LEVEL II SCOUR ANALYSIS FOR BRIDGE 7 (CHESTH00030007) on TOWN HIGHWAY 3 (VT35), crossing the SOUTH BRANCH WILLIAMS RIVER, CHESTER, VERMONT

U.S. Geological Survey
Open-File Report 97-362

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

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By Ronda L. Burns

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Pembroke, New Hampshire

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

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 7 (CHESTH00030007) ON TOWN HIGHWAY 3 (VT 35), CROSSING THE SOUTH BRANCH WILLIAMS RIVER, CHESTER, VERMONT

By **Ronda L. Burns**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CHESTH00030007 on Town Highway 3 which is also State Route 35 crossing the South Branch Williams River, Chester, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (U.S. Department of Transportation, 1993). Results of a Level I scour investigation also are included in Appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in Appendix D.

The site is in the New England Upland section of the New England physiographic province in southern Vermont. The 10.4-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture on the upstream right bank while the immediate bank has some trees. Downstream of the bridge and the upstream left bank are forested.

In the study area, the South Branch Williams River has an incised, sinuous channel with a slope of approximately 0.03 ft/ft, an average channel top width of 65 ft and an average bank height of 4 ft. The channel bed material ranges from gravel to boulder with a median grain size (D_{50}) of 70.5 mm (0.231 ft). The geomorphic assessment at the time of the Level I and Level II site visit on August 26, 1996, indicated that the reach was laterally unstable. There are cutbanks on both the left and right banks alternating with point bars in the upstream reach.

The Town Highway 3 (VT 35) crossing of the South Branch Williams River is a 74-ft-long, two-lane bridge consisting of one 72-foot steel-beam span (Vermont Agency of Transportation, written communication, March 30, 1995). The bridge is supported by spill-through abutments. The channel is skewed approximately 5 degrees to the opening and the opening-skew-to-roadway is also 5 degrees.

Three channel scour holes 1.0 ft deeper than the mean thalweg depth were observed during the Level I assessment in the upstream reach. There are no scour protection measures at the site. Additional details describing conditions at the site are included in the Level II Summary and Appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.0 to 0.4 ft. The worst-case contraction scour occurred at the 100-year. Abutment scour ranged from 4.1 to 15.5 ft. The worst-case abutment scour occurred at the 500-year. 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.

Ludlow, VT. Quadrangle, 1:62,500, 1929 and Saxtons River, VT. Quadrangle, 1:62,500, 1957

NORTH

Figure 1. Location of study area on USGS 1:62,5000 scale map.

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

LEVEL II SUMMARY

Structure Number CHESTH00030007 ***Stream*** South Branch Williams River

County Windsor ***Road*** TH 3 ***District*** 2

Description of Bridge

Bridge length 74 ***ft*** ***Bridge width*** 27.4 ***ft*** ***Max span length*** 72 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 08/26/96

Description of stone fill

Abutments are concrete with stone spill-through slopes in front.

Y 5

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

There is a mild 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	08/26/96	0	0
Level II	08/26/96	0	0

Potential for debris Moderate. There is some debris caught on the stone spill-through slopes and on the upstream banks.

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

None 08/26/96.

Description of the Geomorphic Setting

General topography The channel is located within a narrow valley with steep valley walls on both sides.

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

Date of inspection 08/26/96

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

DS right: Steep valley wall

US left: Steep valley wall

US right: Moderately sloped overbank

Description of the Channel

Average top width 65 *ft* ***Average depth*** 4 *ft*

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

Sinuous with semi-alluvial to non-alluvial channel boundaries and a narrow flood plain.

08/26/96

Vegetative co Trees and brush

DS left: Trees

DS right: Trees

US left: Short grass with trees along the immediate bank.

US right:

Do banks appear stable? N ***If no, describe location and type of instability and date of observation.***

Upstream of the bridge is a pattern of alternating point bars and cutbanks (08/26/96).

Describe any obstructions in channel and date of observation.

The assessment of 08/26/96 noted low flow conditions are influenced by a small stone dam across the channel upstream. In addition, there are dry anabranch channels both upstream and downstream of the bridge.

Hydrology

Drainage area 10.4 ***mi***^{2}

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? No

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi***^{2}

Is there a lake/p No

Calculated Discharges

Q100 2,950 ***ft***^{3}***/s*** ***Q500*** 4,330 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on a drainage area relationship [(10.4/9.5)exp 0.68] with bridge number 10 in Chester. Bridge number 10 crosses the South Branch Williams River upstream of this site and has flood frequency estimates available in the Flood Insurance Study for the town of Chester (Federal Emergency Management Agency, 1982). The drainage area above bridge number 10 is 9.5 square miles. These values are within a range defined by several empirical flood frequency curves (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans Subract 396.0 ft. from the USGS survey to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the upstream end of the left abutment (elev. 497.55 ft, arbitrary survey datum). RM2 is a chiseled X on top of the downstream end of the right abutment (elev. 500.46 ft, arbitrary survey datum).

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXITX	-62	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	15	1	Road Grade section
APPRO	103	2	Modelled Approach section (Templated from APTEM)
APTEM	99	1	Approach section as surveyed (Used as a template)

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

Data and Assumptions Used in WSPRO Model

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

Channel roughness factors (Manning's "n") used in the hydraulic model were estimated using field inspections at each cross section following the general guidelines described by Arcement and Schneider (1989). Final adjustments to the values were made during the modelling of the reach. Channel "n" values for the reach ranged from 0.045 to 0.060, and overbank "n" values ranged from 0.035 to 0.070.

Critical depth at the exit section (EXITX) was assumed as the starting water surface. Normal depth at the exit section was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990) and was determined to be supercritical but within 0.1 feet of critical depth. The slope used was 0.029 ft/ft which was estimated from the 100-year water surface profile downstream of the bridge given in the Flood Insurance Study for the town of Chester (Federal Emergency Managment, 1982).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.033 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This approach also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 500.3 *ft*
Average low steel elevation 496.0 *ft*

100-year discharge 2,950 *ft³/s*
Water-surface elevation in bridge opening 492.2 *ft*
Road overtopping? N *Discharge over road* - *ft³/s*
Area of flow in bridge opening 269 *ft²*
Average velocity in bridge opening 11.0 *ft/s*
Maximum WSPRO tube velocity at bridge 13.0 *ft/s*

Water-surface elevation at Approach section with bridge 494.8
Water-surface elevation at Approach section without bridge 493.0
Amount of backwater caused by bridge 1.8 *ft*

500-year discharge 4,330 *ft³/s*
Water-surface elevation in bridge opening 496.1 *ft*
Road overtopping? N *Discharge over road* - *ft³/s*
Area of flow in bridge opening 511 *ft²*
Average velocity in bridge opening 8.6 *ft/s*
Maximum WSPRO tube velocity at bridge 12.0 *ft/s*

Water-surface elevation at Approach section with bridge 497.0
Water-surface elevation at Approach section without bridge 495.1
Amount of backwater caused by bridge 1.9

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-year discharge was computed by use of the Laursen's clear-water contraction scour equation (Richardson and others, 1995, p. 32, equation 20). At this site, the 500-year discharge resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). In this case, the 100-year model resulted in the worst case contraction scour with a scour depth of 0.4 ft. However, it was not the worst case total scour. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

For the 500-year discharge, additional estimates of contraction scour were computed by use of Laursen's clear-water scour equation. Furthermore, for the 500-year discharge, contraction scour was computed by substituting alternative estimates for the depth of flow in the bridge at the downstream face in the Chang equation and Laursen's clear-water equation. Contraction scour results with respect to these substitutions and for Laursen's clear-water equation are provided in Appendix F.

