24.6, 483.39     27.6, 483.46
GR           30.6, 482.90     34.1, 483.02     36.2, 482.96     38.9, 483.14
GR           46.6, 483.18     48.1, 483.44     57.2, 489.44    189.6, 490.67
GR          270.4, 493.72    300.1, 497.19    390.8, 518.98
N           0.038        0.065        0.050
SA                 -21.0         57.2
*
*
XS   FULLV      0  * * *   0.0095
*
*            SRD     LSEL    XSSKEW
BR   BRIDG     0    495.81      30.0
GR            0.0, 495.47      0.0, 484.07      6.4, 483.36     12.6, 483.88
GR           24.4, 484.14     34.6, 486.16     38.5, 485.95     68.1, 488.33
GR           72.7, 489.88     73.1, 496.15      0.0, 495.47
*
*        BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      38.5 * *     60.0      7.0
PW          486.1, 3
N          0.070
*
*
*            SRD    EMBWID   IPAVE
XR   RDWAY     14      32.8     1
GR         -152.2, 506.28   -118.7, 498.93    -52.9, 498.93    -26.9, 498.93
GR          -21.8, 498.94      0.0, 499.46     33.9, 499.72     68.3, 499.95
GR          133.1, 500.38    281.5, 500.49    384.5, 504.73    490.5, 509.02
GR          518.4, 514.97
*
*
XT   APTEM    127
GR          -61.3, 529.99      0.0, 495.10     13.5, 488.86     30.4, 487.78
GR           32.7, 486.72     34.4, 486.27     39.3, 486.49     49.1, 486.73
GR           52.2, 485.97     60.1, 486.82     75.9, 495.48    104.3, 495.03
GR          249.4, 500.94    414.2, 505.72    464.0, 508.54    499.7, 511.68
GR          516.7, 519.10
*
AS   APPRO     91 * * * 0.0209
GT
N           0.065       0.075
SA                 75.9
*
HP 1 BRIDG   491.78 1 491.78
HP 2 BRIDG   491.78 * * 3570
HP 1 APPRO   493.98 1 493.98
HP 2 APPRO   493.98 * * 3570
* pier scour
HP 2 BRIDG   492.65 * * 3570
*
HP 1 BRIDG   492.26 1 492.26
HP 2 BRIDG   492.26 * * 5240
HP 1 APPRO   496.37 1 496.37
HP 2 APPRO   496.37 * * 5240
* pier scour
HP 2 BRIDG   493.73 * * 5240
*
EX
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File ches043.wsp
        Hydraulic analysis for structure chesvt00110043   Date: 31-JAN-97
        Vermont State Route 11 over the Middle Branch of the Williams River
           *** RUN DATE & TIME: 03-25-97  09:14
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      376     23758     63     73                         5200
   491.78           376     23758     63     73  1.00      0     73     5200
   HP 2 BRIDG   491.78 * * 3570

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       491.78     0.0    72.8   375.5   23758.    3570.   9.51

 X STA.         0.0        4.3        6.9        9.3       11.5       13.8
   A(I)             29.8       18.8       16.9       15.7       15.4
   V(I)             5.98       9.49      10.58      11.40      11.61

 X STA.        13.8       16.1       18.3       20.6       22.9       25.2
   A(I)             15.5       15.2       15.2       15.5       15.3
   V(I)            11.53      11.73      11.75      11.55      11.66

 X STA.        25.2       27.8       30.7       34.1       37.9       41.6
   A(I)             16.1       16.9       17.9       18.5       18.4
   V(I)            11.09      10.58      10.00       9.63       9.72

 X STA.        41.6       45.7       50.2       55.7       62.0       72.8
   A(I)             19.6       19.7       22.1       23.0       30.2
   V(I)             9.13       9.05       8.06       7.77       5.92

     CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      91.
      WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      446     32870     74     78                         6232
   493.98           446     32870     74     78  1.00      1     75     6232

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      91.
         WSEL     LEW     REW    AREA        K        Q    VEL
       493.98     0.8    74.5   446.4   32870.    3570.   8.00

 X STA.         0.8       13.6       18.0       21.8       25.2       28.5
   A(I)             37.8       26.8       23.4       22.2       22.1
   V(I)             4.72       6.66       7.63       8.05       8.09

 X STA.        28.5       31.5       34.0       36.2       38.5       40.7
   A(I)             21.1       20.2       18.6       18.8       18.6
   V(I)             8.44       8.86       9.61       9.49       9.59

 X STA.        40.7       43.0       45.3       47.7       50.0       52.2
   A(I)             18.9       18.7       18.8       18.6       19.1
   V(I)             9.47       9.53       9.49       9.57       9.35

 X STA.        52.2       54.5       56.8       59.4       62.9       74.5
   A(I)             19.5       19.5       21.4       25.3       37.0
   V(I)             9.15       9.15       8.35       7.06       4.82
1
  * pier scour
  HP 2 BRIDG   492.65 * * 3570

    VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
         WSEL     LEW     REW    AREA        K        Q    VEL
       492.65     0.0    72.9   430.4   29360.    3570.   8.29

 X STA.         0.0        4.7        7.4        9.9       12.2       14.6
   A(I)             35.7       21.8       19.5       18.1       18.2
   V(I)             5.00       8.18       9.18       9.87       9.78

 X STA.        14.6       17.0       19.3       21.7       24.1       26.5
   A(I)             17.5       18.0       17.2       17.8       17.9
   V(I)            10.17       9.94      10.40      10.02       9.97

 X STA.        26.5       29.3       32.4       36.0       39.5       43.3
   A(I)             18.7       19.6       20.3       20.4       20.8
   V(I)             9.55       9.10       8.78       8.74       8.57

 X STA.        43.3       47.3       51.9       57.1       63.1       72.9
   A(I)             21.6       22.9       24.6       25.8       33.9
   V(I)             8.26       7.80       7.25       6.92       5.27
```

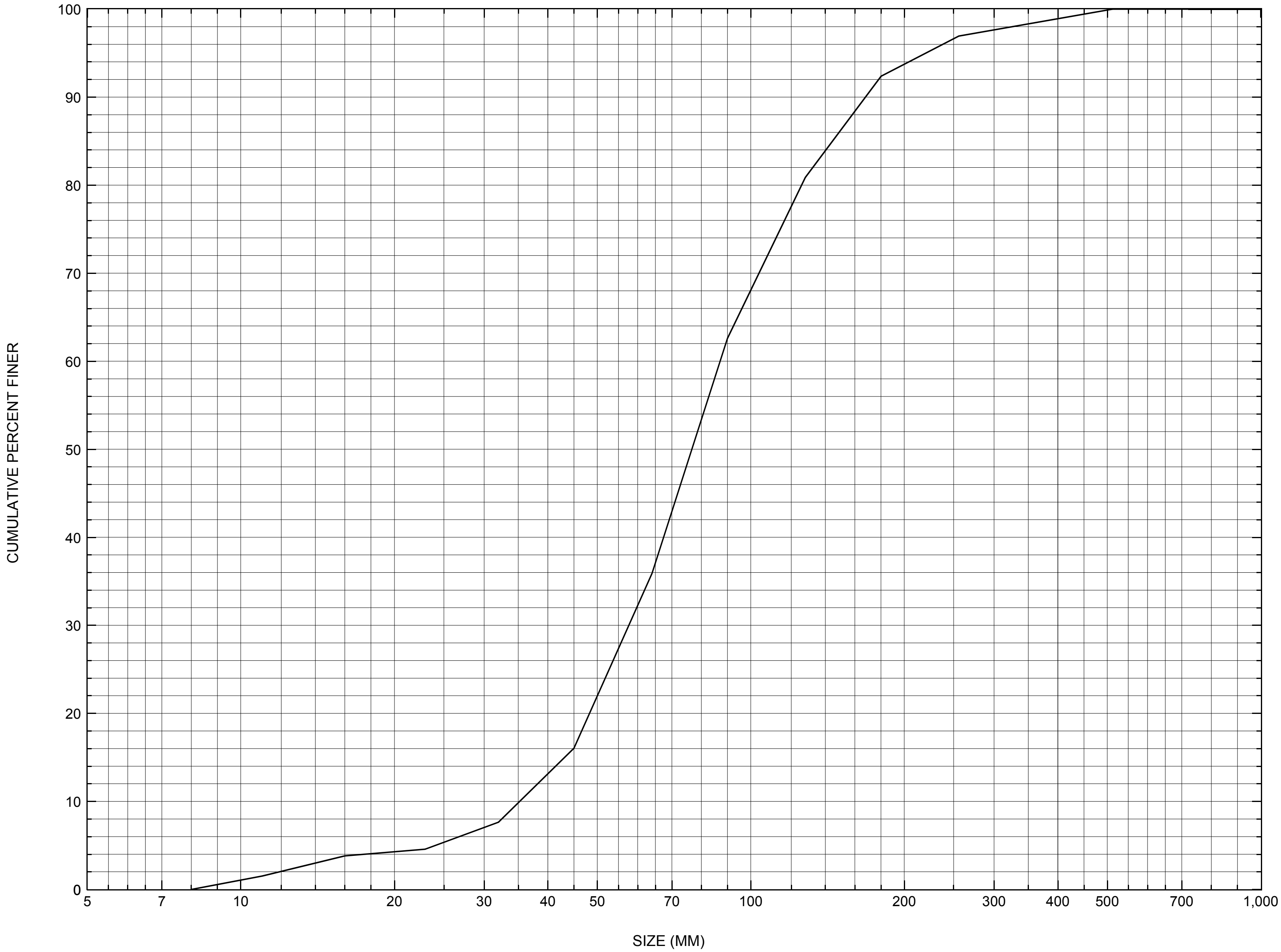
```
              U.S. Geological Survey WSPRO Input File ches043.wsp
         Hydraulic analysis for structure chesvt00110043   Date: 31-JAN-97
         Vermont State Route 11 over the Middle Branch of the Williams River
            *** RUN DATE & TIME: 03-25-97  09:14
       CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
       WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
               1      406     26802     63     74                         5840
      492.26          406     26802     63     74  1.00      0     73     5840

       VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
            WSEL     LEW     REW    AREA         K        Q    VEL
          492.26     0.0    72.9   405.8   26802.    5240.  12.91

   X STA.         0.0         4.6         7.2         9.6        11.9        14.2
     A(I)             33.4        19.8        18.3        17.5        16.7
     V(I)             7.85       13.24       14.28       14.97       15.71

   X STA.        14.2        16.6        18.9        21.2        23.6        26.0
     A(I)             16.8        16.5        16.5        16.5        16.8
     V(I)            15.58       15.85       15.86       15.84       15.62

   X STA.        26.0        28.6        31.7        35.2        38.8        42.5
     A(I)             17.4        18.3        19.4        19.4        20.0
     V(I)            15.04       14.34       13.51       13.47       13.13

   X STA.        42.5        46.7        51.2        56.4        62.6        72.9
     A(I)             20.8        21.5        23.0        24.6        32.5
     V(I)            12.61       12.19       11.37       10.64        8.06

       CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      91.
        WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
               1      631     55416     79     84                        10084
               2      107      2576     80     80                          701
      496.37          737     57992    159    164  1.20     -3    156     8231

       VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      91.
            WSEL     LEW     REW    AREA         K        Q    VEL
          496.37    -3.6   155.7   737.5   57992.    5240.   7.11

   X STA.        -3.6        11.6        16.3        20.4        24.1        27.6
     A(I)             58.5        38.3        34.8        33.0        31.7
     V(I)             4.48        6.85        7.53        7.93        8.28

   X STA.        27.6        30.9        33.9        36.5        39.1        41.7
     A(I)             30.6        30.1        28.4        27.8        27.5
     V(I)             8.56        8.71        9.24        9.43        9.52

   X STA.        41.7        44.3        47.0        49.7        52.2        54.7
     A(I)             27.9        27.7        27.9        27.6        28.1
     V(I)             9.40        9.46        9.40        9.50        9.33

   X STA.        54.7        57.5        60.4        64.3        72.4       155.7
     A(I)             29.1        30.4        35.2        47.2       115.8
     V(I)             9.01        8.61        7.44        5.55        2.26
1
     * pier scour
     HP 2 BRIDG   493.73 * * 5240

       VELOCITY DISTRIBUTION:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
            WSEL     LEW     REW    AREA         K        Q    VEL
          493.73     0.0    72.9   498.6   36812.    5240.  10.51

   X STA.         0.0         4.9         7.9        10.5        13.0        15.5
     A(I)             42.2        26.5        22.7        21.7        21.3
     V(I)             6.21        9.90       11.55       12.08       12.28

   X STA.        15.5        17.9        20.3        22.8        25.3        27.9
     A(I)             20.5        20.4        20.3        20.7        21.1
     V(I)            12.77       12.87       12.91       12.66       12.44

   X STA.        27.9        30.8        34.1        37.6        41.1        44.8
     A(I)             21.6        22.8        23.0        23.3        23.7
     V(I)            12.10       11.50       11.38       11.23       11.05

   X STA.        44.8        48.9        53.2        58.2        63.8        72.9
     A(I)             25.2        25.5        27.5        29.0        39.6
     V(I)            10.40       10.27        9.52        9.04        6.62
```

```
        U.S. Geological Survey WSPRO Input File ches043.wsp
        Hydraulic analysis for structure chesvt00110043   Date: 31-JAN-97
        Vermont State Route 11 over the Middle Branch of the Williams River
           *** RUN DATE & TIME: 03-25-97  09:14

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

EXITX:XS   ******     -8      524  0.91 *****  492.06  490.84    3570  491.16
       -60 ******    202    31042  1.26 ***** *******    0.86    6.81

FULLV:FV       61     -9      596  0.69  0.70  492.76 *******    3570  492.07
         0     61    211    35879  1.24  0.00    0.00    0.72    5.99
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS       91      3      374  1.42  1.27  494.39 *******    3570  492.97
        91     91     73    25493  1.00  0.36    0.00    0.73    9.54
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<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       61      0      375  1.41  1.06  493.18  490.60    3570  491.78
         0     61     73    23735  1.00  0.07    0.00    0.69    9.51

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   0.   1.  1.000  0.045  495.81 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS       53      1      447  0.99  0.93  494.98  491.81    3570  493.98
        91     57     75    32891  1.00  0.87    0.01    0.57    7.99

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.000  0.038   31525.    15.    88.   493.29

