LEVEL II SCOUR ANALYSIS FOR BRIDGE 46 (CHESVT00110046) on STATE ROUTE 11, crossing the MIDDLE BRANCH WILLIAMS RIVER, CHESTER, VERMONT

U.S. Geological Survey
Open-File Report 97-365

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 46 (CHESVT00110046) on STATE ROUTE 11, crossing the MIDDLE BRANCH WILLIAMS RIVER, CHESTER, VERMONT

By EMILY C. WILD

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Pembroke, New Hampshire

1997

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

U.S. GEOLOGICAL SURVEY
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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 46 (CHESVT00110046) ON STATE ROUTE 11, CROSSING THE MIDDLE BRANCH WILLIAMS RIVER, CHESTER, VERMONT

By **Emily C. Wild**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure CHESVT00110046 on State Route 11 crossing the Middle 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 Green Mountain and New England Upland sections of the New England physiographic province in southeastern Vermont. The 28.0-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forested on the upstream left and downstream right overbanks. The upstream right and downstream left overbanks are pasture while the immediate banks have dense woody vegetation.

In the study area, the the Middle Branch Williams River has an incised, sinuous channel with a slope of approximately 0.013 ft/ft, an average channel top width of 81 ft and an average bank height of 11 ft. The channel bed material ranges from gravel to bedrock with a median grain size (D_{50}) of 70.7 mm (0.232 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 12, 1996, indicated that the reach was stable.

The State Route 11 crossing of the Middle Branch Williams River is a 118-ft-long, two-lane steel stringer type bridge consisting of a 114-foot steel plate deck (Vermont Agency of Transportation, written communication, March 29, 1995). The opening length of the structure parallel to the bridge face is 109 ft.The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 45 degrees to the opening while the opening-skew-to-roadway is 50 degrees.

A scour hole 2 ft deeper than the mean thalweg depth was observed 128 feet downstream during the Level I assessment. Type-1 (less than 1 foot) stone fill protects the downstream right wingwall. Type-2 (less than 3 ft diameter) stone fill protects the upstream right wingwall, the left and right abutments, the upstream left and right road embankments. 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.

There was no computed contraction scour for any modelled flows. Abutment scour ranged from 7.0 to 10.3 ft. The worst-case abutment scour occurred at the 500-year discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

It is generally accepted that the Froehlich equation (abutment scour) gives “excessively conservative estimates of scour depths” (Richardson and others, 1995, p. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

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 CHESVT00110046 ***Stream*** Middle Branch Williams River

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

Description of Bridge

Bridge length 118 ***ft*** ***Bridge width*** 42.7 ***ft*** ***Max span length*** 114 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 9/12/96

Description of stone fill Type-2 on the spill-through slopes of the left and right abutments, upstream left and right banks and road approaches.

Brief description of piers/abutments Abutments and wingwalls are concrete. In front of the concrete abutments, type-2 stone fill has been placed to create spill-through slopes.

Is bridge skewed to flood flow according to Y ***survey?*** Y ***Angle*** 45

There is a moderate channel bend in the downstream reach. The scour hole has developed in the location where the bedrock controlled bend is present 150 feet downstream of bridge

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	9/12/96	0	0
Level II	9/12/96	0	0

Potential for debris Moderate.

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

The assessment of 9/12/96 noted a large bend in the channel, approximately 150 feet downstream from the bridge . Also at this location, the channel and right bank is predominately bedrock.

Description of the Geomorphic Setting

General topography The channel is located within a moderately steep valley, with narrow, irregular flood plains.

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

Date of inspection 9/12/96

DS left: Steep channel bank to a narrow terrace

DS right: Steep valley wall

US left: Steep valley wall

US right: Moderately sloped overbank with a narrow terrace

Description of the Channel

Average top width 81 ft ***Average depth*** 11 ft

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

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

9/12/96

Vegetative co

DS left: Grass and Vermont State Route 11

DS right: Trees

US left: Trees and brush

US right: Grass and Vermont State Route 11

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

None. 9/12/97

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 28.0 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
New England/ Green Mountain	85
New England/ New England Upland	15

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

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

USGS gage description --

USGS gage number --

Gage drainage area -- ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 5,810 ***ft³/s*** ***Q500*** 8,510 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(28.0/33.5)exp 0.68] with Federal Insurance Study discharge values at the Lovers Lane Brook confluence (Federal Emergency Management Agency, 1982). Lovers Lane Brook enters the Middle Branch Williams River downstream of this site. The values computed 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 To obtain VTAOT datum and mean sea level, add 299.5 feet to USGS survey.

Description of reference marks used to determine USGS datum. RM1 is a chiseled X on top of the downstream end of the right abutment (elev. 504.03 ft, arbitrary survey datum). RM2 is a brass tablet on top of the upstream end of the left abutment (elev. 500.65 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	-90	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	37	1	Road Grade section
APPRO	145	2	Modelled Approach section (Templated from APTEM)
APTEM	185	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 0.050, and overbank "n" values were 0.030.

Normal depth at the exit section (EXITX) was assumed as the starting water surface. This depth was computed by use of the slope-conveyance method outlined in the user's manual for WSPRO (Shearman, 1990). The slope used was 0.013 ft/ft which was estimated from the 100-year discharge water surface slope downstream of the bridge in the Flood Insurance Study for Chester, VT (Federal Emergency Management Agency, February 1982). This 0.013 ft/ft slope was equivalent to the slope estimated from the topographic map (U.S. Geological Survey, 1971).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0012 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 503.9 ***ft***
Average low steel elevation 496.4 ***ft***

100-year discharge 5,810 ***ft^3/s***
Water-surface elevation in bridge opening 494.2 ***ft***
Road overtopping? N ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 567 ***ft^2***
Average velocity in bridge opening 10.3 ***ft/s***
Maximum WSPRO tube velocity at bridge 12.2 ***ft/s***

Water-surface elevation at Approach section with bridge 494.8
Water-surface elevation at Approach section without bridge 495.6
Amount of backwater caused by bridge N/A ***ft***

500-year discharge 8,510 ***ft^3/s***
Water-surface elevation in bridge opening 496.0 ***ft***
Road overtopping? N ***Discharge over road*** -- ***ft^3/s***
Area of flow in bridge opening 695 ***ft^2***
Average velocity in bridge opening 12.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 15.3 ***ft/s***

Water-surface elevation at Approach section with bridge 496.9
Water-surface elevation at Approach section without bridge 497.6
Amount of backwater caused by bridge N/A ***ft***

Incipient overtopping discharge -- ***ft^3/s***
Water-surface elevation in bridge opening -- ***ft***
Area of flow in bridge opening -- ***ft^2***
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 all modelled discharges was computed by use of the Laursen's live-bed contraction scour equation (Richardson and others, 1995, p. 30, equations 17 and 18). At this site, the 100-year and 500-year discharges resulted in free surface flow. Results of this analysis are presented in figure 8 and tables 1 and 2. The streambed armoring depths computed suggest that armoring will not limit the depth of contraction scour.