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

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(Scour depths in feet)	
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.4	0.0	--
Depth to armoring	10.0	5.8	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	4.1	12.2	--
Right abutment	6.3	15.5	--
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	2.0	2.0	--
Right abutment	1.7	1.7	--
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

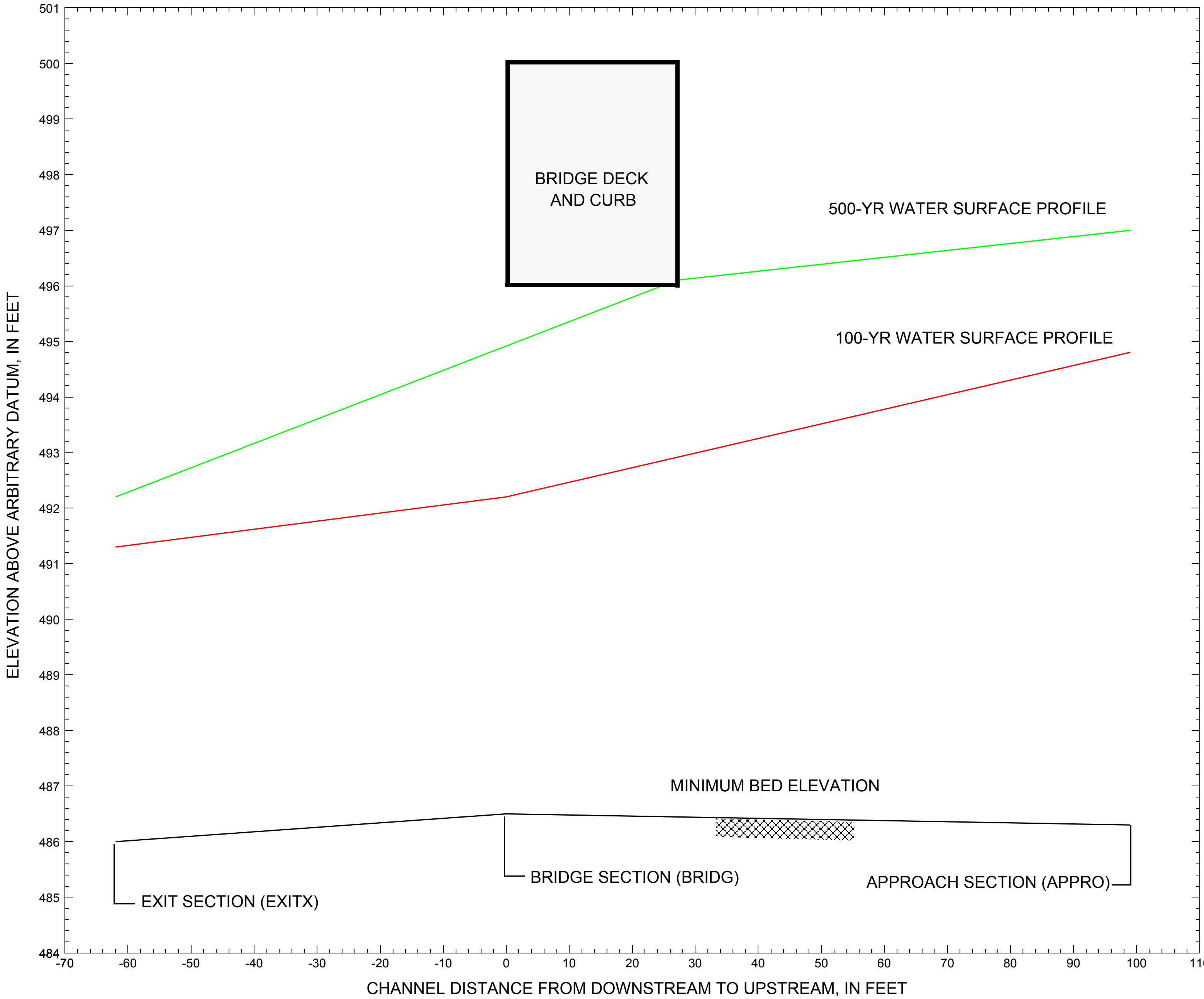

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CHESTH00030007 on Town Highway 3 (VT 35), crossing the South Branch Williams River, Chester, Vermont.

