LEVEL II SCOUR ANALYSIS FOR BRIDGE 75 (CHESTH00170075) on TOWN HIGHWAY 17, crossing the WILLIAMS RIVER, CHESTER, VERMONT

Open-File Report 98-416

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior

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By RONDA L. BURNS and JAMES R. DEGNAN

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Pembroke, New Hampshire

1998

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

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 75 (CHESTH00170075) ON TOWN HIGHWAY 17, CROSSING THE WILLIAMS RIVER, CHESTER, VERMONT

By Ronda L. Burns and James R. Degnan

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CHESTH00170075 on Town Highway 17 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 (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the New England Upland section of the New England physiographic province in southeastern Vermont. The 20.7-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture upstream and downstream of the bridge. The immediate banks downstream have dense woody vegetation.

In the study area, the Williams River has an incised, straight channel with a slope of approximately 0.002 ft/ft, an average channel top width of 76 ft and an average bank height of 4 ft. The channel bed material ranges from sand to cobbles (some exposed bedrock) with a median grain size (D_{50}) of 76.8 mm (0.252 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 22, 1996, indicated that the reach was stable.

The Town Highway 17 crossing of the Williams River is a 63-ft-long, one-lane bridge consisting of two 29-foot steel-beam spans (Vermont Agency of Transportation, written communication, April 6, 1995). The opening length of the structure parallel to the bridge face is 55.2 ft. The bridge is supported by vertical, concrete abutments with one wingwall at the upstream left corner. The channel is skewed approximately 20 degrees to the opening while the opening-skew-to-roadway is zero degrees.

A scour hole 1.5 ft deeper than the mean thalweg depth was observed under the bridge in the channel between the left abutment and the pier during the Level I assessment. Scour protection measures at the site included type-2 stone fill (less than 36 inches diameter) along the upstream and downstream left bank and along the upstream left wingwall and type-1 stone fill (less than 12 inches diameter) at the upstream end of the left abutment. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

Scour depths and recommended rock rip-rap sizes were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and Davis, 1995) for the 100- and 500-year discharges. In addition, the incipient roadway-overtopping discharge was determined and analyzed as another potential worst-case scour scenario. Total scour at a highway crossing is comprised of three components: 1) long-term streambed degradation; 2) contraction scour (due to accelerated flow caused by a reduction in flow area at a bridge) and; 3) local scour (caused by accelerated flow around piers and abutments). Total scour is the sum of the three components. Equations are available to compute depths for contraction and local scour and a summary of the results of these computations follows.

Contraction scour for all modelled flows ranged from 0.0 to 0.8 ft. The worst-case contraction scour occurred at the 500-year discharge. Left abutment scour ranged from 13.3 to 14.5 ft and right abutment scour ranged from 19.9 to 23.4 ft. The worst-case abutment scour occurred at the 500-year discharge. Pier scour ranged from 9.7 to 12.6 ft with the worst-case occurring 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 Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Plymouth, VT. Quadrangle, 1:24,000, 1966
Photoinspected 1983

NORTH

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

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

LEVEL II SUMMARY

Structure Number CHESTH00170075 ***Stream*** Williams River

County Windsor ***Road*** TH 17 ***District*** 2

Description of Bridge

Bridge length 63 ***ft*** ***Bridge width*** 14.0 ***ft*** ***Max span length*** 29 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 8/22/96

Description of stone fill Type-1, at the upstream end of the left abutment. Type-2, along the upstream left wingwall.

Abutments and the upstream left wingwall are concrete. There is a 1.5 ft deep scour hole in the channel under the bridge between the left abutment and the pier.

Yes 20

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

There is a moderate channel bend in the upstream reach.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	8/22/96	0	0
Level II	8/22/96	0	0

Potential for debris Low. There is some debris upstream of the bridge.

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

A point bar between the right abutment and the pier was observed on 8/22/96.

Description of the Geomorphic Setting

General topography The channel is located in a low relief valley.

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

Date of inspection 8/22/96

DS left: Steep channel bank to a narrow overbank to the valley wall

DS right: Irregular and moderately sloped overbank

US left: Steep valley wall

US right: Irregular and moderately sloped overbank

Description of the Channel

Average top width 76 ***ft*** ***Average depth*** 4 ***ft***

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

Perennial and straight with semi-alluvial channel boundaries and irregular point and lateral bars.

8/22/96

Vegetative co[ver] Trees and brush with grass on the overbank

DS left: Trees and brush with grass on the overbank

DS right: Grass

US left: Grass

US right:

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

The assessment of 8/22/96 noted flow conditions up to bank-full level are influenced by bedrock in the channel downstream.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 20.7 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description Williams River near Rockingham, VT

USGS gage number 01153550

Gage drainage area 112 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 4,730 ***ft³/s*** ***Q500*** 6,930 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(20.7/21.3)exp 0.67] with flood frequency estimates available for the Williams River above Whitmore Brook from the Flood Insurance Study for Chester, VT (Federal Emergency Management Agency, February 1982). The drainage area for the Williams River above Whitmore Brook is 21.3 square miles. The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887). Each curve was extended graphically to the 500-year event.

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 upstream end of the pier (elev. 497.50 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the pier (elev. 497.54 ft, arbitrary survey datum). RM3 is a chiseled X on top of the downstream end of the right abutment (elev. 498.49 ft, arbitrary survey datum). RM4 is a chiseled X on the top right end of a bedrock outcrop, located 60 ft downstream in the middle of the channel (elev. 489.21 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]Cross-section	*Section Reference Distance (SRD) in feet*	*[2]Cross-section development*	*Comments*
EXIT2	-1149	2	Modelled Approach section for Bridge 53 (Templated from E2TEM)
E2TEM	-1143	1	Approach section as surveyed for Bridge 53 (Used as a template)
EXITX	-61	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	9	1	Road Grade section
APPRO	72	2	Modelled Approach section (Templated from APTEM)
APTEM	87	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.

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.051, and overbank "n" values ranged from 0.030 to 0.061.

Normal depth at the exit section (EXIT2) was based on a known water surface. The starting water surface was the approach water surface elevation from the model done for Bridge 53 in Chester (Striker and Medalie, 1997), downstream of this site.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0312 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.4 ***ft***
Average low steel elevation 496.8 ***ft***

100-year discharge 4,730 ***ft^3/s***
Water-surface elevation in bridge opening 497.3 ***ft***
Road overtopping? Yes ***Discharge over road*** 49 ***ft^3/s***
Area of flow in bridge opening 505 ***ft^2***
Average velocity in bridge opening 9.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.3 ***ft/s***

Water-surface elevation at Approach section with bridge 498.9
Water-surface elevation at Approach section without bridge 494.0
Amount of backwater caused by bridge 4.9 ***ft***

500-year discharge 6,930 ***ft^3/s***
Water-surface elevation in bridge opening 497.3 ***ft***
Road overtopping? Yes ***Discharge over road*** 1,400 ***ft^3/s***
Area of flow in bridge opening 505 ***ft^2***
Average velocity in bridge opening 11.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.2 ***ft/s***

Water-surface elevation at Approach section with bridge 500.3
Water-surface elevation at Approach section without bridge 495.1
Amount of backwater caused by bridge 5.2 ***ft***

Incipient overtopping discharge 4,380 ***ft^3/s***
Water-surface elevation in bridge opening 496.8 ***ft***
Area of flow in bridge opening 500 ***ft^2***
Average velocity in bridge opening 8.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.4 ***ft/s***

Water-surface elevation at Approach section with bridge 498.5
Water-surface elevation at Approach section without bridge 493.8
Amount of backwater caused by bridge 4.7 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

At this site, the 100-year, 500-year, and incipient roadway-overtopping discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for these discharges was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146).

For comparison, contraction scour also was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20) and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Results from these computations are presented in appendix F. Furthermore, for these discharges which resulted in unsubmerged orifice flow, contraction scour was computed by substituting estimates for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to these substitutions are provided in appendix F.

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

Scour at the right abutment was computed by use of the HIRE equation (Richardson and Davis, 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.

Pier scour was computed by use of an equation developed at Colorado State University (Richardson and Davis, 1995, p. 36, equation 21) for all discharges modelled. Variables for the pier scour equation include pier length, pier width, average depth and maximum velocity (for the Froude number) immediately upstream of the bridge, and correction factors for pier shape, flow attack angle, streambed-form, and streambed armoring.