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.

Because the influence of scour processes on the spill-through embankment material is uncertain, the scour depth at the vertical concrete abutment walls is unknown. Therefore, the total scour depths were applied for the entire spill-through embankment below the elevation at the toe of each embankment as shown in figure 8.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	0.0	0.0	--
Clear-water scour	--	--	--
Depth to armoring	5.1	8.0	--
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour	7.9	10.3	-- 7.0
Left abutment	8.9–	---	---
Right abutment			
Pier scour	--	--	--
Pier 1	--	--	--
Pier 2	--	--	1.8
Pier 3			

Riprap Sizing

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

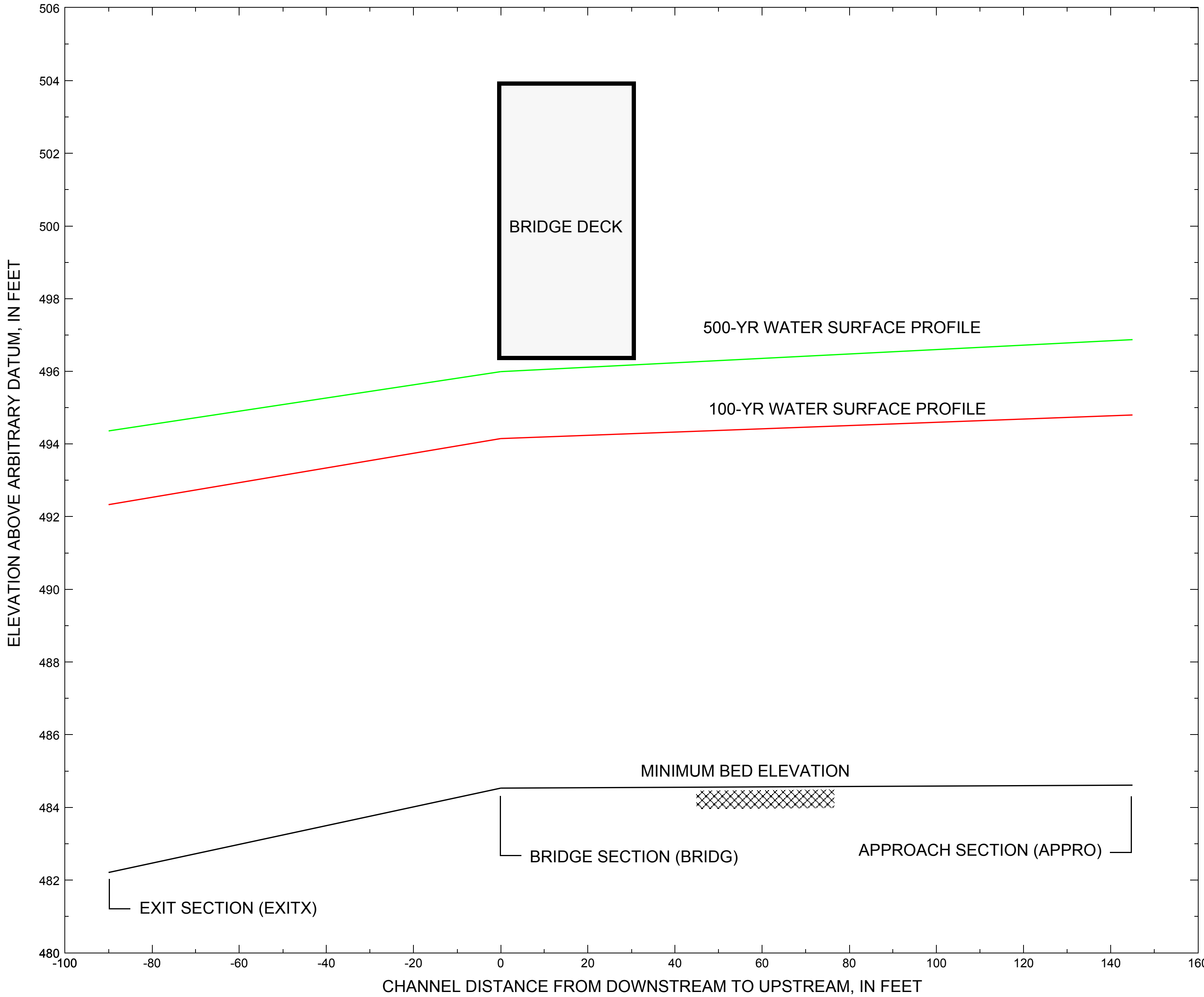

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure CHESVT00110046 on Vermont 11, crossing the Middle Branch Williams River, Chester, Vermont.