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW     REW       Q         K      AREA      VEL    WSEL
   EXITX:XS     -61.     -9.    202.   3570.   31042.      524.     6.81  491.16
   FULLV:FV       0.    -10.    211.   3570.   35879.      596.     5.99  492.07
   BRIDG:BR       0.      0.     73.   3570.   23735.      375.     9.51  491.78
   RDWAY:RG      14.**************        0.******************     1.00********
   APPRO:AS      91.      1.     75.   3570.   32891.      447.     7.99  493.98

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      15.    88.   31525.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX     HF     HO   VHD      EGL    WSEL
   EXITX:XS    490.84    0.86  482.90  518.98************  0.91  492.06  491.16
   FULLV:FV  ********    0.72  483.48  519.56  0.70  0.00  0.69  492.76  492.07
   BRIDG:BR    490.60    0.69  483.36  496.15  1.06  0.07  1.41  493.18  491.78
   RDWAY:RG  ****************  498.93  514.97**********************************
   APPRO:AS    491.81    0.57  485.22  529.24  0.93  0.87  0.99  494.98  493.98
```

```
       U.S. Geological Survey WSPRO Input File ches043.wsp
       Hydraulic analysis for structure chesvt00110043   Date: 31-JAN-97
       Vermont State Route 11 over the Middle Branch of the Williams River
          *** RUN DATE & TIME: 03-25-97  09:14

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

EXITX:XS   ******    -11      727  0.97 *****  493.02  491.68    5240  492.06
       -60 ******    226    45595  1.20 ***** *******    0.80    7.21

FULLV:FV       61    -12      800  0.78  0.71  493.72 *******    5240  492.94
         0     61    234    51421  1.17  0.00   -0.02    0.69    6.55
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    0.89     493.73     493.23

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   492.44     529.24    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   492.44     529.24     493.23

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                        "APPRO"     KRATIO =  0.60

APPRO:AS       91      1      428  2.33  1.57  496.06  493.23    5240  493.73
        91     91     74    30951  1.00  0.77    0.00    0.89   12.24
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<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       61      0      406  2.59  1.37  494.85  492.00    5240  492.26
         0     61     73    26794  1.00  0.46    0.00    0.90   12.92

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1.   0.   1.  1.000  0.046   495.81 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL     ERR       Q    WSEL
   RDWAY:RG      14.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPRO:AS       53     -3      738  0.94  0.99  497.31  493.23    5240  496.37
        91     56    156    58046  1.20  1.47    0.02    0.64    7.10

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.000  0.073   53650.    14.    87.   495.90

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -61.   -12.   226.   5240.   45595.     727.    7.21  492.06
   FULLV:FV       0.   -13.   234.   5240.   51421.     800.    6.55  492.94
   BRIDG:BR       0.     0.    73.   5240.   26794.     406.   12.92  492.26
   RDWAY:RG      14.**************      0.******************    1.00********
   APPRO:AS      91.    -4.   156.   5240.   58046.     738.    7.10  496.37

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      14.    87.   53650.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    491.68    0.80  482.90  518.98************  0.97  493.02  492.06
   FULLV:FV  ********    0.69  483.48  519.56  0.71  0.00  0.78  493.72  492.94
   BRIDG:BR    492.00    0.90  483.36  496.15  1.37  0.46  2.59  494.85  492.26
   RDWAY:RG  ***************  498.93  514.97**********************************
   APPRO:AS    493.23    0.64  485.22  529.24  0.99  1.47  0.94  497.31  496.37
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICAL-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CHESVT00110043, in Chester, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CHESVT00110043

General Location Descriptive

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

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

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

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

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

Mile marker *(I - 11; nnn.nnn)* 000270

Waterway *(I - 6)* MIDDLE BRANCH WILLIAMS RIVER

Road Name *(I - 7):* -

Route Number VT 11

Vicinity *(I - 9)* 5.2 MI E JCT VT 121

Topographic Map Andover

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43154

Longitude *(i - 17; nnnnn.n)* 72048

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20001600431407

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

Maximum span length *(I - 48; nnnn)* 0037

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

Structure length *(I - 49; nnnnnn)* 000076

Average daily traffic, ADT *(I - 29; nnnnnn)* 002736

Deck Width *(I - 52; nn.n)* 328

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

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

Opening skew to Roadway *(I - 34; nn)* 25

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

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

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

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

Year Reconstructed *(I - 106)* 1974

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

Clear span (*nnn.n ft*) -

Number of spans *(I - 45; nnn)* 002

Vertical clearance from streambed (*nnn.n ft*) 10.0

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

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

Comments:

The structural inspection report of 11/10/93 indicates that the structure is a two span concrete T-beam bridge with an asphalt road surface. Both concrete abutment walls have some minor cracks reported with some minor spalls on the wingwalls. There is some scaling noted along the flow line of the left abutment. The pier is solid concrete with a new addition of concrete ends to accommodate the widening of the structure. Apparently the pier joint above span 2 leaks heavily. There are remains of a concrete block support system for the patching of the pier cap alongside the pier. The waterway makes a slight turn through the skewed structure. Presently, all the flow is beneath the left span (Continued, page 31).