Scour Results

Contraction scour:	*100-year discharge*	*500-year discharge*	*Incipient overtopping discharge*
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.8	0.0
Depth to armoring	N/A	21.9	N/A
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	13.7	14.5	13.3
Right abutment	20.4	23.4	19.9
Pier scour			
Pier 1	10.8	12.6	9.7
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	*500-year discharge*	*Incipient overtopping discharge*
		(D_{50} in feet)	
Abutments:			
Left abutment	2.7	3.1	2.6
Right abutment	2.7	3.1	2.6
Piers:			
Pier 1	2.4	3.4	2.2
Pier 2	--	--	--
	--	--	--

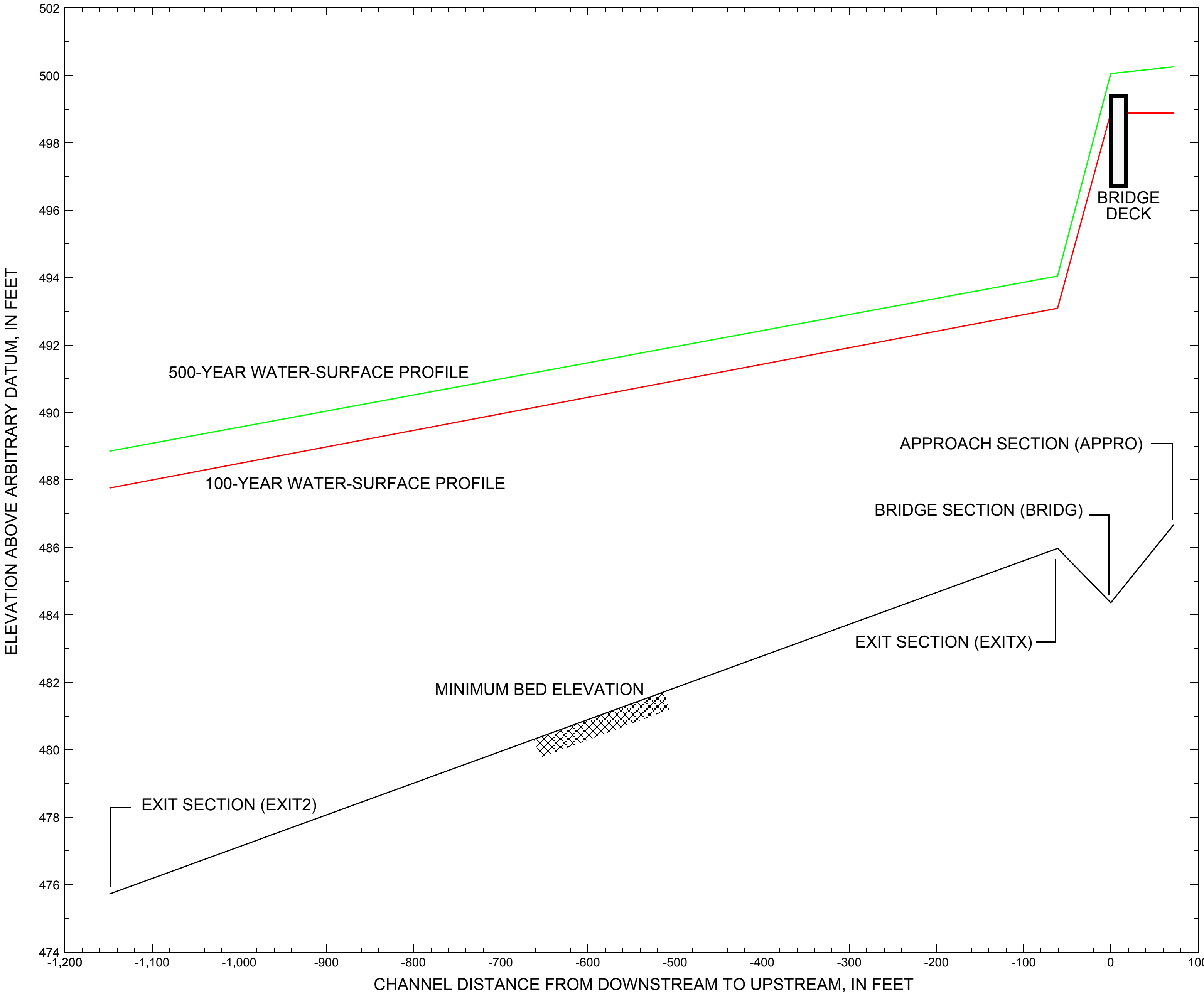

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure CHESTH00170075 on Town Highway 17, crossing the Williams River, Chester, Vermont.

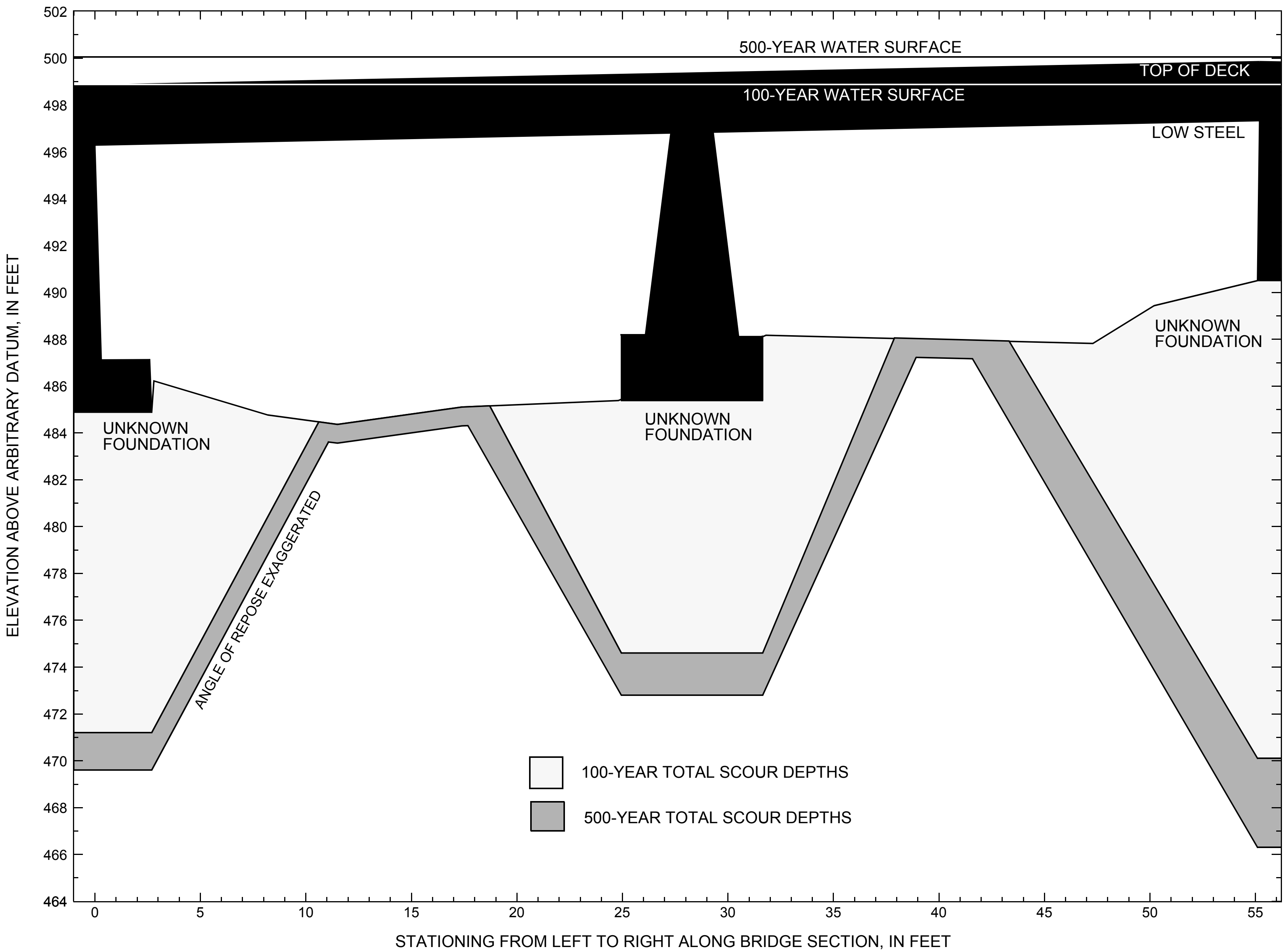

Figure 8. Scour elevations for the 100- and 500-year discharges at structure CHESTH00170075 on Town Highway 17, crossing the Williams River, Chester, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CHESTH00170075 on Town Highway 17, 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/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 4,730 cubic-feet per second											
Left abutment	0.0	--	496.3	--	484.9	0.0	13.7	--	13.7	471.2	--
Pier	28.3	--	--	--	485.4	0.0	--	10.8	10.8	474.6	--
Right abutment	55.2	--	497.3	--	490.5	0.0	20.4	--	20.4	470.1	--