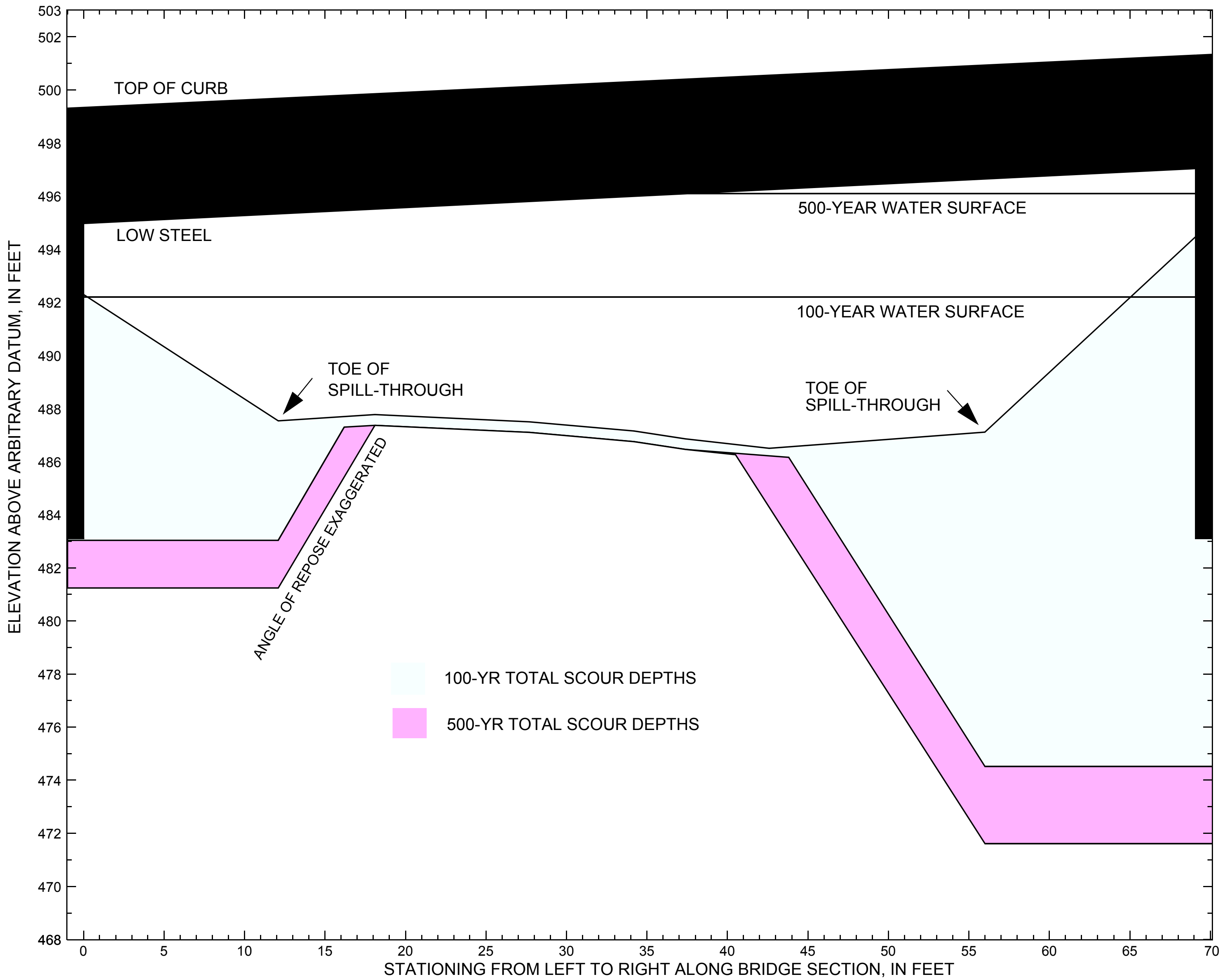

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CHESTH00030007 on Town Highway 3 (VT 35), crossing the South Branch Williams River, Chester, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CHESTH00030007 on Town Highway 3 (VT 35), crossing the South 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 2,950 cubic-feet per second											
Left abutment	0.2	99.0	495.0	483.0	492.3	0.4	--	--	--	--	0.0
LABUT toe	12.1	--	--	--	487.5	0.4	4.1	--	4.5	483.0	--
RABUT toe	56.0	--	--	--	487.1	0.4	12.2	--	12.6	474.5	--
Right abutment	69.1	100.8	497.0	483.0	494.5	0.4	--	--	--	--	-8.5

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 CHESTH00030007 on Town Highway 3 (VT 35), crossing the South 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 4,330 cubic-feet per second											
Left abutment	0.2	99.0	495.0	483.0	492.3	0.0	--	--	--	--	-1.8
LABUT toe	12.1	--	--	--	487.5	0.0	6.3	--	6.3	481.2	--
RABUT toe	56.0	--	--	--	487.1	0.0	15.5	--	15.5	471.6	--
Right abutment	69.1	100.8	497.0	483.0	494.5	0.0	--	--	--	--	-11.4

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, 1957, Saxtons River, Vermont 15 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps, Scale 1:62,500.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File ches007.wsp
T2        Hydraulic analysis for structure CHESTH00030007   Date: 13-FEB-97
T3        South Branch of Williams River crossing TH003 in Chester, VT       RLB
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           2950.0   4330.0
SK          0.029     0.029
*
XS   EXITX    -62           0.
GR         -168.4, 510.33   -113.3, 495.24    -84.2, 496.77    -61.1, 497.68
GR          -48.2, 490.59      0.0, 488.76     12.2, 487.01     19.2, 486.71
GR           25.3, 486.52     32.8, 486.13     40.0, 485.98     44.9, 486.08
GR           48.8, 486.63     54.0, 487.65     64.6, 494.99    117.6, 512.26
*
N           0.070        0.060
SA                   0.0
*
XS   FULLV      0  * * *   0.0084
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    494.97      5.0
GR            0.0, 494.97      0.2, 492.30     12.1, 487.54     18.1, 487.77
GR           27.7, 487.50     34.2, 487.15     37.4, 486.86     42.6, 486.50
GR           47.3, 486.73     56.0, 487.11     69.1, 494.48     69.1, 497.04
GR            0.0, 494.97
*
*         BRTYPE  BRWDTH    EMBSS   EMBELV
CD            3      30.0     2.15    500.3
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     15      27.4     1
GR         -168.4, 510.3       0.0, 499.34     35.0, 500.48     70.0, 501.31
GR          104.5, 501.33    131.9, 502.33    228.1, 512.22
*
XT   APTEM    103           0.
GR          -62.8, 510.46      0.0, 494.43     26.2, 492.03     35.4, 487.42
GR           40.3, 486.87     44.4, 486.44     49.3, 487.03     51.2, 487.29
GR           53.9, 487.97     61.4, 489.75     74.6, 490.82     92.1, 492.97
GR          145.0, 497.41    191.1, 501.49    214.3, 502.73    227.0, 500.84
GR          274.8, 502.25    301.5, 513.25
*
AS   APPRO     99 * * * 0.033
GT
N           0.070        0.060        0.070          0.035
SA                  26.2         61.4         92.1
*
HP 1 BRIDG  492.20 1 492.20
HP 2 BRIDG  492.20 * * 2950
HP 1 APPRO  494.81 1 494.81
HP 2 APPRO  494.81 * * 2950
*
HP 1 BRIDG  496.08 1 496.08
HP 2 BRIDG  496.08 * * 4330
HP 1 APPRO  496.95 1 496.95
HP 2 APPRO  496.95 * * 4330
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File ches007.wsp
      Hydraulic analysis for structure CHESTH00030007   Date: 13-FEB-97
      South Branch of Williams River crossing TH003 in Chester, VT       RLB
         *** RUN DATE & TIME: 03-27-97  13:47

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      269     22640     64     67                          3128
  492.20           269     22640     64     67  1.00      0     65     3128

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      492.20     0.4    65.0   269.4   22640.    2950.  10.95

X STA.         0.4       11.1       14.4       17.5       20.6       23.5
  A(I)            22.5       15.2       13.8       13.7       13.0
  V(I)            6.54       9.69      10.68      10.78      11.32

X STA.        23.5       26.3       28.9       31.5       34.0       36.3
  A(I)            12.9       12.5       12.5       12.2       11.8
  V(I)           11.43      11.84      11.85      12.12      12.49

X STA.        36.3       38.5       40.6       42.6       44.6       46.7
  A(I)            11.5       11.5       11.3       11.3       11.7
  V(I)           12.78      12.81      13.04      13.02      12.59

X STA.        46.7       48.9       51.1       53.6       56.4       65.0
  A(I)            11.7       12.1       12.7       14.4       21.0
  V(I)           12.56      12.23      11.60      10.22       7.03

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      99.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1       45      1320     28     28                           326
            2      241     20924     35     37                          3568
            3      115      5864     31     31                          1260
            4       23       975     23     24                           131
  494.81           424     29083    118    120  1.29     -1    116     4022

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      99.