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: **13.6**

Terrain character: **hilly and forested**

Stream character & type: -

Streambed material: **stone and gravel with some boulders**

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} **1650** Q_{25} **2300**

Q_{50} **2900** Q_{100} **3500** Q_{500} -

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

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

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

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

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

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

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

The watershed storage area is: - (*1-mainly at the headwaters; 2- uniformly distributed; 3-immediatly upstream oi the site*)

Water Surface Elevation Estimates for Existing Structure:

Peak discharge frequency	$Q_{2.33}$	Q_{10}	Q_{25}	Q_{50}	Q_{100}
Water surface elevation (*ft*))	-	**4.1**	**5.2**	**6.1**	**6.9**
Velocity (*ft / sec*)					

Long term stream bed changes: -

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

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

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

Upstream distance (*miles*): - Town: **Andover** Year Built: **1974**

Highway No. : **TH0029** Structure No. : **027** Structure Type: **STEEL BEAM**

Clear span (*ft*): **32** Clear Height (*ft*): **9** Full Waterway (*ft²*): -

Downstream distance (*miles*): - Town: CHESTER Year Built: 1974

Highway No. : TH0056 Structure No. : 061 Structure Type: STEEL BEAM

Clear span (*ft*): 26 Clear Height (*ft*): 7 Full Waterway (ft^2): -

Comments:

None of the footings are in view. The streambed consists of stone and gravel with some boulders. Approximately 300 feet upstream there is some heavy bank erosion along a high bank.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 13.70 mi^2 Lake and pond area 0 mi^2

Watershed storage *(ST)* 0 %

Bridge site elevation 940 ft Headwater elevation 2894 ft

Main channel length 7.34 mi

10% channel length elevation 1000 ft 85% channel length elevation 1772 ft

Main channel slope *(S)* 140.19 ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

Are plans available? **Y** *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: **01** / **1969**

Project Number **FAP 100G** Minimum channel bed elevation: **78.0**

Low superstructure elevation: USLAB **89.8** DSLAB **-** USRAB **90.0** DSRAB **-**

Benchmark location description:

BM#2 spike is in a root or trunk of an 18" elm tree at the intersect point of the upstream right road embankment bottom of the older bridge and the top of the right stream bank, elevation 85.41. There is also riprap stones drawn as they existed for the original bridge. The benchmark is a few feet upstream of the end of the riprap, upstream from the right abutment on the original structure.

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

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

If 1: Footing Thickness **2.0** Footing bottom elevation: **72.5**

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:

There was no foundation material information available.

Comments:

The available plans are for the bridge widening project using the original abutments and pier. Elevations are taken from plans of original structure attached to the bridge widening plans. The other elevation points are: 1) the upstream end, streamward corner on top of concrete of the upstream left wingwall, elevation 83.75 and 2) a point at the some location described above except on the upstream right wingwall, elevation 88.0. The low superstructure elevation for the pier is about 90 with a footing bottom elevation of about 72.5. The pier footing is 2 feet thick.

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.**

Station	489	501	526	530	534	540	546	567	-	-	-
Feature	LAB							RAB	-	-	-
Low cord elevation	936.8	936.8	936.8	936.8	936.8	936.8	936.8	936.8	-	-	-
Bed elevation	924.8	924.8	925.8	928.8	926.8	926.6	926.8	930.3	-	-	-
Low cord to bed length	12	12	11	8	10	10.2	10	6.5	-	-	-
Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low cord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low cord to bed length	-	-	-	-	-	-	-	-	-	-	-

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

Comments: -

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 10/02/96
Computerized by: EW Date: 10/02/96
Reviewd by: LKS Date: 03/14/97

Structure Number CHESVT00110043

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. BURNS Date *(MM/DD/YY)* 09 / 11 / 1996
2. Highway District Number 02 Mile marker 000270
County WINDSOR (027) Town CHESTER (13675)
Waterway *(I - 6)* The Middle Branch Williams River Road Name -
Route Number VT 11 Hydrologic Unit Code: 01080107
3. Descriptive comments:
The bridge is located 5.2 miles east of the junction of VT 11.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 6 LBDS 6 RBDS 4 Overall 6
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 2 UB 2 DS 2 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 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 76 *(feet)* Span length 37 *(feet)* Bridge width 32.8 *(feet)*

Road approach to bridge:

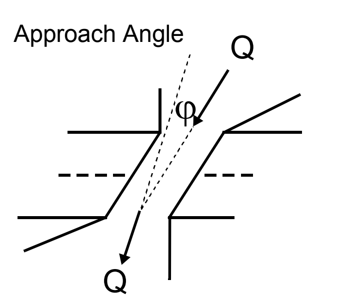
8. LB 0 RB 0 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left - US right -