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 CHESTH00170075 on Town Highway 17, 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/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 6,930 cubic-feet per second											
Left abutment	0.0	--	496.3	--	484.9	0.8	14.5	--	15.3	469.6	--
Pier	28.3	--	--	--	485.4	0.8	--	12.6	12.6	472.8	--
Right abutment	55.2	--	497.3	--	490.5	0.8	23.4	--	24.2	466.3	--

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

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APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File ches075.wsp
T2        Hydraulic analysis for structure CHESTH00170075   Date: 29-DEC-97
T3        TH 17 CROSSING THE WILLIAMS RIVER 0.02 TO JCT WITH VT 103, LKS
*
J1         * * 0.002
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           4730.0   6930.0    4380.0
WS          487.76   488.85    487.43
*
XT   E2TEM     -1143
GR          -64.3, 496.17    -46.1, 491.53    -40.7, 487.42     -6.1, 485.79
GR            0.0, 483.69     12.3, 476.91     13.2, 475.79     19.5, 476.47
GR           28.7, 476.39     37.3, 476.55     39.7, 476.94     46.5, 478.76
GR           54.8, 484.90    247.6, 487.57    347.6, 497.57
*
XS   EXIT2     -1149 * * * 0.0111
GT
N           0.030     0.050     0.030
SA                -6.1     54.8
*
XS   EXITX    -61           0.
GR         -255.8, 509.09   -156.1, 501.45   -142.7, 502.74   -115.9, 502.50
GR          -81.3, 498.60    -60.4, 497.14    -45.7, 488.62    -13.9, 489.64
GR            0.0, 491.79      7.0, 486.19     14.4, 486.22     23.9, 485.97
GR           45.6, 488.44     60.7, 488.16     72.3, 490.96     96.6, 489.49
GR          102.7, 489.33    158.7, 497.30    191.3, 495.85    248.9, 501.37
GR          357.3, 506.44
N           0.061        0.051        0.058
SA                 -60.4         72.3
*
XS   FULLV      0  * * *   0.0003
*
*              SRD     LSEL    XSSKEW
BR   BRIDG     0    496.81       0.0
GR            0.0, 496.29      0.3, 487.11      2.6, 487.12      2.8, 486.22
GR            2.8, 484.88      8.2, 484.76     11.5, 484.36     17.4, 485.10
GR           24.8, 485.38     31.8, 488.17     37.9, 488.05     47.3, 487.82
GR           50.2, 489.43     55.1, 490.50     55.2, 497.33      0.0, 496.29
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV   WWANGL
CD           4      17.3      1.8    499.3     47.6
PW        485.38, 6.7  488.18, 6.7  488.18, 4.4  496.72, 2.0
N           0.045
*
*              SRD    EMBWID   IPAVE
XR   RDWAY      9      14.0     2
GR         -172.4, 508.24   -169.2, 503.76   -155.2, 501.75   -137.0, 501.45
GR         -103.2, 502.65    -80.4, 498.78    -48.2, 498.51      0.0, 498.85
GR           28.7, 499.25     55.6, 499.85     97.2, 499.11    153.8, 498.58
GR          186.7, 499.06    277.0, 500.90    398.7, 508.77
*
XT   APTEM     87           0.
GR         -107.0, 507.04   -105.2, 505.42    -91.0, 501.13    -81.7, 501.14
GR          -55.1, 502.51    -29.5, 494.53     -8.6, 493.84      0.0, 493.52
GR            2.0, 491.35      6.8, 489.22     15.1, 488.21     15.3, 487.49
GR           16.2, 487.14     21.7, 487.47     31.1, 487.71     42.1, 487.67
GR           44.8, 487.72     47.9, 487.85
GR           69.0, 488.23     77.8, 491.61     98.5, 494.29    140.3, 491.33
GR          176.4, 495.87    234.1, 495.98    255.7, 499.05
GR          275.2, 499.94    356.0, 504.66    417.8, 507.69
*
```

```
AS   APPRO     72 * * * 0.0312
GT
N           0.043        0.051        0.035
SA                   0.0         77.8
*




HP 1 BRIDG   497.33 1 497.33
HP 2 BRIDG   497.33 * * 4688
HP 1 BRIDG   493.71 1 493.71
HP 2 RDWAY   498.88 * * 49
HP 1 APPRO   498.88 1 498.88
HP 2 APPRO   498.88 * * 4730
*
HP 1 BRIDG   497.33 1 497.33
HP 2 BRIDG   497.33 * * 5534
HP 1 BRIDG   494.77 1 494.77
HP 2 RDWAY   500.05 * * 1407
HP 1 APPRO   500.25 1 500.25
HP 2 APPRO   500.25 * * 6930
*
HP 1 BRIDG   496.84 1 496.84
HP 2 BRIDG   496.84 * * 4380
HP 1 BRIDG   493.54 1 493.54
HP 1 APPRO   498.54 1 498.54
HP 2 APPRO   498.54 * * 4380
HP 2 BRIDG   497.17 * * 4380
*
EX
ER
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APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

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WSPRO          FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188            MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ches075.wsp
        Hydraulic analysis for structure CHESTH00170075   Date: 29-DEC-97
        TH 17 CROSSING THE WILLIAMS RIVER 0.02 TO JCT WITH VT 103, LKS
           *** RUN DATE & TIME: 08-21-98  09:16

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     552.  48148.     0.   129.                            0.
   497.33          552.  48148.     0.   129.  1.00     0.    55.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.33     0.0    55.2   552.2   48148.    4688.   8.49

X STA.         0.0         5.5         7.4         9.4        11.3        13.2
  A(I)            55.2        22.7        23.3        22.8        22.7
  V(I)            4.24       10.33       10.04       10.27       10.34

X STA.        13.2        15.2        17.2        19.2        21.3        23.3
  A(I)            23.5        23.0        23.9        23.5        23.5
  V(I)            9.98       10.18        9.81        9.96        9.99

X STA.        23.3        25.4        27.6        30.3        33.4        36.4
  A(I)            22.9        24.5        26.1        27.1        27.1
  V(I)           10.24        9.56        8.98        8.65        8.65

X STA.        36.4        39.4        42.3        45.1        48.0        55.2
  A(I)            26.4        27.0        25.9        26.9        54.3
  V(I)            8.89        8.70        9.06        8.73        4.32

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     381.  39919.    55.    68.                         5694.
   493.71          381.  39919.    55.    68.  1.00     0.    55.   5694.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = RDWAY;  SRD =       9.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.88   -81.0   174.4    25.2     229.      49.   1.95

X STA.       -81.0       -68.3       -62.7       -58.7       -55.6       -52.8
  A(I)             1.9         1.3         1.0         0.9         0.9
  V(I)            1.32        1.92        2.37        2.64        2.69

X STA.       -52.8       -50.2       -47.7       -45.1       -42.3       -40.4
  A(I)             0.9         0.9         0.9         0.9         0.6
  V(I)            2.75        2.73        2.69        2.59        3.98

X STA.       -40.4       -39.0       -35.9       -32.4       -28.1        51.2
  A(I)             0.5         0.9         1.0         1.1         3.7
  V(I)            5.35        2.75        2.58        2.32        0.67

X STA.        51.2       142.9       149.2       153.5       158.0       174.4
  A(I)             2.1         1.4         1.2         1.2         2.0
  V(I)            1.17        1.71        2.03        2.03        1.25

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      72.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     194.  17605.    45.    46.                         2285.
             2     853. 120106.    78.    81.                        16016.
             3     851. 100186.   184.   185.                        10379.
   498.88         1898. 237897.   307.   311.  1.05   -45.   262.  26152.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      72.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.88   -45.0   262.2  1897.8  237897.    4730.   2.49

X STA.       -45.0        -9.3         7.5        15.6        22.2        28.9
  A(I)           141.3       117.3        87.3        79.1        78.3
  V(I)            1.67        2.02        2.71        2.99        3.02

X STA.        28.9        35.7        42.5        49.4        56.6        63.7
  A(I)            79.3        79.2        80.7        81.4        80.5
  V(I)            2.98        2.98        2.93        2.90        2.94

X STA.        63.7        71.2        82.0        95.0       111.4       124.1
  A(I)            82.2        91.5        82.3        89.6        81.9
  V(I)            2.88        2.58        2.87        2.64        2.89