        WSEL     LEW     REW    AREA        K        Q    VEL
      494.81    -2.0   115.6   423.9   29083.    2950.   6.96

X STA.        -2.0       27.1       32.2       35.0       37.2       39.2
  A(I)            48.1       23.8       18.7       16.5       15.9
  V(I)            3.07       6.20       7.88       8.94       9.26

X STA.        39.2       41.1       42.9       44.7       46.4       48.3
  A(I)            15.4       15.0       14.7       14.5       15.0
  V(I)            9.60       9.87      10.01      10.18       9.82

X STA.        48.3       50.2       52.2       54.5       57.1       60.3
  A(I)            15.1       15.4       16.2       17.1       18.6
  V(I)            9.80       9.56       9.10       8.63       7.92

X STA.        60.3       64.8       70.1       76.8       86.7      115.6
  A(I)            23.2       24.8       28.1       32.2       35.7
  V(I)            6.37       5.94       5.25       4.59       4.13
```

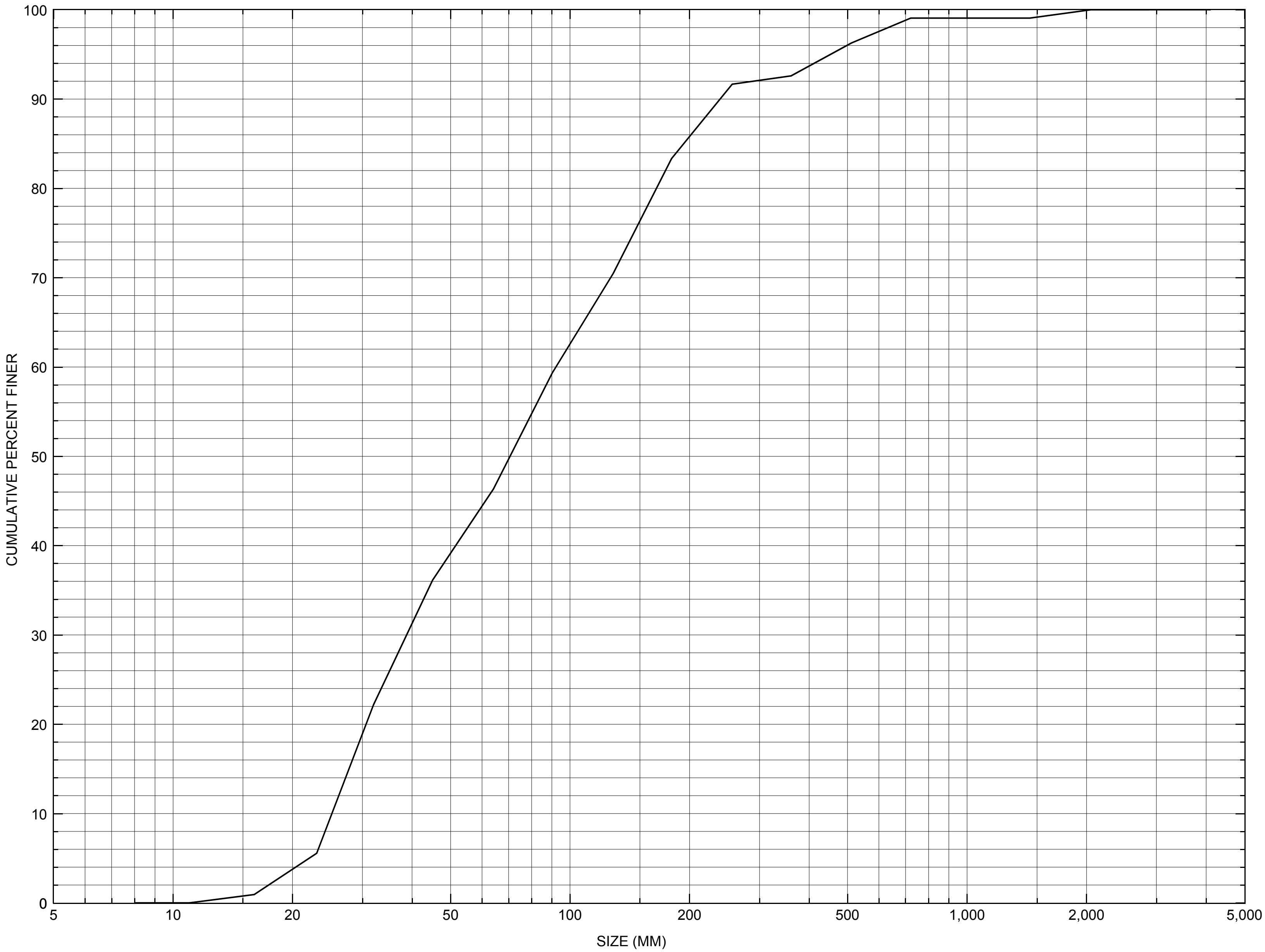
```
       U.S. Geological Survey WSPRO Input File ches007.wsp
       Hydraulic analysis for structure CHESTH00030007   Date: 13-FEB-97
       South Branch of Williams River crossing TH003 in Chester, VT       RLB
          *** RUN DATE & TIME: 03-27-97  13:47

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      511     46356     32    113                        11606
  496.08           511     46356     32    113  1.00      0     69    11606

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      496.08     0.0    69.1   511.1   46356.    4330.   8.47

 X STA.         0.0         9.9        14.3        18.5        22.4        26.2
  A(I)             46.5        32.9        32.2        31.1        30.4
  V(I)             4.66        6.58        6.72        6.97        7.11

 X STA.        26.2        29.8        33.3        36.6        38.9        41.0
  A(I)             29.7        30.1        29.5        21.5        19.3
  V(I)             7.28        7.19        7.34       10.07       11.22

 X STA.        41.0        43.0        45.0        46.9        48.9        50.8
  A(I)             18.9        18.8        18.2        18.3        18.1
  V(I)            11.47       11.49       11.88       11.81       11.98

 X STA.        50.8        52.9        55.0        57.3        60.5        69.1
  A(I)             18.6        19.3        20.1        23.4        34.2
  V(I)            11.61       11.22       10.80        9.26        6.33

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      99.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      115      5188     37     37                         1152
            2      316     32949     35     37                         5369
            3      180     12468     31     31                         2483
            4      101      6917     49     49                          820
  496.95           712     57521    151    154  1.23     -9    141     7901

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      99.