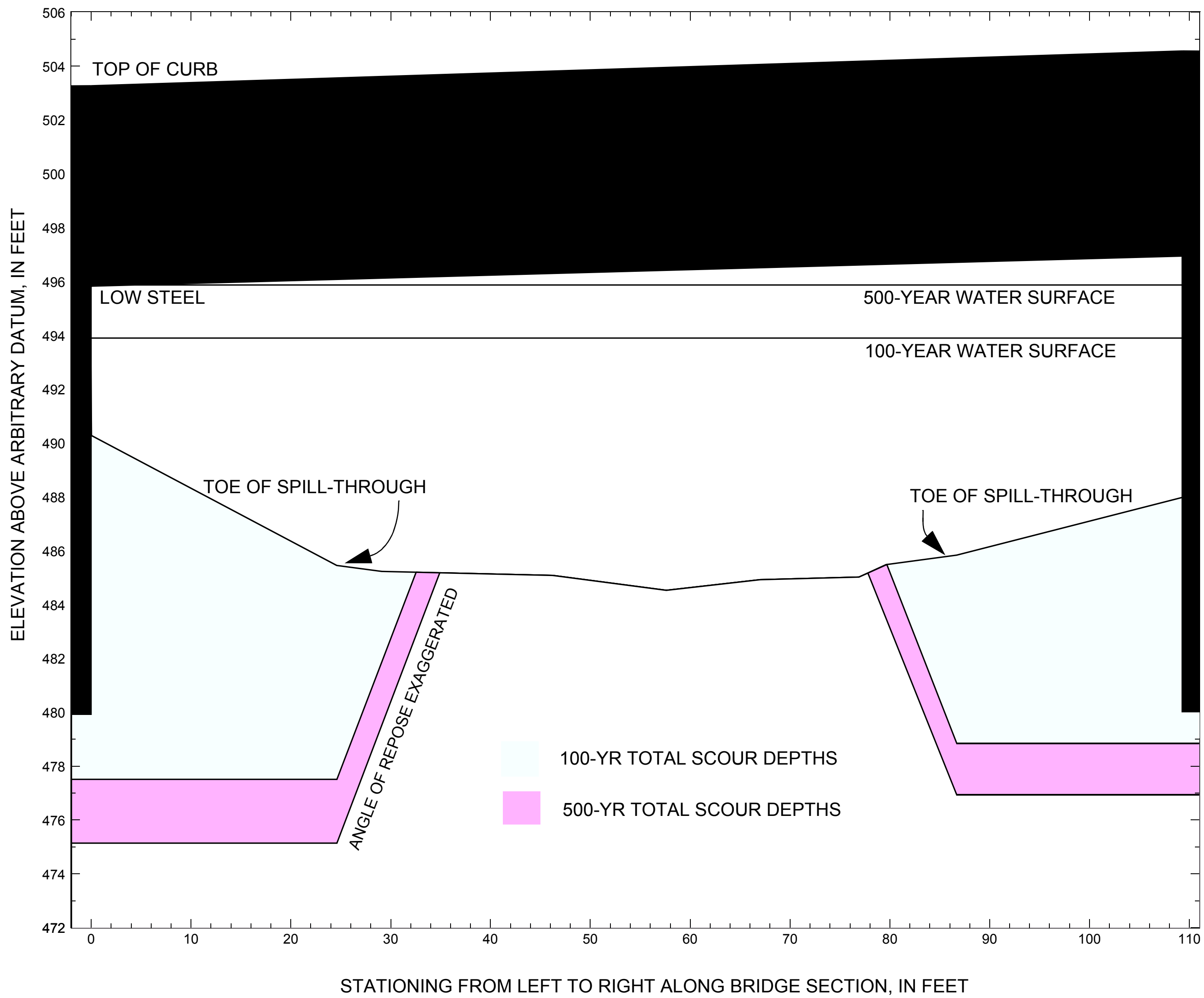

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure CHESVT00110046 on Vermont 11, crossing the Middle Branch Williams River, Chester, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure CHESVT00110046 on State Route 11, crossing the Middle Branch Williams River, Chester, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 5,810 cubic-feet per second											
Left abutment	0.0	--	495.8	480	490.3	--	--	--	--	--	-2
Spill-through toe	24.6	--	--	--	485.5	0.0	7.9	--	7.9	477.6	--
Spill-through toe	86.7	--	--	--	485.8	0.0	7.0	--	7.0	478.8	--
Right abutment	109.3	--	496.9	480	488.0	--	--	--	--	--	-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 CHESVT00110046 on State Route 11, crossing the Middle Branch Williams River, Chester, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 8,510 cubic-feet per second											
Left abutment	0.0	--	495.8	480	490.3	--	--	--	--	--	-5
Spill-through toe	24.6	--	--	--	485.5	0.0	10.3	--	10.3	475.2	--
Spill-through toe	86.7	--	--	--	485.8	0.0	8.9	--	8.9	476.9	--
Right abutment	109.3	--	496.9	480	488.0	--	--	--	--	--	-3

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

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

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File ches046.wsp
T2        Hydraulic analysis for structure CHESVT00110046   Date: 27-JAN-97
T3        VERMONT ROUTE 11, MIDDLE BRANCH WILLIAMS RIVER, CHESTER, VERMONT  ECW
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           5810     8510
SK          0.013   0.013
*
XS   EXITX    -90
GR         -176.1, 509.46    -98.9, 498.21    -42.7, 501.64    -20.0, 490.11
GR          -10.8, 484.39      0.0, 483.50      1.8, 482.84      8.9, 482.70
GR           14.3, 482.89     17.5, 482.21     19.0, 483.60     37.5, 485.98
GR           45.1, 490.74     88.0, 514.17
N             0.030    0.050
SA                 -42.7
*
XS   FULLV      0  * * *   0.016
*
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    496.39      50.0
GR            0.0, 495.83      0.0, 495.26    0.1, 490.29    24.6, 485.45
GR           29.1, 485.23     46.2, 485.08   57.6, 484.53    67.0, 484.92
GR           76.9, 485.02     79.6, 485.48   86.7, 485.84   109.3, 487.98
GR          109.3, 496.95     0.0, 495.83
N             0.045
CD           1 79 * * 10 25
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     37      42.7     1
GR         -149.9, 527.98    -98.6, 511.54     -76.0, 499.34   -47.9, 499.84
GR         -4.9, 502.40      -4.7, 503.25      0.0, 503.27     102.9, 504.56
GR         105.4, 504.63     105.6, 503.89     264.0, 504.28   590.0, 507.62
GR         1055.1, 521.88
*
*
*
XT   APTEM    185
GR          -45.8, 528.23      0.0, 495.77      7.6, 490.18     15.4, 488.59
GR           17.5, 486.94     22.1, 485.85     24.1, 485.51     28.5, 485.02
GR           31.5, 484.66     36.6, 485.47     42.1, 485.75     48.1, 485.98
GR           53.0, 487.24     64.1, 493.41     73.5, 499.07     98.8, 500.77
GR          258.0, 503.56    414.9, 506.83    830.8, 519.09
*
AS   APPRO    145    *  *  *  0.0012
GT
N           0.050        0.030
SA                  73.5
*
HP 1 BRIDG 494.15 1 494.15
HP 2 BRIDG 494.15 * * 5810
HP 1 APPRO 494.80 1 494.80
HP 2 APPRO 494.80 * * 5810
*
HP 1 BRIDG 495.99 1 495.99
HP 2 BRIDG 495.99 * * 8510
HP 1 APPRO 496.87 1 496.87
HP 2 APPRO 496.87 * * 8510
*
EX
ER
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
     U.S. Geological Survey WSPRO Input File ches046.wsp
     Hydraulic analysis for structure CHESVT00110046   Date: 27-JAN-97
     VERMONT ROUTE 11, MIDDLE BRANCH WILLIAMS RIVER, CHESTER, VERMONT  ECW
        *** RUN DATE & TIME: 03-25-97  13:52