X STA.       124.1       134.7       143.7       155.2       178.5       262.2
  A(I)            76.3        70.8        78.5       109.4       230.8
  V(I)            3.10        3.34        3.01        2.16        1.02
```

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ches075.wsp
        Hydraulic analysis for structure CHESTH00170075   Date: 29-DEC-97
        TH 17 CROSSING THE WILLIAMS RIVER 0.02 TO JCT WITH VT 103, LKS
           *** RUN DATE & TIME: 08-21-98  09:16

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     552.   48148.     0.   129.                           0.
   497.33          552.   48148.     0.   129.  1.00     0.    55.      0.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.33     0.0    55.2   552.2   48148.    5534.  10.02

X STA.        0.0        5.5        7.4        9.4       11.3       13.2
  A(I)            55.2       22.7       23.3       22.8       22.7
  V(I)            5.01      12.19      11.86      12.12      12.21

X STA.       13.2       15.2       17.2       19.2       21.3       23.3
  A(I)            23.5       23.0       23.9       23.5       23.5
  V(I)           11.78      12.01      11.57      11.75      11.79

X STA.       23.3       25.4       27.6       30.3       33.4       36.4
  A(I)            22.9       24.5       26.1       27.1       27.1
  V(I)           12.09      11.29      10.60      10.22      10.21

X STA.       36.4       39.4       42.3       45.1       48.0       55.2
  A(I)            26.4       27.0       25.9       26.9       54.3
  V(I)           10.50      10.26      10.69      10.31       5.10

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     440.   49591.    55.    70.                        7048.
   494.77          440.   49591.    55.    70.  1.00     0.    55.   7048.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = RDWAY;  SRD =       9.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.05   -87.9   235.3   314.6    8376.    1407.   4.47

X STA.      -87.9      -70.5      -60.7      -52.6      -44.9      -36.7
  A(I)            17.7       13.7       11.9       11.8       12.2
  V(I)            3.97       5.14       5.92       5.98       5.78

X STA.      -36.7      -27.9      -18.4       -8.0        3.9       13.3
  A(I)            12.5       12.9       13.4       14.5       10.1
  V(I)            5.61       5.44       5.23       4.85       6.99

X STA.       13.3       22.8       94.8      111.8      125.3      136.9
  A(I)             9.1       39.9       16.9       15.5       14.6
  V(I)            7.76       1.76       4.17       4.55       4.82

X STA.      136.9      147.1      156.4      166.5      178.5      235.3
  A(I)            13.9       13.3       13.8       14.3       32.7
  V(I)            5.07       5.29       5.09       4.92       2.15

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      72.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     258.   26669.    49.    50.                        3357.
             2     959.  146160.    78.    81.                       19111.
             3    1123.  145504.   211.   212.                       14713.
   500.25         2341.  318333.   338.   342.  1.04   -49.   289.  34290.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      72.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.25   -49.4   288.5  2340.7  318333.    6930.   2.96

X STA.      -49.4      -12.5        5.8       14.7       22.2       29.8
  A(I)           171.3      143.1      104.9      101.0       99.8
  V(I)            2.02       2.42       3.30       3.43       3.47

X STA.       29.8       37.4       44.9       52.7       60.6       68.5
  A(I)            98.4       98.3       99.6      100.8       99.6
  V(I)            3.52       3.53       3.48       3.44       3.48

X STA.       68.5       79.2       90.5      106.0      119.1      130.1
  A(I)           113.3       92.9      106.0       96.7       91.6
  V(I)            3.06       3.73       3.27       3.58       3.78

X STA.      130.1      139.9      150.1      163.9      190.6      288.5
  A(I)            87.9       89.7      100.5      139.1      306.4
  V(I)            3.94       3.86       3.45       2.49       1.13
```

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ches075.wsp
        Hydraulic analysis for structure CHESTH00170075   Date: 29-DEC-97
        TH 17 CROSSING THE WILLIAMS RIVER 0.02 TO JCT WITH VT 103, LKS
           *** RUN DATE & TIME: 08-21-98  09:16

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     546.  55034.    26.   103.                       14192.
   496.84          546.  55034.    26.   103.  1.00     0.    55.  14192.

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       496.84     0.0    55.2   545.9   55034.    4380.   8.02

X STA.         0.0        6.9         9.1        11.2        13.3        15.4
  A(I)            71.6        26.2        24.6        25.6        25.4
  V(I)            3.06        8.35        8.90        8.57        8.63

X STA.        15.4       17.7        19.9        22.2        24.5        26.7
  A(I)            26.0        25.9        26.0        26.4        24.0
  V(I)            8.43        8.47        8.44        8.31        9.11

X STA.        26.7       29.1        31.6        34.1        36.6        39.2
  A(I)            25.0        22.7        22.3        21.8        22.3
  V(I)            8.76        9.67        9.81       10.06        9.81

X STA.        39.2       41.6        44.0        46.4        48.9        55.2
  A(I)            21.7        21.1        21.4        22.0        44.1
  V(I)           10.09       10.38       10.23        9.96        4.97

    CROSS-SECTION PROPERTIES:  ISEQ =  4;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     372.  38428.    55.    67.                        5486.
   493.54          372.  38428.    55.    67.  1.00     0.    55.   5486.

    CROSS-SECTION PROPERTIES:  ISEQ =  6;  SECID = APPRO;  SRD =      72.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     179.  15642.    44.    45.                        2048.
             2     826. 113960.    78.    81.                       15276.
             3     790.  90669.   178.   178.                        9452.
   498.54         1795. 220271.   299.   303.  1.05   -44.   255.  24342.

    VELOCITY DISTRIBUTION:  ISEQ =  6;  SECID = APPRO;  SRD =      72.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.54   -43.9   255.4  1794.8  220271.    4380.   2.44

X STA.       -43.9       -8.1         7.9        16.0        22.2        28.8
  A(I)           135.5       109.2        85.2        72.3        75.8
  V(I)            1.62        2.00        2.57        3.03        2.89

X STA.        28.8       35.4        42.0        48.8        55.6        62.6
  A(I)            74.6        74.5        76.0        75.4        76.9
  V(I)            2.94        2.94        2.88        2.90        2.85

X STA.        62.6       69.7        80.0        91.9       109.6       122.7
  A(I)            76.6        88.9        75.6        90.2        78.5
  V(I)            2.86        2.46        2.90        2.43        2.79

X STA.       122.7      133.5       142.6       153.6       174.1       255.4
  A(I)            73.6        67.6        73.8        96.6       217.8
  V(I)            2.97        3.24        2.97        2.27        1.01

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       497.17     0.0    55.2   551.5   50321.    4380.   7.94

X STA.         0.0        5.8         7.8         9.9        11.8        13.8
  A(I)            59.3        23.4        24.1        23.6        23.2
  V(I)            3.69        9.35        9.07        9.27        9.43

X STA.        13.8       15.8        17.9        19.9        22.1        24.2
  A(I)            24.1        23.6        24.0        24.5        24.4
  V(I)            9.10        9.28        9.12        8.94        8.97

X STA.        24.2       26.5        29.0        32.1        35.3        38.4
  A(I)            25.1        26.2        28.3        28.2        27.7
  V(I)            8.72        8.36        7.73        7.76        7.91

X STA.        38.4       41.5        44.6        47.3        49.8        55.2
  A(I)            28.1        27.7        25.1        21.6        39.1
  V(I)            7.78        7.91        8.72       10.12        5.60
```

WSPRO OUTPUT FILE (continued)

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WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ches075.wsp
        Hydraulic analysis for structure CHESTH00170075   Date: 29-DEC-97
        TH 17 CROSSING THE WILLIAMS RIVER 0.02 TO JCT WITH VT 103, LKS
           *** RUN DATE & TIME: 08-21-98  09:16

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

EXIT2:XS   ******   -41.     892.  0.53 *****  488.29  484.40   4730.  487.76
    -1149. ******   250.   88867.  1.22 ***** *******    0.59    5.30

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "EXITX"     KRATIO =  0.57

EXITX:XS    1088.   -53.     705.  0.76  5.43  493.85 *******   4730.  493.09
      -61.  1088.   129.   50479.  1.08  0.11    0.02    0.63    6.71

FULLV:FV      61.   -54.     816.  0.57  0.43  494.27 *******   4730.  493.71
        0.    61.   133.   62943.  1.08  0.00    0.00    0.51    5.80
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      72.   -26.     617.  1.02  0.49  494.98 *******   4730.  493.96
       72.    72.   165.   52447.  1.12  0.23   -0.01    0.80    7.66
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   493.48     497.41     497.63     496.81

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

BRIDG:BR      61.     0.     505.  1.34 *****  498.67  493.44   4688.  497.33
        0. ******    55.   48148.  1.00 ***** *******    0.54    9.28

     TYPE PPCD FLOW      C     P/A    LSEL   BLEN   XLAB   XRAB
       4.   0.   5.  0.450  0.086  496.81 ****** ****** ******

    XSID:CODE     SRD   FLEN     HF    VHD     EGL      ERR       Q    WSEL
   RDWAY:RG        9.    58.   0.02  0.10  498.96     0.00     49.  498.88

             Q   WLEN    LEW     REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     34.    81.   -81.      0.   0.4   0.2   2.1   1.9   0.3   2.6
   RT:     15.    53.   121.    175.   0.3   0.2   1.9   1.9   0.2   2.6

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

APPRO:AS      55.   -45.    1899.  0.10  0.12  498.99  493.08   4730.  498.88
       72.    64.   262.  238121.  1.05  0.32    0.00    0.18    2.49

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD     LEW     REW       Q          K       AREA     VEL    WSEL
   EXIT2:XS    -1149.    -41.    250.   4730.    88867.      892.    5.30  487.76
   EXITX:XS      -61.    -53.    129.   4730.    50479.      705.    6.71  493.09
   FULLV:FV        0.    -54.    133.   4730.    62943.      816.    5.80  493.71
   BRIDG:BR        0.      0.     55.   4688.    48148.      505.    9.28  497.33
   RDWAY:RG        9.*******      34.     49.******************    2.00  498.88
   APPRO:AS       72.    -45.    262.   4730.   238121.     1899.    2.49  498.88

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS      FR#    YMIN     YMAX     HF     HO   VHD      EGL     WSEL
   EXIT2:XS     484.40     0.59  475.72   497.50************  0.53   488.29   487.76
   EXITX:XS   ********     0.63  485.97   509.09   5.43   0.11  0.76   493.85   493.09
   FULLV:FV   ********     0.51  485.99   509.11   0.43   0.00  0.57   494.27   493.71
   BRIDG:BR     493.44     0.54  484.36   497.33************  1.34   498.67   497.33
   RDWAY:RG   ***************  498.51   508.77   0.02******  0.10   498.96   498.88
   APPRO:AS     493.08     0.18  486.67   507.22   0.12   0.32  0.10   498.99   498.88
```