        WSEL     LEW     REW    AREA        K        Q    VEL
      496.95   -10.4   141.1   711.8   57521.    4330.   6.08

 X STA.       -10.4        16.8        27.7        32.6        35.9        38.6
  A(I)             71.4        51.4        34.9        29.5        26.3
  V(I)             3.03        4.21        6.21        7.33        8.23

 X STA.        38.6        41.0        43.5        45.8        48.2        50.7
  A(I)             25.1        25.3        24.6        25.1        25.2
  V(I)             8.62        8.57        8.78        8.61        8.60

 X STA.        50.7        53.5        56.7        60.3        65.2        70.9
  A(I)             26.5        27.7        29.4        35.7        38.5
  V(I)             8.18        7.81        7.36        6.07        5.62

 X STA.        70.9        77.4        85.5        95.3       105.8       141.1
  A(I)             40.5        44.2        42.3        35.9        52.3
  V(I)             5.35        4.90        5.12        6.03        4.14

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      395     40547     68     73                         5408
  494.10           395     40547     68     73  1.00      0     68     5408
```

```
       U.S. Geological Survey WSPRO Input File ches007.wsp
       Hydraulic analysis for structure CHESTH00030007   Date: 13-FEB-97
       South Branch of Williams River crossing TH003 in Chester, VT       RLB
          *** RUN DATE & TIME: 03-27-97  13:47

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                          WSI,CRWS =   491.15     491.29

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

EXITX:XS   ******    -48      331  1.48 *****  492.77  491.29    2950  491.29
       -61 ******     59    18456  1.19 ***** *******    0.99    8.92

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                          "FULLV"     KRATIO =  1.62

FULLV:FV       62    -51      464  0.73  0.98  493.74 *******    2950  493.02
         0     62     61    29807  1.16  0.00   -0.01    0.59    6.36
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    1.00     493.93     493.85

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   492.52     513.12    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   492.52     513.12     493.85

APPRO:AS       99      4      328  1.61  1.37  495.55  493.85    2950  493.94
        99     99    105    21148  1.28  0.44    0.00    1.00    8.99
         <<<<<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       62      0      269  1.86  1.29  494.06  492.02    2950  492.20
         0     62     65    22648  1.00  0.00    0.00    0.94   10.95

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   1.  1.000 ******  494.97 ****** ****** ******

   XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      15.        <<<<<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       69     -1      423  0.97  1.02  495.78  493.85    2950  494.81
        99     76    116    29040  1.29  0.71    0.02    0.73    6.97

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     0.345  0.097   26060.    12.    77.   494.06

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

  FIRST USER DEFINED TABLE.

   XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -62.   -49.    59.   2950.   18456.     331.    8.92  491.29
   FULLV:FV       0.   -52.    61.   2950.   29807.     464.    6.36  493.02
   BRIDG:BR       0.     0.    65.   2950.   22648.     269.   10.95  492.20
   RDWAY:RG      15.**************      0.******************     1.00********
   APPRO:AS      99.    -2.   116.   2950.   29040.     423.    6.97  494.81

   XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      12.    77.   26060.

 SECOND USER DEFINED TABLE.

   XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL     WSEL
   EXITX:XS    491.29    0.99  485.98  512.26************  1.48  492.77  491.29
   FULLV:FV  ********    0.59  486.50  512.78  0.98  0.00  0.73  493.74  493.02
   BRIDG:BR    492.02    0.94  486.50  497.04  1.29  0.00  1.86  494.06  492.20
   RDWAY:RG  ****************  499.34  512.22**********************************
   APPRO:AS    493.85    0.73  486.31  513.12  1.02  0.71  0.97  495.78  494.81
```

```
        U.S. Geological Survey WSPRO Input File ches007.wsp
        Hydraulic analysis for structure CHESTH00030007   Date: 13-FEB-97
        South Branch of Williams River crossing TH003 in Chester, VT       RLB
           *** RUN DATE & TIME: 03-27-97  13:47

 ===015 WSI IN WRONG FLOW REGIME AT SECID "EXITX":  USED WSI = CRWS.
                     WSI,CRWS =   492.06     492.20

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

EXITX:XS   ******    -50      431  1.83 *****  494.03  492.20    4330  492.20
       -61 ******     61    26768  1.17 ***** *******    0.98   10.06

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                     "FULLV"     KRATIO =  1.57

FULLV:FV       62    -53      588  0.95  1.03  495.05 *******    4330  494.10
         0     62     63    42120  1.13  0.00   -0.01    0.61    7.37
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80     0.99     495.04     495.06

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   493.60     513.12    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   493.60     513.12     495.06

APPRO:AS       99     -2      454  1.82  1.39  496.88  495.06    4330  495.06
        99     99    119    31771  1.28  0.43    0.01    0.99    9.53
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   493.26     496.08     496.87     494.97

 ===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       62      0      511  1.15 *****  497.23  493.32    4400  496.08
         0 ******     69    46375  1.00 ***** *******    0.56    8.61

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       3. ****   2.  0.444 ******  494.97 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL      ERR       Q    WSEL
   RDWAY:RG      15.        <<<<<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       69     -9      713  0.71  0.53  497.66  495.06    4330  496.95
        99     76    141    57603  1.23  0.68    0.02    0.55    6.08

      M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   496.55

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXITX:XS     -62.   -51.    61.   4330.   26768.     431.   10.06  492.20
   FULLV:FV       0.   -54.    63.   4330.   42120.     588.    7.37  494.10
   BRIDG:BR       0.     0.    69.   4400.   46375.     511.    8.61  496.08
   RDWAY:RG      15.**************      0.        0.       0.    1.00********
   APPRO:AS      99.   -10.   141.   4330.   57603.     713.    6.08  496.95

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    492.20    0.98  485.98  512.26************  1.83  494.03  492.20
   FULLV:FV  ********    0.61  486.50  512.78  1.03  0.00  0.95  495.05  494.10
   BRIDG:BR    493.32    0.56  486.50  497.04************  1.15  497.23  496.08
   RDWAY:RG  ****************  499.34  512.22************  0.26  499.66********
   APPRO:AS    495.06    0.55  486.31  513.12  0.53  0.68  0.71  497.66  496.95
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CHESTH00030007, in Chester, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CHESTH00030007

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 30 / 95

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

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

Town *(FIPS place code; I - 4; nnnnn)* 13600

Mile marker *(I - 11; nnn.nnn)* 002080

Waterway *(I - 6)* SOUTH BR. WILLIAMS RIVER

Road Name *(I - 7):* -

Route Number TH003

Vicinity *(I - 9)* 0.5 MI S JCT. VT.11

Topographic Map Chester

Hydrologic Unit Code: 01080107

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

Longitude *(i - 17; nnnnn.n)* 72361

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20012500071407

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

Maximum span length *(I - 48; nnnn)* 0072

Year built *(I - 27; YYYY)* 1949

Structure length *(I - 49; nnnnnn)* 000074

Average daily traffic, ADT *(I - 29; nnnnnn)* 000800

Deck Width *(I - 52; nn.n)* 274

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

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

Opening skew to Roadway *(I - 34; nn)* 05

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

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

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

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

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 070.0

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

Vertical clearance from streambed (*nnn.n ft*) 007.0

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

Waterway of full opening (*nnn.n* ft^2) 270.0

Comments:

The structural inspection report of 8/23/94 indicates the structure is a steel stringer type bridge with a concrete deck and an asphalt roadway surface. This bridge is part of the Federal Aid System and is listed under the route number FAS 125. The abutment walls are concrete. The upstream half of the right abutment has some random hairline cracks reported. Otherwise the abutment walls are reported as fairly clean. The abutment footings are not in view. There are flow-through type abutment embankments in front of both concrete abutment walls, which are protected with boulder riprap. The riprap is reported in good condition. The waterway makes a slight bend into the crossing. The streambed **(Continued, page 31)**