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

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      567     68485     70     81                         9131
494.15           567     68485     70     81  1.00      0    109     9131

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    494.15     0.0   109.3   566.6   68485.    5810.  10.25

X STA.        0.0       13.6       20.8       26.1       30.8       35.3
  A(I)           45.3       33.3       28.6       26.9       25.8
  V(I)           6.41       8.72      10.17      10.79      11.27

X STA.       35.3       39.7       44.0       48.2       52.3       56.3
  A(I)           25.6       24.8       24.7       24.4       24.2
  V(I)          11.34      11.71      11.76      11.90      12.03

X STA.       56.3       60.1       64.2       68.3       72.5       76.8
  A(I)           23.9       24.3       24.6       24.7       25.5
  V(I)          12.15      11.96      11.80      11.76      11.40

X STA.       76.8       81.4       86.4       91.9       98.5      109.3
  A(I)           26.1       26.8       28.9       31.8       46.3
  V(I)          11.13      10.83      10.04       9.12       6.28


 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     145.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      449     46150     65     70                         6675
494.80           449     46150     65     70  1.00      1     66     6675

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     145.

      WSEL     LEW     REW    AREA        K        Q    VEL
    494.80     1.3    66.5   448.6   46150.    5810.  12.95

X STA.        1.3       12.2       16.6       19.6       22.1       24.3
  A(I)           38.3       27.5       23.5       21.7       20.1
  V(I)           7.58      10.55      12.36      13.40      14.44

X STA.       24.3       26.4       28.3       30.2       31.9       33.8
  A(I)           19.7       18.5       18.8       18.0       18.3
  V(I)          14.76      15.66      15.48      16.14      15.87

X STA.       33.8       35.7       37.7       39.7       41.8       44.0
  A(I)           18.3       18.9       18.9       18.9       19.8
  V(I)          15.91      15.39      15.36      15.37      14.64

X STA.       44.0       46.2       48.6       51.3       54.7       66.5
  A(I)           20.0       21.0       23.0       25.7       39.6
  V(I)          14.50      13.81      12.64      11.30       7.34
```

WSPRO OUTPUT FILE (continued)

```
     U.S. Geological Survey WSPRO Input File ches046.wsp
     Hydraulic analysis for structure CHESVT00110046   Date: 27-JAN-97
     VERMONT ROUTE 11, MIDDLE BRANCH WILLIAMS RIVER, CHESTER, VERMONT  ECW
        *** RUN DATE & TIME: 03-25-97  13:52

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

  WSEL  SA#     AREA         K  TOPW  WETP  ALPH    LEW    REW      QCR
          1      695     86860    60    95                         13398
495.99           695     86860    60    95  1.00      0    109     13398

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    495.99     0.0   109.3   695.0   86860.    8510.  12.24

X STA.        0.0       15.6       23.0       28.4       33.3       37.9
  A(I)            71.3       45.2       36.9       33.5       32.4
  V(I)            5.96       9.42      11.54      12.69      13.13

X STA.       37.9       42.4       46.7       50.8       54.8       58.7
  A(I)            31.1       30.3       29.1       28.8       28.3
  V(I)           13.69      14.05      14.60      14.80      15.03

X STA.       58.7       62.5       66.4       70.5       74.4       78.6
  A(I)            28.3       27.9       28.9       27.9       29.6
  V(I)           15.05      15.27      14.73      15.25      14.39

X STA.       78.6       83.0       87.8       93.0       99.2      109.3
  A(I)            29.4       31.4       33.0       36.8       55.0
  V(I)           14.46      13.56      12.90      11.57       7.73

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     145.

  WSEL  SA#     AREA         K  TOPW  WETP  ALPH    LEW    REW      QCR
          1      590     68072    72    77                          9618
496.87           590     68072    72    77  1.00     -1     70      9618

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     145.

      WSEL     LEW     REW    AREA        K        Q    VEL
    496.87    -1.6    69.9   590.1   68072.    8510.  14.42

X STA.       -1.6       10.5       14.9       18.4       21.1       23.5
  A(I)            51.5       33.8       32.8       27.7       26.9
  V(I)            8.26      12.57      12.99      15.38      15.82

X STA.       23.5       25.7       27.8       29.8       31.8       33.7
  A(I)            25.2       25.0       23.7       23.9       23.7
  V(I)           16.86      17.00      17.94      17.81      17.97

X STA.       33.7       35.8       37.9       40.1       42.3       44.6
  A(I)            24.1       24.3       24.7       24.8       25.5
  V(I)           17.65      17.54      17.19      17.18      16.72