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ches075.wsp
        Hydraulic analysis for structure CHESTH00170075   Date: 29-DEC-97
        TH 17 CROSSING THE WILLIAMS RIVER 0.02 TO JCT WITH VT 103, LKS
           *** RUN DATE & TIME: 08-21-98  09:16

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

EXIT2:XS   ******   -43.    1216.  0.55 *****  489.40  487.62   6930.  488.85
    -1149. ******   261.  135438.  1.10 ***** *******    0.53    5.70

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "EXITX"     KRATIO =  0.52

EXITX:XS    1088.   -55.     884.  1.03  5.43  495.08 *******   6930.  494.05
      -61.  1088.   136.   71044.  1.08  0.24    0.01    0.67    7.84

FULLV:FV      61.   -56.    1020.  0.78  0.47  495.54 *******   6930.  494.77
        0.    61.   141.   87955.  1.08  0.00   -0.01    0.55    6.80
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      72.   -33.     837.  1.17  0.50  496.22 *******   6930.  495.06
       72.    72.   174.   79012.  1.10  0.20   -0.01    0.76    8.28
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   500.78       0.00     495.36     498.51

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   494.75     499.59     499.79     496.81

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

BRIDG:BR      61.     0.     505.  1.87 *****  499.20  494.21   5534.  497.33
        0. ******    55.   48148.  1.00 ***** *******    0.64   10.96

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       4.   0.   5.  0.484  0.086  496.81 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD      EGL      ERR       Q   WSEL
   RDWAY:RG        9.    58.  0.03  0.14  500.36     0.00   1407.  500.05

             Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    642.   110.   -88.    22.   1.5   1.3   5.6   4.6   1.6   3.0
   RT:    765.   213.    22.   235.   1.5   0.8   4.7   4.3   1.1   3.0

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

APPRO:AS      55.   -49.    2340.  0.14  0.17  500.39  494.36   6930.  500.25
       72.    66.   288.  318123.  1.04  0.27    0.00    0.20    2.96

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

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

   FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT2:XS    -1149.   -43.   261.   6930.  135438.    1216.    5.70  488.85
   EXITX:XS      -61.   -55.   136.   6930.   71044.     884.    7.84  494.05
   FULLV:FV        0.   -56.   141.   6930.   87955.    1020.    6.80  494.77
   BRIDG:BR        0.     0.    55.   5534.   48148.     505.   10.96  497.33
   RDWAY:RG        9.*******   642.   1407.******************    2.00  500.05
   APPRO:AS       72.   -49.   288.   6930.  318123.    2340.    2.96  500.25

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

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS      FR#    YMIN     YMAX     HF     HO  VHD      EGL    WSEL
   EXIT2:XS     487.62     0.53  475.72  497.50************  0.55  489.40  488.85
   EXITX:XS   ********     0.67  485.97  509.09  5.43  0.24  1.03  495.08  494.05
   FULLV:FV   ********     0.55  485.99  509.11  0.47  0.00  0.78  495.54  494.77
   BRIDG:BR     494.21     0.64  484.36  497.33************  1.87  499.20  497.33
   RDWAY:RG   ****************  498.51  508.77  0.03******  0.14  500.36  500.05
   APPRO:AS     494.36     0.20  486.67  507.22  0.17  0.27  0.14  500.39  500.25
```

WSPRO OUTPUT FILE (continued)

```
WSPRO         FEDERAL HIGHWAY ADMINISTRATION - U. S. GEOLOGICAL SURVEY
V060188             MODEL  FOR  WATER-SURFACE  PROFILE  COMPUTATIONS

        U.S. Geological Survey WSPRO Input File ches075.wsp
        Hydraulic analysis for structure CHESTH00170075   Date: 29-DEC-97
        TH 17 CROSSING THE WILLIAMS RIVER 0.02 TO JCT WITH VT 103, LKS
           *** RUN DATE & TIME: 08-21-98  09:16

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

EXIT2:XS   ******   -41.     796.  0.59 *****  488.02  484.04   4380.  487.43
    -1149. ******   242.   77646.  1.25 ***** *******    0.65    5.50

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

EXITX:XS    1088.   -53.     683.  0.69  5.59  493.66 *******   4380.  492.97
      -61.  1088.   128.   48097.  1.08  0.05    0.00    0.61    6.42

FULLV:FV      61.   -54.     785.  0.52  0.41  494.07 *******   4380.  493.54
        0.    61.   132.   59425.  1.08  0.00    0.00    0.50    5.58
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      72.   -21.     585.  0.97  0.47  494.76 *******   4380.  493.78
       72.    72.   164.   48989.  1.12  0.23   -0.01    0.78    7.49
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   493.17     496.84     497.08     496.81

 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

BRIDG:BR      61.     0.     500.  1.19 *****  498.03  493.17   4376.  496.84
        0. ******    55.   55050.  1.00 ***** *******    0.51    8.76

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       4.   0.   2.  0.437  0.085  496.81 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       9.          <<<<<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      55.   -44.    1794.  0.10  0.10  498.64  492.83   4380.  498.54
       72.    64.   255.  220192.  1.05  0.33    0.00    0.18    2.44

       M(G)   M(K)        KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   498.52

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD     LEW    REW       Q        K      AREA     VEL    WSEL
   EXIT2:XS   -1149.    -41.   242.   4380.   77646.     796.    5.50  487.43
   EXITX:XS     -61.    -53.   128.   4380.   48097.     683.    6.42  492.97
   FULLV:FV       0.    -54.   132.   4380.   59425.     785.    5.58  493.54
   BRIDG:BR       0.      0.    55.   4376.   55050.     500.    8.76  496.84
   RDWAY:RG       9.**************      0.       0.        0.    2.00********
   APPRO:AS      72.    -44.   255.   4380.  220192.    1794.    2.44  498.54