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

Q_{50} - Q_{100} - Q_{500} -

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

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

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

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

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

Downstream distance (*miles*): - Town: - Year Built: -
Highway No. : - Structure No. : - Structure Type: -
Clear span (*ft*): - Clear Height (*ft*): - Full Waterway (ft^2): -

Comments:

consists of stone and gravel. Presently, all of the flow is noted as proceeding along the right abutment side of the channel. The report indicates there has been no channel scour or bank erosion. In addition, point bars and debris accumulation problems are reported as not evident.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **10.36** mi^2 Lake and pond area **0.07** mi^2
Watershed storage *(ST)* **0.7** %
Bridge site elevation **680** ft Headwater elevation **1940** ft
Main channel length **8.76** mi
10% channel length elevation **820** ft 85% channel length elevation **1654** ft
Main channel slope *(S)* **126.84** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in
Maximum 2yr-24hr precipitation event *(I24,2)* - in
Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

Are plans available? **Y** *If no, type ctrl-n pl* Date issued for construction *(MM / YYYY)*: **10** / **1951**

Project Number **S 156(3)** Minimum channel bed elevation: **91.2**

Low superstructure elevation: USLAB **98.05** DSLAB **98.99** USRAB **99.90** DSRAB **100.84**

Benchmark location description:

There are no specific benchmarks noted on the plans. A couple of points that are given with elevations are: 1) the point on the top streamward edge of the upstream left wingwall concrete where the concrete slope changes from horizontal to downward, elevation 101.52.

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 **3.0*** Footing bottom elevation: **87.0**

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

If 3: Footing bottom elevation: ______

Is boring information available? **Y** *If no, type ctrl-n bi* Number of borings taken: **2**

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

Briefly describe material at foundation bottom elevation or around piles:

Both abutment footings are probably set in gravel.

Comments:

***The right abutment footing is shown on the plans to be 3.75 feet thick.**

Cross-sectional Data

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

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

Comments: **NO CROSS SECTION INFORMATION**

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: EW Date: 9/18/96
Computerized by: EW Date: 9/18/96
Reviewd by: RB Date: 3/26/97

Structure Number CHESTH00030007

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. BURNS Date *(MM/DD/YY)* 08 / 26 / 1996
2. Highway District Number 02 Mile marker 002080
   County WINDSOR 027 Town CHESTER 13600
   Waterway *(I - 6)* SOUTH BR. WILLIAMS RIVER Road Name -
   Route Number TH003 Hydrologic Unit Code: 01080107
3. Descriptive comments:

Located 0.5 miles south of the junction with VT 11. This bridge has flow through type abutment embankments.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 4 LBDS 6 RBDS 6 Overall 6
   *(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 1 UB 1 DS 2 *(**1**- pool; **2**- riffle)*
6. Bridge structure type 1 *(**1**- single span; **2**- multiple span; **3**- single arch; **4**- multiple arch; **5**- cylindrical culvert; **6**- box culvert; or **7**- other)*
7. Bridge length 74 *(feet)* Span length 72 *(feet)* Bridge width 27.4 *(feet)*

Road approach to bridge:

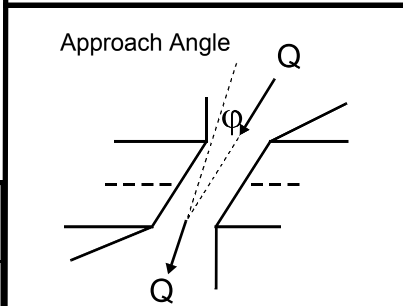
8. LB 1 RB 2 *(**0** even, **1**- lower, **2**- higher)*
9. LB 1 RB 1 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
    US left 12:5:1 US right 13:7:1

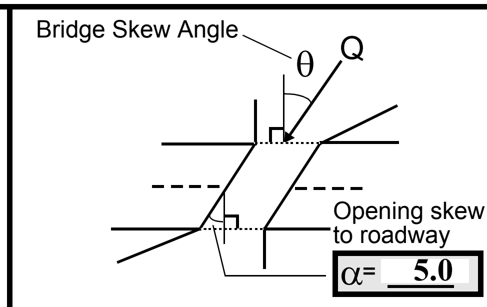
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	2	1
RBUS	0	-	2	1
RBDS	0	-	2	1
LBDS	0	-	2	1

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

Channel approach to bridge (BF):

15. Angle of approach: 5 16. Bridge skew: 5





17. Channel impact zone 1: Exist? Y *(Y or N)*
    Where? LB *(LB, RB)* Severity 2
    Range? 250 feet US *(US, UB, DS)* to 150 feet US
    Channel impact zone 2: Exist? Y *(Y or N)*
    Where? RB *(LB, RB)* Severity 1
    Range? 150 feet DS *(US, UB, DS)* to 200 feet DS

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

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

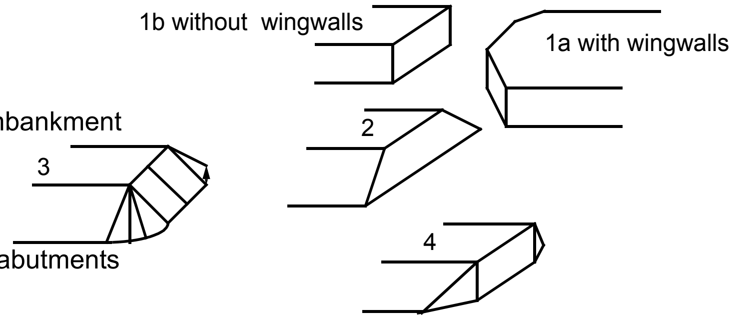
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

2- Vertical abutments and wingwalls, sloping embankment
Wingwalls perpendicular to abut. face

3- Spill through abutments

4- Sloping embankment, vertical wingwalls and abutments
Wingwall angle less than 90°.



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

#4: On the RBUS, there are trees along the immediate bank and field beyond. On the RBDS, there is a gravel driveway that runs parallel with the stream.

#5: US water surface is riffle from 72 feet upstream to further upstream.

#7: Measured bridge length = 74 feet; bridge width = 27.4 feet (between outside concrete posts and rail edges); and bridge span = 70 feet (measured between abutment faces).

#11-14: On the RBDS, there is some road wash at the end of the guard rail, not near the ends of the abutments, like in the other three cases.

#18: There is placed stone fill in front of the abutments, creating spill through abutment slopes.

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
75.5	**4.5**			**2.0**	**4**	**4**	**543**	**543**	**2**	**1**

23. Bank width **25.0** 24. Channel width **5.0** 25. Thalweg depth **66.0** 29. Bed Material **543**

30 .Bank protection type: LB **0** RB **0** 31. 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*

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

At 320 feet upstream, a small stone dam has been built across the channel, and another exists at 150 feet upstream.
At 300 feet upstream, the stream begins a gradual bend toward the bridge.
At 340 feet upstream, there is a dry, anabranched channel along the right bank which runs along the bankward side of the point bar.
At 62 feet upstream, runoff from the adjacent field enters the channel from the right bank.