X STA.       44.6       47.0       49.6       52.5       56.5       69.9
  A(I)            26.2       28.2       29.9       35.4       53.0
  V(I)           16.23      15.11      14.25      12.03       8.03
```

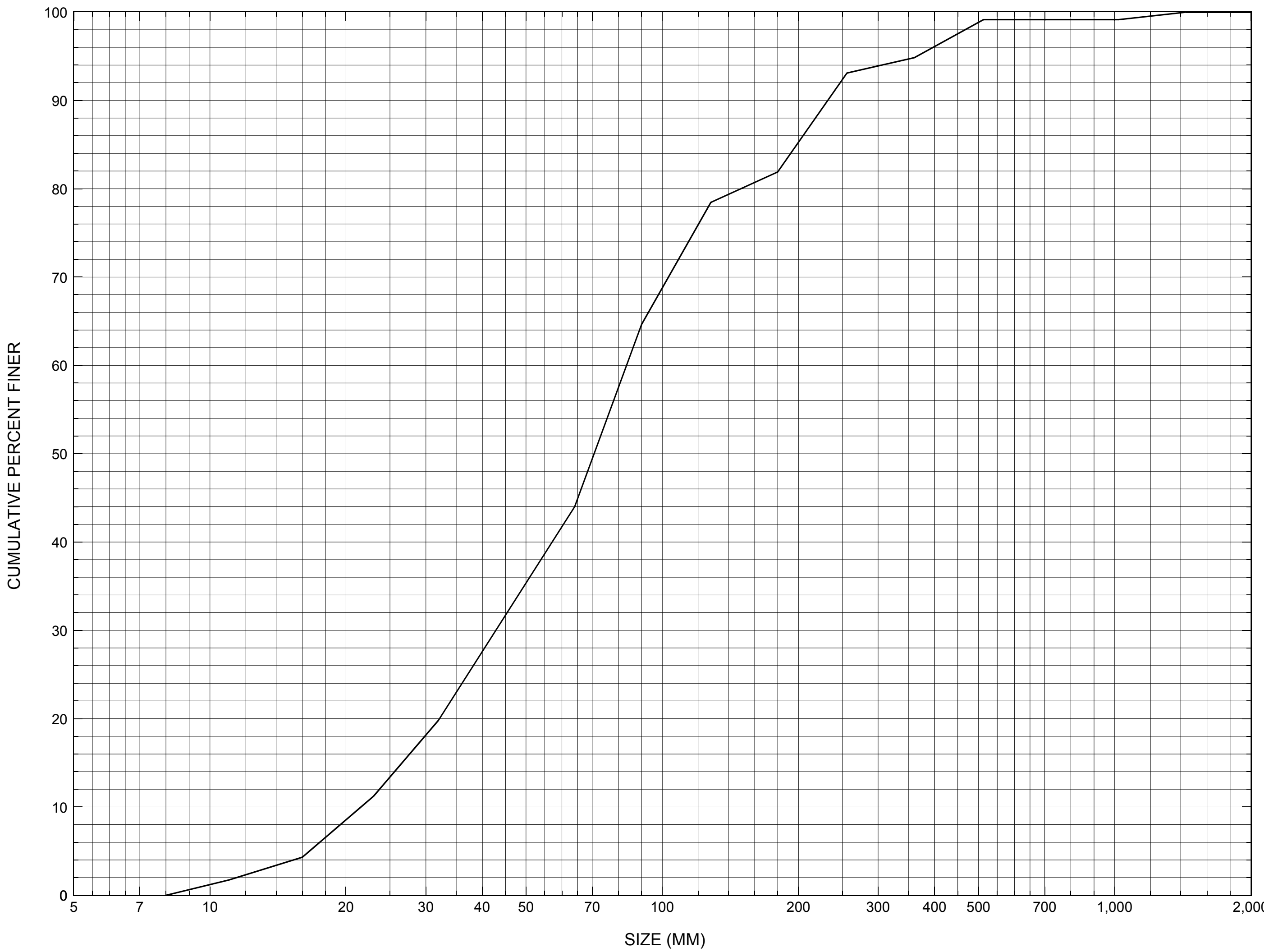
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File ches046.wsp
        Hydraulic analysis for structure CHESVT00110046   Date: 27-JAN-97
        VERMONT ROUTE 11, MIDDLE BRANCH WILLIAMS RIVER, CHESTER, VERMONT  ECW
           *** RUN DATE & TIME: 03-25-97  13:52

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

EXITX:XS   ******    -23      495  2.14 *****  494.47  491.19    5810  492.33
       -89 ******     48    50935  1.00 ***** *******    0.79   11.73

 ===125 FR# EXCEEDS FNTEST AT SECID “FULLV”:  TRIALS CONTINUED.
            FNTEST,FR#,WSEL,CRWS =  0.80    0.84     493.48     492.63

 ===110 WSEL NOT FOUND AT SECID “FULLV”:  REDUCED DELTAY.
                 WSLIM1,WSLIM2,DELTAY =   491.83     515.61    0.50

 ===115 WSEL NOT FOUND AT SECID “FULLV”:  USED WSMIN = CRWS.
                 WSLIM1,WSLIM2,CRWS =   491.83     515.61     492.63

FULLV:FV       90    -23      474  2.34  1.25  495.81  492.63    5810  493.47
         0     90     47    47896  1.00  0.10    0.00    0.84   12.25
         <<<<<THE ABOVE RESULTS REFLECT “NORMAL” (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      145      0      504  2.07  1.88  497.70 *******    5810  495.63
       145    145     68    54460  1.00  0.00    0.01    0.75   11.53
         <<<<<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       90      0      567  1.64  1.29  495.79  492.05    5810  494.15
         0     90    109    68486  1.00  0.03    0.01    0.64   10.25

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.39 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      37.        <<<<<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       66      1      449  2.61  1.04  497.41  494.13    5810  494.80
       145     66     66    46180  1.00  0.57    0.00    0.87   12.95

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.000  0.000   46226.   -23.    87.   493.19

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXITX:XS     -90.   -24.    48.   5810.   50935.     495.   11.73  492.33
   FULLV:FV       0.   -24.    47.   5810.   47896.     474.   12.25  493.47
   BRIDG:BR       0.     0.   109.   5810.   68486.     567.   10.25  494.15
   RDWAY:RG      37.**************      0.******************     1.00********
   APPRO:AS     145.     1.    66.   5810.   46180.     449.   12.95  494.80

      XSID:CODE   XLKQ   XRKQ       KQ
     APPRO:AS     -23.    87.   46226.


 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    491.19    0.79  482.21  514.17************  2.14  494.47  492.33
   FULLV:FV    492.63    0.84  483.65  515.61  1.25  0.10  2.34  495.81  493.47
   BRIDG:BR    492.05    0.64  484.53  496.95  1.29  0.03  1.64  495.79  494.15
   RDWAY:RG  ****************  499.34  527.98**********************************
   APPRO:AS    494.13    0.87  484.61  528.18  1.04  0.57  2.61  497.41  494.80
```

```
        U.S. Geological Survey WSPRO Input File ches046.wsp
        Hydraulic analysis for structure CHESVT00110046   Date: 27-JAN-97
        VERMONT ROUTE 11, MIDDLE BRANCH WILLIAMS RIVER, CHESTER, VERMONT  ECW
           *** RUN DATE & TIME: 03-25-97  13:52

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

EXITX:XS   ******    -27      650  2.67 *****  497.02  493.12    8510  494.36
       -89 ******     52    74607  1.00 ***** *******    0.81   13.09

 ===125 FR# EXCEEDS FNTEST AT SECID "FULLV":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.85     495.49     494.56

 ===110 WSEL NOT FOUND AT SECID "FULLV":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   493.86     515.61    0.50

 ===115 WSEL NOT FOUND AT SECID "FULLV":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   493.86     515.61     494.56

FULLV:FV       90    -27      625  2.88  1.24  498.37  494.56    8510  495.48
         0     90     51    70650  1.00  0.11    0.00    0.85   13.62
          <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      145     -2      642  2.74  1.94  500.31 *******    8510  497.58
       145    145     71    76561  1.00  0.00    0.01    0.79   13.26
          <<<<<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       90      0      695  2.33  1.29  498.32  493.78    8510  495.99
         0     90    109    86916  1.00  0.01    0.00    0.86   12.25

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  1.000 ******  496.39 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      37.        <<<<<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       66     -1      590  3.23  1.03  500.10  496.14    8510  496.87
       145     66     70    68086  1.00  0.76    0.01    0.89   14.42

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.000  0.000   67965.   -22.    87.   495.27

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -90.   -28.    52.   8510.   74607.     650.   13.09  494.36
   FULLV:FV       0.   -28.    51.   8510.   70650.     625.   13.62  495.48
   BRIDG:BR       0.     0.   109.   8510.   86916.     695.   12.25  495.99
   RDWAY:RG      37.**************      0.******************     1.00********
   APPRO:AS     145.    -2.    70.   8510.   68086.     590.   14.42  496.87

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS     -22.    87.   67965.


 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    493.12    0.81  482.21  514.17************  2.67  497.02  494.36
   FULLV:FV    494.56    0.85  483.65  515.61  1.24  0.11  2.88  498.37  495.48
   BRIDG:BR    493.78    0.86  484.53  496.95  1.29  0.01  2.33  498.32  495.99
   RDWAY:RG  ****************  499.34  527.98**********************************