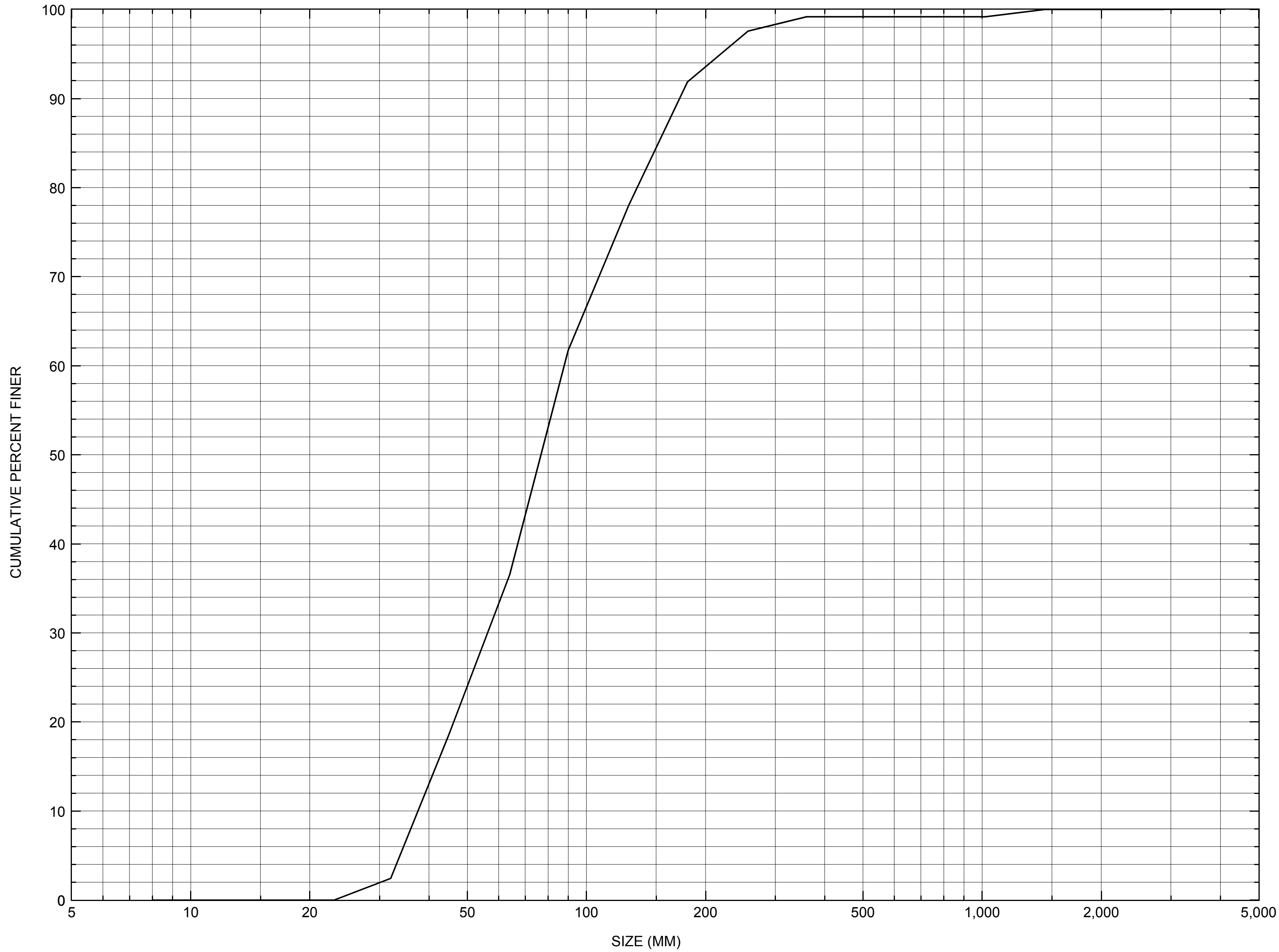
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS      FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT2:XS    484.04    0.65  475.72  497.50************  0.59  488.02  487.43
   EXITX:XS  ********    0.61  485.97  509.09  5.59  0.05  0.69  493.66  492.97
   FULLV:FV  ********    0.50  485.99  509.11  0.41  0.00  0.52  494.07  493.54
   BRIDG:BR    493.17    0.51  484.36  497.33************  1.19  498.03  496.84
   RDWAY:RG  ****************  498.51  508.77************  0.10  498.61********
   APPRO:AS    492.83    0.18  486.67  507.22  0.10  0.33  0.10  498.64  498.54
  ER
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CHESTH00170075, in Chester, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number **CHESTH00170075**

General Location Descriptive

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

Date *(MM/DD/YY)* **04** / **06** / **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)* **000000**

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

Road Name *(I - 7):* **-**

Route Number **TH017**

Vicinity *(I - 9)* **0.02 MI TO JCT W VT103**

Topographic Map **Chester**

Hydrologic Unit Code: **01080107**

Latitude *(I - 16; nnnn.n)* **43178**

Longitude *(i - 17; nnnnn.n)* **72363**

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* **10140700751407**

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

Maximum span length *(I - 48; nnnn)* **0029**

Year built *(I - 27; YYYY)* **1930**

Structure length *(I - 49; nnnnnn)* **000063**

Average daily traffic, ADT *(I - 29; nnnnnn)* **000035**

Deck Width *(I - 52; nn.n)* **140**

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

Channel & Protection *(I - 61; n)* **4**

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

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

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

Underwater Inspection Frequency *(I - 92B; XYY)* **Y12**

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

Year Reconstructed *(I - 106)* **1968**

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

Clear span (*nnn.n ft*) **56.0**

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

Vertical clearance from streambed (*nnn.n ft*) **12.0**

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

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

Comments:

The structural inspection report of 09/23/95 indicates the structure is a two span, steel beam type bridge with a timber deck. The footing is exposed along the left abutment, and the downstream end is undermined. The undermining extends roughly two feet behind the front face of footing. There apparently are some slabs of bedrock directly below the undermined area. There is a bedrock outcrop just downstream of the abutment. The upstream left wingwall is founded on bedrock or a massive boulder. There are some rocks cast into the left abutment footing, directly below the centerline of the roadway. The pier is solid concrete and the footing is exposed. It appears that the upstream end of the pier **(Continued, page 34)**

Bridge Hydrologic Data

Is there hydrologic data available? Y *if No, type ctrl-n h* VTAOT Drainage area *(mi^2)*: 23.8

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} 3000 Q_{25} 3700

Q_{50} 4400 Q_{100} 5200 Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

Upstream distance (*miles*): 0.4 Town: Chester Year Built: 1969

Highway No. : TH18 Structure No. : 62 Structure Type: I-beam

Clear span (*ft*): 30 Clear Height (*ft*): 11 Full Waterway (*ft^2*):

Downstream distance (*miles*): **0.5** Town: **Chester** Year Built: **1938**

Highway No. : **TH118** Structure No. : **53** Structure Type: **I beam**

Clear span (*ft*): **38** Clear Height (*ft*): **7.5** Full Waterway (ft^2): **-**

Comments:

was undermined at one time, and the entire stem and footing settled roughly 12 - 18 inches. There are no settlement cracks in the concrete. The streambed drops from 6 inches below the top of footing at the upstream end to about 2.5 below that at the downstream end under the left span. There is a fairly high gravel point bar beneath the right span. Presently, all of the flow is beneath the left span. The waterway takes a moderate to sharp turn into the structure. There is a gravel bar, which has some minor vegetation growing along it, just upstream of the left abutment. There is a bedrock outcrop across the channel roughly 100 feet downstream. Roughly 50 feet upstream, there is a short concrete wall **(Continued, page 35)**

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **20.73** mi^2 Lake/pond/swamp area **0.03** mi^2

Watershed storage *(ST)* **0.2** %

Bridge site elevation **640** ft Headwater elevation **2854** ft

Main channel length **13.03** mi

10% channel length elevation **680** ft 85% channel length elevation **1700** ft

Main channel slope *(S)* **104.44** 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:

across the channel. It may be a check dam of some sort. The underwater bridge inspection report of 07/20/94 indicated scour under the pier with a 12 inch maximum depth of undermining reported. The scour extends a length of 20 feet from the upstream end of the pier along the channel flow. Penetration ranging from 12 - 24 inches under the footing is possible on the left side of the pier.

Cross-sectional Data

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

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

Comments: **The measurements are in feet.**

Station	232	246	258	262	274	288	-	--	-	-	-
Feature	LCL	-	-	-	-	LCR	-	-	-	-	-
Low chord elevation	642.5	642.5	642.5	642.6	642.6	642.6	-	-	-	-	-
Bed elevation	632.6	632.1	634.2	634.7	636.1	635.8	-	-	-	-	-
Low chord to bed	9.9	10.4	8.3	7.9	6.5	6.8	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments: -

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **01/23/97**
Computerized by: **RB** Date: **04/24/97**
Reviewd by: **RB** Date: **05/27/98**

Structure Number **CHESTH00170075**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **J** . **DEGNAN** Date *(MM/DD/YY)* **08** / **22** / 19**96**

2. Highway District Number **02** Mile marker **0000**

County **Windsor (027)** Town **Chester (13675)**

Waterway *(I - 6)* **Williams River** Road Name **Wymans Falls Rd.**

Route Number **TH017** Hydrologic Unit Code: **01080107**

3. Descriptive comments:
This is a single lane timber deck bridge with one pier. The bridge is located 0.02 miles to the junction with VT 103.