33. Point/Side bar present? **Y** (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: **0 US** 35. Mid-bar width: **22**

36. Point bar extent: **68** feet **US** (US, UB) to **87** feet **DS** (US, UB, DS) positioned **0** %LB to **50** %RB

37. Material: **432**

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

An additional point bar exists on the right bank from 267 feet upstream to 45 feet upstream. Mid-bar distance is 137 feet upstream where it is 56 feet wide. It is positioned from 25% LB to 100% RB. It is comprised of cobble, gravel and boulders on top of sand. At 255 feet upstream, a third point bar begins along the left bank.

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: **36** 42. Cut bank extent: **42** feet **US** (US, UB) to **15** 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.):

Another cut-bank exists along the left bank from 255 feet upstream to 62 feet upstream. Mid-bank distances 94 feet upstream. It is eroded and a couple of large trees are undermined at the mid-bank.

45. Is channel scour present? **Y** (Y or if N type ctrl-n cs) 46. Mid-scour distance: **20 US**

47. Scour dimensions: Length **11 ft.** Width **6 ft.** Depth : **1 ft.** Position **70** %LB to **90** %RB

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

The scour hole exists from 23 feet upstream to 12 feet upstream, where the thalweg is 1 foot. Another scour hole is present with a mid-scour distance at 62 feet upstream. The scour dimensions are: length = 10 feet; width = 7 feet; and depth = 1 foot. It is positioned 25% LB to 50% RB. There is a third scour hole between a large boulder and a stone dam, from 179 feet upstream to 162 feet upstream. It is positioned 10% LB to 25% RB and it is 1 foot deep at 170 feet upstream.

49. Are there major confluences? **N** (Y or if N type ctrl-n mc) 50. How many? **-**

51. Confluence 1: Distance **-** 52. Enters on **-** (LB or RB) 53. Type **-** (1- perennial; 2- ephemeral)

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

54. Confluence comments (eg. confluence name):

NO MAJOR CONFLUENCES

D. Under Bridge Channel Assessment

55. Channel restraint (BF)? LB **2** RB _____ (1- natural bank; 2- abutment; 3- artificial levee)

56. Height (BF) LB	56. Height (BF) RB	57 Angle (BF) LB	57 Angle (BF) RB	61. Material (BF) LB	61. Material (BF) RB	62. Erosion (BF) LB	62. Erosion (BF) RB
39.0		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.):

435

The upstream point bar exists along the left abutment as it extends downstream. The main channel flow at this water level is along the base of the right abutment protection.

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

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

70. Debris and Ice Comments:

2

There is debris along the left bank, on top of the right bank point bar, as well as on top of the stone protection in front of the abutments.

There are some ice scars on the trees upstream 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		-	50	2	0	-	-	90.0
RABUT	2	10	50			2	0	69.0

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.):

-

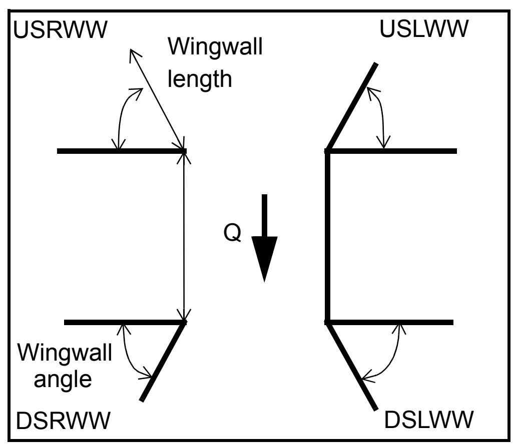
-

2

Behind the spill-through slopes of stone are vertical concrete abutment walls.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						69.0	
USRWW:	N		-		-	0.5	
DSLWW:	-		-		N	30.0	
DSRWW:	-		-		-	30.0	



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	-	-	-	-	-
Condition	N	-	-	-	-	-	-	-
Extent	-	-	-	-	-	0	0	-

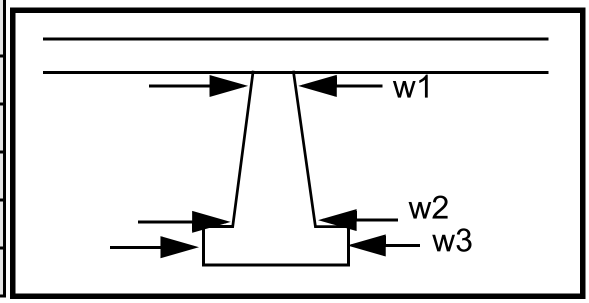
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? _____ *(Y or if N type ctrl-n pr)*

85. Pier no.	width (w) feet			elevation (e) feet		
	w1	w2	w3	e@w1	e@w2	e@w3
Pier 1	-	-	-	-	-	-
Pier 2	-	-	-	-	-	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



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

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

E. Downstream Channel Assessment

100.

SRD	Bank height (BF) LB	Bank height (BF) RB	Bank angle (BF) LB	Bank angle (BF) RB	% Veg. cover (BF) LB	% Veg. cover (BF) RB	Bank material (BF) LB	Bank material (BF) RB	Bank erosion (BF) LB	Bank erosion (BF) RB
-	-			-	-	NO	PIE	RS		

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

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

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

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

3
4
432
435
1
2
543
0
0
-
-
The right bank is a very steep hill, the left bank is low and flat.

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

103. Drop: - feet 104. Structure material: **81** *(**1**- steel sheet pile; **2**- wood pile; **3**- concrete; **4**- other)*

105. Drop structure comments (eg. downstream scour depth):
feet downstream, a dry channel begins on the left bank and ends approximately 500 feet downstream. The bank is about 50 feet wide from the left edge of the water to the dry channel. There is a lot of debris caught in the vegetation on the bank, which is mostly sand.

At 120 feet downstream, the channel begins to bend slightly.

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

Point bar extent: smal feet l (US, UB, DS) to bed- feet roc (US, UB, DS) positioned k %LB to out %RB

Material: cro

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

p on the right bank at 56 feet upstream.

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

Cut bank extent: N feet - (US, UB, DS) to NO feet DR (US, UB, DS)

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

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

STRUCTURE

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

Scour dimensions: Length Y Width ______ Depth: _____ Positioned ____ %LB to ____ %RB

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

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

Confluence 1: Distance r to Enters on upst (LB or RB) Type rea (1- perennial; 2- ephemeral)

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

Confluence comments (eg. confluence name):

assessment.

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)*:

Y
RB
135
112
DS
175
DS
1
-

109. G. Plan View Sketch

N

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: CHESTH00030007 Town: CHESTER
Road Number: TH003 County: WINDSOR
Stream: SOUTH BRANCH OF THE WILLIAMS RIVER

Initials RLB Date: 3/4/97 Checked: SAO

Analysis of contraction scour, live-bed or clear water?