   APPRO:AS    496.14    0.89  484.61  528.18  1.03  0.76  3.23  500.10  496.87
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure CHESVT00110046, in Chester, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number CHESVT00110046

General Location Descriptive

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

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

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

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

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

Mile marker *(I - 11; nnn.nnn)* 002090

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

Road Name *(I - 7):* -

Route Number VT011

Vicinity *(I - 9)* 3.0 MI W JCT. VT.103 N

Topographic Map Andover

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43158

Longitude *(i - 17; nnnnn.n)* 72389

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20001600461407

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

Maximum span length *(I - 48; nnnn)* 0114

Year built *(I - 27; YYYY)* 1992

Structure length *(I - 49; nnnnnn)* 000118

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

Deck Width *(I - 52; nn.n)* 427

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

Channel & Protection *(I - 61; n)* 8

Opening skew to Roadway *(I - 34; nn)* 50

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*) 069.0

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

Vertical clearance from streambed (*nnn.n ft*) 012.0

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

Waterway of full opening (*nnn.n* ft^2) 700.0

Comments:

The structural inspection report of 11/18/93 indicates that the structure is a steel stringer type bridge with a steel plate deck and an asphalt roadway surface. The abutment walls and wingwalls are constructed of concrete and are reported in "like-new" condition. The footings are noted as not in view at the surface. The waterway proceeds straight through the structure then makes a sharp turn just downstream. The streambed consists of stone and gravel. The embankments and abutment walls are well protected with stone fill.

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: **27.2**

Terrain character: **Rolling to hilly**

Stream character & type: **Mountainous type stream and a tributary to Williams River.**

Streambed material: **Sand & gravel - armored with rock and boulders.**

Discharge Data *(cfs)*: $Q_{2.33}$ **1150** Q_{10} **2650** Q_{25} **3700**

Q_{50} **4700** Q_{100} **5650** Q_{500} **-**

Record flood date *(MM / DD / YY)*: **09** / **-** / **38** Water surface elevation *(ft)*: **-**

Estimated Discharge *(cfs)*: **-** Velocity at Q **50** *(ft/s)*: **12.4**

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

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

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

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

Watershed storage area (*in percent*): **0.5** %

The watershed storage area is: **2** (*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*)	**791.2**	**793.0**	**794.0**	**794.9**	**795.7**
Velocity (*ft / sec*)	**8.5**	**10.7**	**11.7**	**12.5**	**13.3**

Long term stream bed changes: **Scour estimate indicated on report is 4 feet calculated.**

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

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

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

Upstream distance (*miles*): **0.3** Town: **Chester** Year Built: **-**

Highway No. : **VT11** Structure No. : **45** Structure Type: **-**

Clear span (*ft*): **70.0** Clear Height (*ft*): **11.0** Full Waterway (*ft²*): **770.0**

Downstream distance (*miles*): **0.75** Town: **Chester** Year Built: **-**

Highway No. : **TH57** Structure No. : **69** Structure Type: **-**

Clear span (*ft*): **40.0** Clear Height (*ft*): **10.0** Full Waterway (ft^2): **400.0**

Comments:

Hydraulic report recommended class III stone fill to be used for protection.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **28.00** mi^2 Lake and pond area **0** mi^2

Watershed storage *(ST)* **0** %

Bridge site elevation **780** ft Headwater elevation **2894** ft

Main channel length **9.22** mi

10% channel length elevation **860** ft 85% channel length elevation **1614** ft

Main channel slope *(S)* **109.08** 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)*: **02** / **1992**

Project Number **BRF-F016-1(3)** Minimum channel bed elevation: **784.5**

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

Benchmark location description:

VTAOT reference mark, bronze disk on top of concrete at corner where the upstream left wingwall and left abutment meet, no elevation is shown on plans yet for this mark as plans are not finalized.

Reference Point (*MSL, Arbitrary, Other*): **MSL** Datum (*NAD27, NAD83, Other*): **NGVD1929**

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

If 1: Footing Thickness **2.5** Footing bottom elevation: **779.0**

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? **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:

Some borings may eventually be available on the plans when finalized.

Comments:

Other points shown on the plans with elevations are: 1) The point on the streamward edge on top of the concrete at the end of the upstream left wingwall, elevation 799.50; and 2) the point at the same location but on the upstream right wingwall, elevation 800.50.

Cross-sectional Data

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

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

Comments: **FEMA data (February 1982) of bridge cross-section pre-dates this bridge, which was built in 1992.**

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: -
-