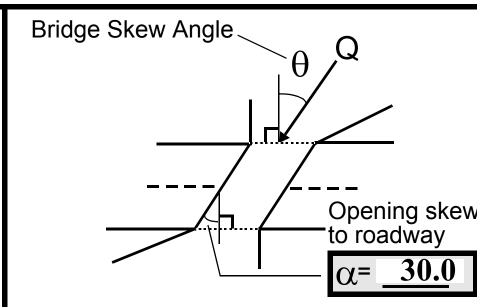
	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	0	-	2	1
RBUS	0	-	2	1
RBDS	0	-	0	-
LBDS	2	1	2	1

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

Channel approach to bridge (BF):

15. Angle of approach: 20 16. Bridge skew: 35





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 0 feet US *(US, UB, DS)* to 0 feet DS
Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 70 feet DS *(US, UB, DS)* to 100 feet DS

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

18. Bridge Type: **1a**

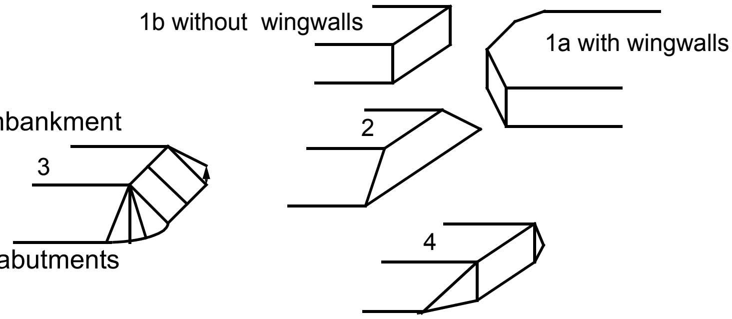
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls 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: There are trees along the immediate DSRB, and an open field on the overbank.

#7: Measured bridge length = 82 feet; span length = 40 feet; and bridge width = 38 feet.

C. Upstream Channel Assessment

20. SRD	21. Bank height (BF) LB	21. Bank height (BF) RB	22. Bank angle (BF) LB	22. Bank angle (BF) RB	26. % Veg. cover (BF) LB	26. % Veg. cover (BF) RB	27. Bank material (BF) LB	27. Bank material (BF) RB	28. Bank erosion (BF) LB	28. Bank erosion (BF) RB
74.0	**6.0**			**8.5**	**4**	**3**	**432**	**432**	**1**	**1**

23. Bank width **25.0** 24. Channel width **30.0** 25. Thalweg depth **76.0** 29. Bed Material **453**

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.):

#30: The left bank protection extends from 12 feet upstream to the end of the upstream left wingwall. Approximately 12 feet upstream on the left bank there is a transition from type 2 to type 1 stone fill. Type 1 stone fill extends from 12 feet upstream to 70 feet upstream, however, there is type 1 dumped stone fill built up like a levee along the left bank.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **0 DS** 35. Mid-bar width: **48**

36. Point bar extent: **54** feet **US** (US, UB) to **68** feet **DS** (US, UB, DS) positioned **50** %LB to **100** %RB

37. Material: **432**

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

The point bar is vegetated with grass and shrubs upstream and downstream of the bridge. Under the bridge, the point bar material is almost exclusively sand with cobbles and gravel along the pier. Another point bar extends from 234 feet upstream to the bridge. It is cobbles, boulders, and gravel with grass along the left bank. It is positioned 0%LB to 60%RB, with a mid-bar distance at 134 feet upstream where it is 32 feet wide.

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

41. Mid-bank distance: **173** 42. Cut bank extent: **308** feet **US** (US, UB) to **71** feet **US** (US, UB, DS)

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

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

From 236 feet upstream to 173 feet upstream, some large trees have fallen across the stream from the right bank. On the left bank from 360 feet upstream to 152 feet upstream, there is a land slide area. Large trees are lying across the stream at the upstream and downstream ends of the landslide.

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

47. Scour dimensions: Length **-** Width **-** Depth : **-** Position **-** %LB to **-** %RB

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

There is no channel scour present as of 9/11/96.

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):

There are no major confluences present.

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
46.5		1.0		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.):

453

The main channel goes between the pier and the left abutment. The bridge deck was widened with steel I-beams which where placed on the upstream and downstream faces. These I-beams are 1 foot higher than the concrete low cord, and 0.2 feet higher than the bridge seat.

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

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

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

70. Debris and Ice Comments:

2

#67: The debris potential is moderate because of vegetation and trees along the unstable channel banks which have already slumped into the stream channel.

#68/69: The capture efficiency and ice blockage potential is moderate because of the pier.

There is debris accumulation upstream at the cut-bank and the landslide.