Critical Velocity of Bed Material (converted to English units)
Vc=11.21*y1^0.1667*D50^0.33 with Ss=2.65
(Richardson and others, 1995, p. 28, eq. 16)

Approach Section Characteristic	100 yr	500 yr	other Q
Total discharge, cfs	2950	4330	0
Main Channel Area, ft2	241	316	0
Left overbank area, ft2	45	115	0
Right overbank area, ft2	138	281	0
Top width main channel, ft	35	35	0
Top width L overbank, ft	28	37	0
Top width R overbank, ft	54	80	0
D50 of channel, ft	0.231	0.231	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.9	9.0	ERR
y1, average depth, LOB, ft	1.6	3.1	ERR
y1, average depth, ROB, ft	2.6	3.5	ERR
Total conveyance, approach	29083	57521	0
Conveyance, main channel	20924	32949	0
Conveyance, LOB	1320	5188	0
Conveyance, ROB	6839	19385	0
Percent discrepancy, conveyance	0.0000	-0.0017	ERR
Qm, discharge, MC, cfs	2122.4	2480.3	ERR
Ql, discharge, LOB, cfs	133.9	390.5	ERR
Qr, discharge, ROB, cfs	693.7	1459.2	ERR
Vm, mean velocity MC, ft/s	8.8	7.8	ERR
Vl, mean velocity, LOB, ft/s	3.0	3.4	ERR
Vr, mean velocity, ROB, ft/s	5.0	5.2	ERR
Vc-m, crit. velocity, MC, ft/s	9.5	9.9	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	241	316	0
Main channel width, ft	35	35	0
y1, main channel depth, ft	6.89	9.03	ERR

Bridge Section	Q100	Q500	Qother
(Q) total discharge, cfs	2950	4330	0
(Q) discharge thru bridge, cfs	2950	4330	0
Main channel conveyance	22640	46356	0
Total conveyance	22640	46356	0
Q2, bridge MC discharge,cfs	2950	4330	ERR
Main channel area, ft2	269	511	0
Main channel width (skewed), ft	50.0	50.0	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	50	50	0
y_bridge (avg. depth at br.), ft	5.38	10.22	ERR
Dm, median (1.25*D50), ft	0.28875	0.28875	0
y2, depth in contraction,ft	5.82	8.08	ERR
ys, scour depth (y2-ybridge), ft	0.44	-2.14	N/A

Armoring

Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]
Depth to Armoring=3*(1/Pc-1)
(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	2950	4330	N/A
Main channel area (DS), ft2	269	395	0
Main channel width (normal), ft	50	50	0.0
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	50.0	50.0	0.0
D90, ft	0.7830	0.7830	0.0000
D95, ft	1.4850	1.4850	0.0000
Dc, critical grain size, ft	0.6181	0.5231	ERR
Pc, Decimal percent coarser than Dc	0.156	0.213	0.000
Depth to armoring, ft	10.03	5.80	ERR

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	0	4330	0
Q, thru bridge MC, cfs	N/A	4330	N/A
Vc, critical velocity, ft/s	N/A	9.93	N/A
Va, velocity MC approach, ft/s	N/A	7.85	N/A
Main channel width (normal), ft	0.0	50.0	0.0
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	0.0	50.0	0.0
qbr, unit discharge, ft2/s	ERR	86.6	ERR
Area of full opening, ft2	0.0	511.0	0.0
Hb, depth of full opening, ft	ERR	10.22	ERR
Fr, Froude number, bridge MC	0	0.56	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	395	N/A
**Hb, depth at downstream face, ft	ERR	7.90	ERR
**Fr, Froude number at DS face	ERR	0.69	ERR
**Cf, for downstream face (<=1.0)	N/A	1.00	N/A
Elevation of Low Steel, ft	0	494.97	0
Elevation of Bed, ft	N/A	484.75	N/A
Elevation of Approach, ft	0	496.95	0
Friction loss, approach, ft	0	0.53	0
Elevation of WS immediately US, ft	0.00	496.42	0.00
ya, depth immediately US, ft	N/A	11.67	N/A
Mean elevation of deck, ft	0	500.33	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	ERR	0.97	ERR
**Cc, for downstream face (<=1.0)	ERR	0.898143	ERR
Ys, scour w/Chang equation, ft	N/A	-1.20	N/A
Ys, scour w/Umbrell equation, ft	N/A	0.94	N/A

**=for UNsubmerged orifice flow only.

**Ys, scour w/Chang equation, ft	N/A	1.81	N/A

**Ys, scour w/Umbrell equation, ft	ERR	3.26	ERR

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

y2, from Laursen's equation, ft	0.00	8.08	0.00
WSEL at downstream face, ft	--	494.10	--
Depth at downstream face, ft	ERR	9.35	ERR
Ys, depth of scour (Laursen), ft	N/A	-1.27	N/A

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	2950	4330	0	2950	4330	0
a', abut.length blocking flow, ft	8.2	16.6	0	59.4	84.9	0
Ae, area of blocked flow ft2	13.55	43.58	0	168.52	323.13	0
Qe, discharge blocked abut.,cfs	41.56	132.13	0	936.06	1765.83	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.07	3.03	ERR	5.55	5.46	ERR
ya, depth of f/p flow, ft	1.65	2.63	ERR	2.84	3.81	ERR
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.55	0.55	0.55	0.55	0.55	0.55
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	95	95	95	85	85	85
K2	1.01	1.01	1.01	0.99	0.99	0.99
Fr, froude number f/p flow	0.420	0.330	ERR	0.581	0.494	ERR
ys, scour depth, ft	4.09	6.33	N/A	12.17	15.46	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)	8.2	16.6	0	59.4	84.9	0
y1 (depth f/p flow, ft)	1.65	2.63	ERR	2.84	3.81	ERR
a'/y1	4.96	6.32	ERR	20.94	22.31	ERR
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	1.00	1.00
Froude no. f/p flow	0.42	0.33	N/A	0.58	0.49	N/A
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	ERR	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	ERR	ERR
spill-through	ERR	ERR	ERR	ERR	ERR	ERR

Abutment riprap Sizing

Isbash Relationship

D50=y*K*Fr^2/(Ss-1) and D50=y*K*(Fr^2)^0.14/(Ss-1)

(Richardson and others, 1995, p112, eq. 81,82)

Characteristic	Q100	Q500	Qother			
Fr, Froude Number	0.94	0.56	0	0.94	0.56	0
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	5.38	10.22	0.00	5.38	10.22	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	ERR	1.98	0.00	ERR	1.98	0.00
Fr>0.8 (vertical abut.)	2.21	ERR	ERR	2.21	ERR	ERR
Fr<=0.8 (spillthrough abut.)	ERR	1.73	0.00	ERR	1.73	0.00
Fr>0.8 (spillthrough abut.)	1.95	ERR	ERR	1.95	ERR	ERR