B. Bridge Deck Observations

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

5. Ambient water surface... US **2** UB **1** DS **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 **63** *(feet)* Span length **29** *(feet)* Bridge width **14** *(feet)*

Road approach to bridge:

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

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

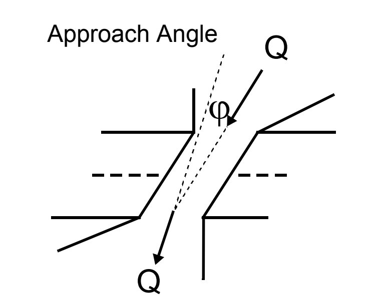
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

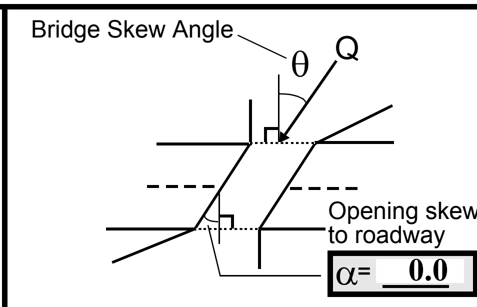
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	2	1
RBUS	2	1	1	1
RBDS	2	2	1	1
LBDS	2	1	3	1

*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: **15** 16. Bridge skew: **20**





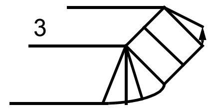
17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **2**
Range? **50** feet **US** *(US, UB, DS)* to **0** feet **DS**

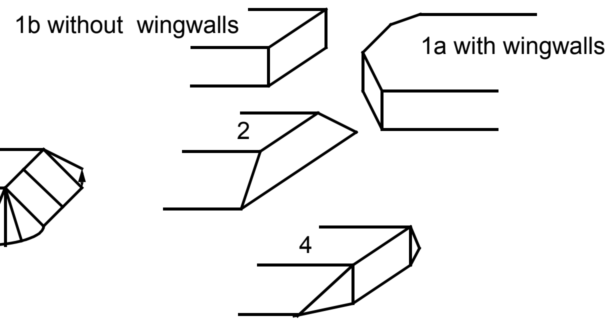
Channel impact zone 2: Exist? **N** *(Y or N)*
Where? **-** *(LB, RB)* Severity **-**
Range? **-** feet **-** *(US, UB, DS)* to **-** feet **-**

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

18. Bridge Type: **4**

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





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

4. There are shrubs, brush, and trees along the banks DS.
5. Downstream of the DS bedrock control, the water surface becomes a riffle again.
7. The bridge dimension values were taken from VTAOT. The measured bridge dimensions are the same.
8. The right road approach is lower immediately off the deck and then begins to rise after the intersection between TH 17 and TH 45 (Bailey's Mill Road).
18. There is only one wingwall, the US left wingwall.

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	**4.5**			**3.5**	**1**	**1**	**263**	**23**	**1**	**1**

23. Bank width **25.0** 24. Channel width **20.0** 25. Thalweg depth **78.5** 29. Bed Material **432**

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.):

27. The left bank has bedrock outcrops from 270 ft US to 158 ft US and from 50 ft US to 28 ft US.
29. From 270 ft US to 154 ft US there is bedrock in the channel.
30. The left bank protection extends from 28 ft US to 0 ft US. It is dumped stone along the wingwall base. There is a 1.5 ft high concrete drop structure at 70 ft US. Local residents report that it was installed to protect a water pipe that is no longer in use. At ambient flows, water pools as far US as 255 ft, as a result of the drop structure. The drop structure has deteriorated and water passes through the left half, which is a few tenths of a foot lower.

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

36. Point bar extent: **32** feet **US** *(US, UB)* to **60** feet **DS** *(US, UB, DS)* positioned **40** %LB to **100** %RB

37. Material: **342**

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

The point bar ends at the DS bedrock control. There is a center channel bar from 70 ft US to 15 ft US with a mid-bar distance of 45 ft and a width of 25 ft. The bar is made of cobbles, gravel, and sand.

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

41. Mid-bank distance: **150** 42. Cut bank extent: **158** feet **US** *(US, UB)* to **125** 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.):

The cut bank is a result of eddy currents at the DS end of the left bank bedrock outcrop.

45. Is channel scour present? **Y** *(Y or if N type ctrl-n cs)* 46. Mid-scour distance: **150**

47. Scour dimensions: Length **45** Width **20** Depth : **4** Position **10** %LB to **65** %RB

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

The channel scour is DS of the bedrock bed support and US of the drop structure. The scour extent is 160 ft US to 115 ft US. There is local scour around boulders. The scour depth is based on an average thalweg of 0.5 ft.

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 upstream at this site.

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
62.0		**0.5**		**2**	**7**	**7**	**-**

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

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

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

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

432

The scour hole under the bridge is described in the DS channel assessment.

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 1____ (1- Low; 2- Moderate; 3- High)

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

70. Debris and Ice Comments:

2

The upstream point bars and pier increase the ice blockage potential and the capture efficiency of the bridge.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		20	90	2	2	0	2	90.0
RABUT	1	0	90			0	0	55.0

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

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

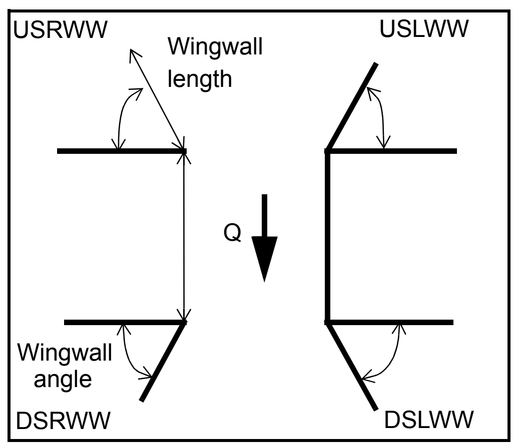
0
0
1

A local resident reported that the left abutment was undermined, but at the time of this assessment, stone fill was found on the US half of the abutment and the US left wingwall leaving only the top of the footing exposed.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						55.0	
USRWW:	Y		1		2	2.0	
DSLWW:	0		0.5		N	17.5	
DSRWW:	-		-		-	17.0	

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



82. Bank / Bridge Protection:

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

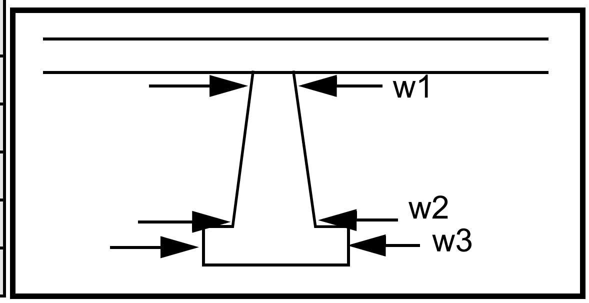
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

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			-	**50.0**	**17.5**	-
Pier 2	-	-	**2.0**	-	-	-
Pier 3	**4.4**	**6.7**	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e pro-**	**d on**	**The**	**half of**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**tec-**	**the**	**left**	**the**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**tion**	**left**	**abut**	**abut**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**is an**	**bank**	**ment**	**ment**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**exte**	**in**	**pro-**	**.**	*Y- yes; N- no*
91. Attack ∠ (BF)	**nsio**	**the**	**tec-**		
92. Pushed	**n of**	**US**	**tion**		*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**the**	**chan**	**exte**		
95. Cross-members	**pro-**	**nel**	**nds**		***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**tec-**	**asses**	**alon**		***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**tion**	**smen**	**g the**		
98. Exposure depth	**note**	**t.**	**US**		

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

Y
MCM
1
2
3
Y
5
LB

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
-	-			-	0	0	4	0	2.5	-

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

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

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

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

101. Is a drop structure present? - *(Y or N, if N type ctrl-n ds)* 102. Distance: 23.1 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 Th %LB to e %RB

Material: pie

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

r has settled US leaving the exposed footing higher at the DS end. A concrete shim has been added to the top US end to create a level surface for the bridge. The left side of the pier footing has 0.5 ft of horizontal penetration along the entire base length of the footing.

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

Cut bank extent: _____ feet ____ (US, UB, DS) to _____ feet 3 (US, UB, DS)

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

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

643
32
1
1

Is channel scour present? 364 (Y or if N type ctrl-n cs) Mid-scour distance: 2

Scour dimensions: Length 0 Width 1 Depth: - Positioned The %LB to left %RB

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

bank protection extends from 0 ft DS to 10 ft DS. It is the same protection noted in the road approach section. The left bank consists of a bedrock outcrop from 10 ft DS to 72 ft DS. Bedrock in the channel bed is from 28 ft DS to 75 ft DS. The greatest channel constriction due to the bedrock is at 63 ft DS.