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		10	90	2	0	-	-	90.0
RABUT	1	0	90			0	0	62.0

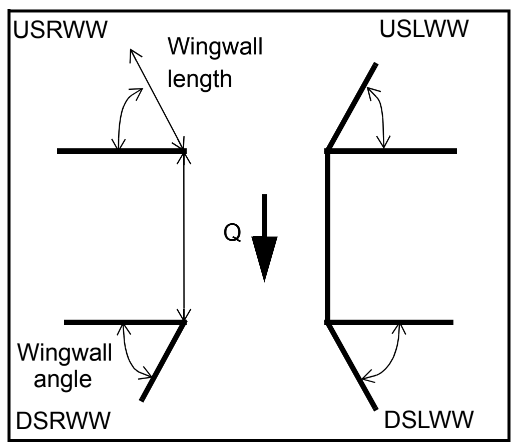
Pushed: LB or RB *Toe Location (Loc.): 0- even, 1- set back, 2- protrudes*
Scour cond.: 0- not evident; 1- evident (comment); 2- footing exposed; 3-undermined footing; 4- piling exposed; 5- settled; 6- failed
Materials: *1-* Concrete; *2-* Stone masonry or drywall; *3-* steel or metal; *4-* wood

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

-
-
1
-

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						62.0	
USRWW:	Y		1		0	0.5	
DSLWW:	-		-		Y	28.0	
DSRWW:	1		0		-	28.5	



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

82. **Bank / Bridge Protection**:

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

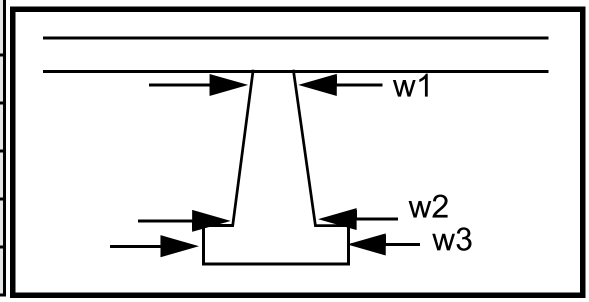
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

83. Wingwall and protection comments (eg. undermined penetration, unusual scour processes, etc.):
-
-
-
-
-
2
1
3
0
-
-

Piers:

84. Are there piers? **Th** *(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				**90.0**	**12.5**	**30.0**
Pier 2				**15.5**	**30.0**	**18.0**
Pier 3			**3**	**85.0**	**12.0**	**485.95**
Pier 4	**-**	**3**	**-**	**-**	**495.81**	**-**



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e**	**of**	**alon**	**cov-**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**dow**	**type**	**g the**	**ered**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**nstre**	**1 fill**	**bot-**	**by**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**am**	**at**	**tom**	**free**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**left**	**the**	**half**	**pour**	*Y- yes; N- no*
91. Attack ∠ (BF)	**wing**	**top**	**of**	**ed**	
92. Pushed	**wall**	**of**	**the**	**asph**	*LB or RB*
93. Length (feet)	**-**	**-**	**-**	**-**	
94. # of piles	**pro-**	**the**	**bank**	**alt.**	
95. Cross-members	**tec-**	**bank**	**. The**		***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**tion**	**and**	**fill**	**Ther**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**con-**	**type**	**has**	**e is**	
98. Exposure depth	**sists**	**2 fill**	**been**	**bank**	

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

material in front of the downstream right wingwall.

Y
MCM

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
-	-			-	**1**	**2**	**2**	**Y**	**0**	**LB**

Bank width (BF) - Channel width (Amb) - Thalweg depth (Amb) - Bed Material **0**

Bank protection type (Qmax): LB **0** RB **0** Bank protection condition: LB - RB -

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

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

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

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

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

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

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

Material: -

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

-
-

There is an 8 ft. x 3.7 ft. x 3.4ft concrete block attached to the middle of the left side of the pier. It is 0.75 feet

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

Cut bank extent: strea feet m (US, UB, DS) to bed feet alo (US, UB, DS)

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

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

its entire length. The pier faces are at a 10 degrees off from vertical angle (the pier is slightly longer at low steel than the stream bed). The upstream pier face concrete facing ends 2 feet above the stream bed and the old pier is exposed beneath it. There is a large placed boulder at the upstream pier face.

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

Scour dimensions: Length ____ Width ____ Depth: 4 Positioned 2 %LB to 453 %RB

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

453
0
1
453

Are there major confluences? 0 (Y or if N type ctrl-n mc) How many? 2

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

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

Confluence comments (eg. confluence name):

tion on right bank is dumped fill, extending from 68 feet downstream to 237 feet downstream.