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **10/02/96**
Computerized by: **RB** Date: **10/02/96**
Reviewd by: **EW** Date: **4/7/97**

Structure Number **CHESVT00110046**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **E. WILD** Date *(MM/DD/YY)* **09** / **12** / 19**96**

2. Highway District Number **02**
   Mile marker **002090**
   County **027 WINDSOR**
   Town **13675 CHESTER**
   Waterway *(I - 6)* **MIDDLE BR. WILLIAMS RIVER**
   Road Name **-**
   Route Number **VT11**
   Hydrologic Unit Code: **01080107**

3. Descriptive comments:
Located 3.0 miles west of the junction with VT 103 North. This is a steel stringer type bridge with a steel plate deck and an asphalt roadway surface.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **4** LBDS **4** 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 **2** UB **1** DS **2** *(**1**- pool; **2**- riffle)*

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

7. Bridge length **118** *(feet)* Span length **114** *(feet)* Bridge width **42.7** *(feet)*

Road approach to bridge:

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

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

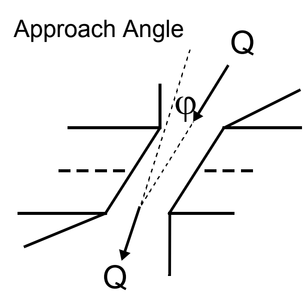
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

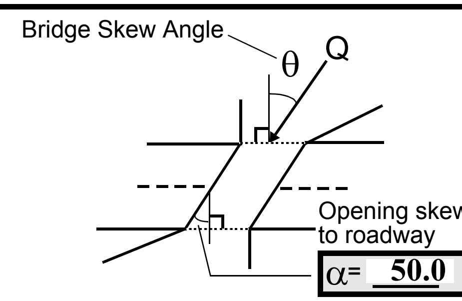
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	2	1	0	-
RBUS	2	1	0	-
RBDS	0	-	0	-
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

15. Angle of approach: **0**
16. Bridge skew: **45**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **350** feet **US** *(US, UB, DS)* to **107** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **90** feet **DS** *(US, UB, DS)* to **157** feet **DS**

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

18. Bridge Type: **1a**

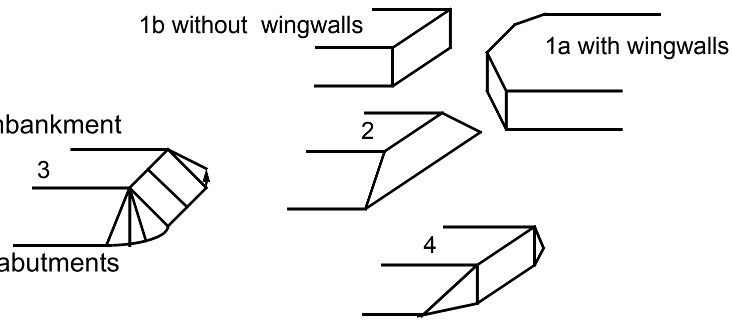
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

4. The left bank upstream and right bank downstream are steep forested hills. The right bank upstream has a dirt parking area and grass along VT 11. The left bank downstream is grass and small trees along VT 11 and forest beyond.
5. The upstream is a series of pool and riffle. Under the bridge it is mostly pooled. Downstream the water surface is riffle until 100 feet downstream where the bedrock is in the channel and there is a scour hole and the water is pooled.
7. Values are from the Vermont AOT database. Measured bridge length is 113.7 feet downstream and 119.4 feet upstream, span length is 107 feet downstream and 113.4 feet upstream, and bridge width is 41.5 feet.
8. Both road approaches are even, but the bridge is banked so that the downsteam face of the bridge is higher than the upstream.
17. There is no cut bank in the impact zone downstream, though it is a very sharp bend in the stream because the right bank is all bedrock.

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
145.0	9.0			12.0	2	1	324	324	2	1

23. Bank width **25.0** 24. Channel width **30.0** 25. Thalweg depth **73.5** 29. Bed Material **435**

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

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

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

27. On the left and right banks near the bridge, the bank material is all placed bank protection.
28. The left bank is creeping into the channel as a side bar US of the protection. There is light fluvial erosion on the right bank US of the protection.
30. The left bank protection extends 129 ft. US to 0 ft. US. The right bank protection extends from the wing-wall to 165 ft upstream.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 119 35. Mid-bar width: 13

36. Point bar extent: 182 feet US (US, UB) to 10 feet US (US, UB, DS) positioned 50 %LB to 100 %RB

37. Material: 4352

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

An additional side bar extends from 278 feet upstream to 170 feet upstream. It is mostly cobble with some boulders, gravel and grass. It is 12.5 feet wide uniformly throughout. It is positioned from 0% LB to 40% RB.

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

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

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

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

NO CUT BANKS

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

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

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

NO CHANNEL SCOUR
Some localized scour near large boulders in the stream.

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
35.5		1.5		2	7	7	-

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

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

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

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

43
-

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

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

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

70. Debris and Ice Comments:

1

-

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		0	90	2	0	-	-	90.0
RABUT	1	0	90			2	0	70.5

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

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

-

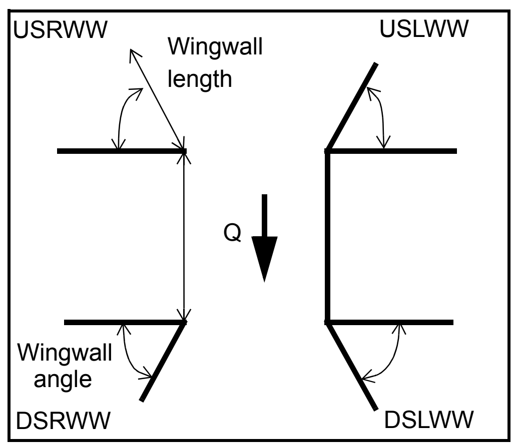
-

1

-

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						70.5	
USRWW:	Y		1		0	1.0	
DSLWW:	-		-		Y	71.0	
DSRWW:	1		0		-	78.0	



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

82. **Bank / Bridge Protection**:

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

Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee

Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed

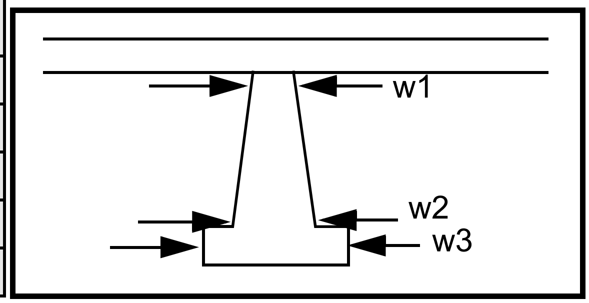
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

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				**10.0**	**19.5**	**10.0**