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

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

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

N

-

NO DROP STRUCTURE

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: CHESTH00170075            Town:    CHESTER
Road Number:      TH 17                     County:  WINDSOR
Stream:  WILLIAMS RIVER

Initials RLB      Date:    4/24/98  Checked: MAI
```

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 Davis, 1995, p. 28, eq. 16)

Approach Section

Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	4730	6930	4380
Main Channel Area, ft2	853	959	826
Left overbank area, ft2	194	258	179
Right overbank area, ft2	851	1123	790
Top width main channel, ft	78	78	78
Top width L overbank, ft	45	49	44
Top width R overbank, ft	184	211	178
D50 of channel, ft	0.2518	0.2518	0.2518
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	10.9	12.3	10.6
y1, average depth, LOB, ft	4.3	5.3	4.1
y1, average depth, ROB, ft	4.6	5.3	4.4
Total conveyance, approach	237897	318333	220271
Conveyance, main channel	120106	146160	113960
Conveyance, LOB	17605	26669	15642
Conveyance, ROB	100186	145504	90669
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	2388.0	3181.9	2266.0
Ql, discharge, LOB, cfs	350.0	580.6	311.0
Qr, discharge, ROB, cfs	1992.0	3167.6	1802.9
Vm, mean velocity MC, ft/s	2.8	3.3	2.7
Vl, mean velocity, LOB, ft/s	1.8	2.3	1.7
Vr, mean velocity, ROB, ft/s	2.3	2.8	2.3
Vc-m, crit. velocity, MC, ft/s	10.5	10.8	10.5
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

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	4688	5534	4380
Main channel area (DS), ft2	334.9	433.9	325.9
Main channel width (normal), ft	55.2	55.2	55.2
Cum. width of piers, ft	3.2	3.2	3.2
Adj. main channel width, ft	52.0	52.0	52.0
D90, ft	0.5639	0.5639	0.5639
D95, ft	0.7168	0.7168	0.7168
Dc, critical grain size, ft	0.8107	0.6076	0.7556
Pc, Decimal percent coarser than Dc	0.030	0.077	0.041
Depth to armoring, ft	N/A	21.85	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 Davis, 1995, p. 32, eq. 20, 20a)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	4730	6930	4380
(Q) discharge thru bridge, cfs	4688	5534	4380
Main channel conveyance	48148	48148	55034
Total conveyance	48148	48148	55034
Q2, bridge MC discharge,cfs	4688	5534	4380
Main channel area, ft2	505	505	500
Main channel width (normal), ft	55.2	55.2	55.2
Cum. width of piers in MC, ft	3.2	3.2	3.2
W, adjusted width, ft	52	52	52
y_bridge (avg. depth at br.), ft	9.71	9.71	9.62
Dm, median (1.25*D50), ft	0.31475	0.31475	0.31475
y2, depth in contraction,ft	8.16	9.41	7.70
ys, scour depth (y2-ybridge), ft	-1.55	-0.30	-1.92

Pressure Flow Scour (contraction scour for orifice flow conditions)

Chang pressure flow equation   Hb+Ys=Cq*qbr/Vc
Cq=1/Cf*Cc   Cf=1.5*Fr^0.43 (<=1)   Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79 (<=1)
Umbrell pressure flow equation
(Hb+Ys)/ya=1.1021*[(1-w/ya)*(Va/Vc)]^0.6031
(Richardson and Davis, 1995, p. 144-146)

	Q100	Q500	OtherQ
Q, total, cfs	4730	6930	4380
Q, thru bridge MC, cfs	4688	5534	4380
Vc, critical velocity, ft/s	10.55	10.75	10.49
Va, velocity MC approach, ft/s	2.80	3.32	2.74
Main channel width (normal), ft	55.2	55.2	55.2
Cum. width of piers in MC, ft	3.2	3.2	3.2
W, adjusted width, ft	52.0	52.0	52.0
qbr, unit discharge, ft2/s	90.2	106.4	84.2
Area of full opening, ft2	505.0	505.0	500.0
Hb, depth of full opening, ft	9.71	9.71	9.62
Fr, Froude number, bridge MC	0.54	0.64	0.51
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
**Area at downstream face, ft2	334.9	433.9	325.9
**Hb, depth at downstream face, ft	6.44	8.34	6.27
**Fr, Froude number at DS face	0.97	0.78	0.95
**Cf, for downstream face (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	496.81	496.81	496.81
Elevation of Bed, ft	487.10	487.10	487.19
Elevation of Approach, ft	498.88	500.25	498.54
Friction loss, approach, ft	0.12	0.17	0.1
Elevation of WS immediately US, ft	498.76	500.08	498.44
ya, depth immediately US, ft	11.66	12.98	11.25
Mean elevation of deck, ft	499.35	499.35	499.35
w, depth of overflow, ft (>=0)	0.00	0.73	0.00
Cc, vert contrac correction (<=1.0)	0.96	0.94	0.96
**Cc, for downstream face (<=1.0)	0.79	0.900035	0.79
Ys, scour w/Chang equation, ft	-0.76	0.79	-1.27
Ys, scour w/Umbrell equation, ft	-3.94	-2.91	-4.10

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

**Ys, scour w/Chang equation, ft	4.38	2.65	3.90
**Ys, scour w/Umbrell equation, ft	-0.66	-1.55	-0.75

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

y2, from Laursen’s equation, ft	8.16	9.41	7.70
WSEL at downstream face, ft	493.71	494.77	493.54
Depth at downstream face, ft	6.44	8.34	6.27
Ys, depth of scour (Laursen), ft	1.72	1.06	1.43

Abutment Scour

Froehlich's Abutment Scour
Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1
(Richardson and Davis, 1995, p. 48, eq. 28)

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	4730	6930	4380	4730	6930	4380
a', abut.length blocking flow, ft	56.3	60.7	55.2	195.7	222	188.9
Ae, area of blocked flow ft2	293.28	311.58	280.46	954.8	1192.37	897.12
Qe, discharge blocked abut.,cfs	--	--	529.93	--	--	2069.7
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.95	2.39	1.89	2.37	2.84	2.31
ya, depth of f/p flow, ft	5.21	5.13	5.08	4.88	5.37	4.75
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	1	1	1
--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	0.149	0.169	0.148	0.188	0.211	0.187
ys, scour depth, ft	13.66	14.48	13.30	24.42	28.75	23.62

HIRE equation (a'/ya > 25)
ys = 4*Fr^0.33*y1*K/0.55
(Richardson and Davis, 1995, p. 49, eq. 29)

Characteristic	Left 100 yr Q	500 yr Q	Other Q	Right 100 yr Q	500 yr Q	Other Q
a'(abut length blocked, ft)	56.3	60.7	55.2	195.7	222	188.9
y1 (depth f/p flow, ft)	5.21	5.13	5.08	4.88	5.37	4.75
a'/y1	10.81	11.83	10.86	40.11	41.33	39.78
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.15	0.17	0.15	0.19	0.21	0.19
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	20.44	23.38	19.85
vertical w/ ww's	ERR	ERR	ERR	16.76	19.17	16.27
spill-through	ERR	ERR	ERR	11.24	12.86	10.92

Abutment riprap Sizing

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

Characteristic	Q100	Q500	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.97	0.78	0.95	0.97	0.78	0.95
y, depth of flow in bridge, ft	6.44	8.34	6.27	6.44	8.34	6.27
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	3.14	ERR	ERR	3.14	ERR
Fr>0.8 (vertical abut.)	2.67	ERR	2.58	2.67	ERR	2.58

Pier Scour

ys/y1=2.0*K1*K2*K3*K4*(a/y1)^0.65*Fr1^0.43
(Richardson and Davis, 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	28.3	28.3	28.3
Area of WSPRO flow tube, ft2	22.7	22.7	23.2
Skewed width of flow tube, ft	1.9	1.9	2
y1, pier approach depth, ft	11.95	11.95	11.60
y1 in meters	3.641	3.641	3.536
V1, pier approach velocity, ft/s	10.34	12.2	9.43
a, pier width, ft	4.4	4.4	4.4
L, pier length, ft	23.12	23.12	23.12
Fr1, Froude number at pier	0.527	0.622	0.488
Pier attack angle, degrees	5	5	5
K1, shape factor	0.9	0.9	0.9
K2, attack factor	1.28	1.28	1.28
K3, bed condition factor	1.1	1.1	1.1
D50, ft	0.2518	0.2518	0.2518
D50, m	0.076745	0.076745	0.076745
D90, ft	0.5639	0.5639	0.5639
D90, m	0.171868	0.171868	0.171868
Vc50,critical velocity(D50),m/s	3.263	3.263	3.247
Vc90,critical velocity(D90),m/s	4.269	4.269	4.248
Vi,incipient velocity,m/s	1.808	1.808	1.800
Vr, velocity ratio	0.546	0.776	0.439
K4, armor factor	0.90	0.98	0.85
ys, scour depth (K4 applicable) ft	10.82	12.56	9.72
ys, scour depth (K4 not applied)ft	ERR	ERR	ERR

Pier rip-rap sizing
D50=0.692(K*V)^2/(Ss-1)*2*g
(Richardson and Davis, 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	12.9	15.3	12.3
Used 1.4 to adjust velocity			
D50, median stone diameter, ft	2.44	3.43	2.22