F. Geomorphic Channel Assessment

107. Stage of reach evolution ____

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

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

N

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: CHESVT00110043 Town: CHESTER
Road Number: VT 11 County: WINDSOR
Stream: MIDDLE BRANCH WILLIAMS RIVER

Initials LKS Date: 02/13/97 Checked: EB

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	3570	5240	0
Main Channel Area, ft2	446	631	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	107	0
Top width main channel, ft	74	79	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	80	0
D50 of channel, ft	0.25144	0.25144	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.0	8.0	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	1.3	ERR
Total conveyance, approach	32870	57992	0
Conveyance, main channel	32870	55416	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	2576	0
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	3570.0	5007.2	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	0.0	232.8	ERR
Vm, mean velocity MC, ft/s	8.0	7.9	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	2.2	ERR
Vc-m, crit. velocity, MC, ft/s	9.5	10.0	N/A
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	N/A
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Clear Water Contraction Scour in MAIN CHANNEL

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

Approach Section	Q100	Q500	Qother
Main channel Area, ft2	446	631	0
Main channel width, ft	74	79	0
y1, main channel depth, ft	6.03	7.99	ERR

Bridge Section			
(Q) total discharge, cfs	3570	5240	0
(Q) discharge thru bridge, cfs	3570	5240	0
Main channel conveyance	23758	26802	0
Total conveyance	23758	26802	0
Q2, bridge MC discharge,cfs	3570	5240	ERR
Main channel area, ft2	376	406	0
Main channel width (skewed), ft	63.0	63.1	0.0
Cum. width of piers in MC, ft	3.0	3.0	0.0
W, adjusted width, ft	60	60.1	0
y_bridge (avg. depth at br.), ft	5.97	6.43	ERR
Dm, median (1.25*D50), ft	0.3143	0.3143	0
y2, depth in contraction,ft	5.72	7.93	ERR
ys, scour depth (y2-ybridge), ft	-0.25	1.50	N/A

ARMORING			
D90	0.5504	0.5504	0
D95	0.7231	0.7231	0
Critical grain size,Dc, ft	0.3809	0.6827	ERR
Decimal-percent coarser than Dc	0.2416	0.0575	0
Depth to armoring,ft	3.59	33.57	ERR

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	3570	5240	0	3570	5240	0
a', abut.length blocking flow, ft	4.1	8.5	0	6.5	87.7	0
Ae, area of blocked flow ft2	12.1	32.7	0	20.7	141.4	0
Qe, discharge blocked abut.,cfs	57.2	146.5	0	100	404.3	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	4.73	4.48	ERR	4.83	2.86	ERR
ya, depth of f/p flow, ft	2.95	3.85	ERR	3.18	1.61	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	120	120	120	60	60	60
K2	1.04	1.04	1.04	0.95	0.95	0.95
Fr, froude number f/p flow	0.485	0.403	ERR	0.477	0.397	ERR
ys, scour depth, ft	7.18	9.85	N/A	8.05	10.65	N/A

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)	4.1	8.5	0	6.5	87.7	0
y1 (depth f/p flow, ft)	2.95	3.85	ERR	3.18	1.61	ERR
a'/y1	1.39	2.21	ERR	2.04	54.39	ERR
Skew correction (p. 49, fig. 16)	1.07	1.07	1.07	0.90	0.90	0.90
Froude no. f/p flow	0.48	0.40	N/A	0.48	0.40	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	7.78	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	6.38	ERR
spill-through	ERR	ERR	ERR	ERR	4.28	ERR

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.69	0.9	0	0.69	0.9	0
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5.97	6.43	0.00	5.97	6.43	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	1.76	ERR	0.00	1.76	ERR	0.00
Fr>0.8 (vertical abut.)	ERR	2.61	ERR	ERR	2.61	ERR
Fr<=0.8 (spillthrough abut.)	1.53	ERR	0.00	1.53	ERR	0.00
Fr>0.8 (spillthrough abut.)	ERR	2.31	ERR	ERR	2.31	ERR

Pier Scour(both live-bed and clear water 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	36.5	36.5	0
Area of WSPRO flow tube, ft2	17.2	20.3	0
Skewed width of flow tube, ft	2.08	2.16	0
y1, pier approach depth, ft	8.27	9.40	ERR
y1 in meters	2.520	2.864	N/A
V1, pier approach velocity, ft/s	10.4	12.86	0
a, pier width, ft	3	3	3

L, pier length, ft	39	39	0
Fr1, Froude number at pier	0.637	0.739	ERR
Pier attack angle, degrees	0	0	0
K1, shape factor	1	1	0
K2, attack factor	1.00	1.00	1.00
K3, bed condition factor	1.1	1.1	0
D50, ft	0.25144	0.25144	0
D50, m	0.076635	0.076635	0
D90, ft	0.5504	0.5504	0
D90, m	0.167754	0.167754	0
Vc50,critical velocity(D50),m/s	3.067	3.133	N/A
Vc90,critical velocity(D90),m/s	3.983	4.068	N/A
Vi,incipient velocity,m/s	1.735	1.772	N/A
Vr, velocity ratio	0.638	0.935	ERR
K4, armor factor	0.94	1.00	N/A
ys, scour depth (K4 applicable) ft	7.29	8.63	ERR
ys, scour depth (K4 not applied)ft	ERR	ERR	ERR

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.	1.7	1.7	0
V, char. aver. velocity, ft/s	10.78	13.65	0
D50, median stone diameter, ft	2.19	3.51	0.00