Pier 2		**0.0**		**31.0**	**22.5**	**65.0**
Pier 3		-	-	**12.5**	-	-
Pier 4	-	-	-	-	-	-



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

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

-
-
-
-
-
-
-
-
-
-

E. Downstream Channel Assessment

100.

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

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

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

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

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

1
3
324
634
1
1
634
2
2
1
1
The left bank protection extends from 0 feet downstream to 137 feet downstream. Where the protection ends, the bank has been well eroded. On the right bank the protection extends from 0 feet downstream to 25 feet

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

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

105. Drop structure comments (eg. downstream scour depth):
stream where bedrock is prevalent along the bank.

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

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

Material: **NO**

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

DROP STRUCTURE

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

Cut bank extent: **130** feet **16** *(US, UB, DS)* to **55** feet **DS** *(US, UB, DS)*

Bank damage: **218** *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

DS
0
45
34

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

Scour dimensions: Length **tiona** Width **l side** Depth: **bar** Positioned **exis** %LB to **ts** %RB

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

from 0 feet downstream to 36 feet downstream. The mid-bar distance is 15 feet downstream and 11 feet wide. The bar material is cobble and it is positioned 75% LB to 100% RB.

Are there major confluences? **N** *(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):

NO CUT BANKS

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
128
90
7
2
70
85
On the right side of the scour hole there is bedrock. On the left side of the scour hole a point bar is present. Scour depth assumes thalweg is 1 foot.

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: CHESVT00110046 Town: CHESTER
Road Number: VERMONT 11 County: WINDSOR
Stream: MIDDLE BRANCH WILLIAMS RIVER

Initials ECW Date: 2/5/97 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	5810	8510	0
Main Channel Area, ft2	449	590	0
Left overbank area, ft2	0	0	0
Right overbank area, ft2	0	0	0
Top width main channel, ft	65	72	0
Top width L overbank, ft	0	0	0
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.232	0.232	0
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	6.9	8.2	ERR
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	46150	68072	0
Conveyance, main channel	46150	68072	0
Conveyance, LOB	0	0	0
Conveyance, ROB	0	0	34
Percent discrepancy, conveyance	0.0000	0.0000	ERR
Qm, discharge, MC, cfs	5810.0	8510.0	ERR
Ql, discharge, LOB, cfs	0.0	0.0	ERR
Qr, discharge, ROB, cfs	0.0	0.0	ERR
Vm, mean velocity MC, ft/s	12.9	14.4	ERR
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	9.5	9.8	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	1	1	N/A

Live-Bed Contraction Scour

Laursen's Live Bed Contraction Scour
y2/y1 = (Q2/Q1)^(6/7)*(W1/W2)^(k1)
ys=y2-y_bridge
(Richardson and others, 1995, p. 30, eq. 17 and 18)

	Approach			Bridge		
Characteristic	100 yr	500 yr	Other Q	100 yr	500 yr	Other Q
Q1, discharge, cfs	5810	8510	0	5810	8510	0
Total conveyance	46150	68072	0	68485	86860	0
Main channel conveyance	46150	68072	0	68485	86860	0
Main channel discharge	5810	8510	ERR	5810	8510	ERR
Area - main channel, ft2	449	590	0	567	695	0
(W1) channel width, ft	65	72	0	70.3	70.3	0
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	65	72	0	70.3	70.3	0
D50, ft	0.232	0.232	0.232			
w, fall velocity, ft/s (p. 32)	3.94	3.94	0			
y, ave. depth flow, ft	6.91	8.19	N/A	8.07	9.89	ERR
S1, slope EGL	0.013	0.013	0			
P, wetted perimeter, MC, ft	70	81	0			
R, hydraulic Radius, ft	6.414	7.284	ERR			
V*, shear velocity, ft/s	1.639	1.746	N/A			
V*/w	0.416	0.443	ERR			
Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)						
k1	0.59	0.59	0			
y2,depth in contraction, ft	6.60	8.31	ERR			
ys, scour depth, ft (y2-y_bridge)	-1.47	-1.58	N/A			

ARMORING

D90	0.762	0.762	0.762
D95	1.198	1.198	1.198
Critical grain size,Dc, ft	0.4481	0.5895	ERR
Decimal-percent coarser than Dc	0.209	0.181	0
depth to armoring, ft	5.09	8.00	ERR

Abutment Scour

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

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	5810	8510	0	5810	8510	0
a', abut.length blocking flow, ft	5.1	8.2	0	5.1	8.2	0
Ae, area of blocked flow ft2	17.9	35	0	17.1	32.5	0
Qe, discharge blocked abut.,cfs	135.7	289.2	0	125.3	261	0
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	7.58	8.26	ERR	7.34	8.03	ERR
ya, depth of f/p flow, ft	3.51	4.27	ERR	3.35	3.96	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	140	140	140	40	40	40
K2	1.06	1.06	1.06	0.90	0.90	0.90
Fr, froude number f/p flow	0.713	0.706	ERR	0.706	0.711	ERR
ys, scour depth, ft	7.94	10.31	N/A	7.00	8.91	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)	5.1	8.2	0	5.1	8.2	0
y1 (depth f/p flow, ft)	3.51	4.27	ERR	3.35	3.96	ERR
a'/y1	1.45	1.92	ERR	1.52	2.07	ERR
Skew correction (p. 49, fig. 16)	1.11	1.11	1.11	0.72	0.72	0.72
Froude no. f/p flow	0.71	0.71	N/A	0.71	0.71	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	0.64	0.86	0	0.64	0.86	0
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	8.07	9.89	0.00	8.07	9.89	0.00
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	2.04	ERR	0.00	2.04	ERR	0.00
Fr>0.8 (vertical abut.)	ERR	3.96	ERR	ERR	3.96	ERR
Fr<=0.8 (spillthrough abut.)	1.78	ERR	0.00	1.78	ERR	0.00
Fr>0.8 (spillthrough abut.)	ERR	3.50	ERR	ERR	3.50	ERR