LEVEL II SCOUR ANALYSIS FOR BRIDGE 39 (ANDOVT00110039) on STATE ROUTE 11, crossing the MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT

U.S. Geological Survey
Open-File Report 97-373

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

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By Ronda L. Burns and Emily C. Wild

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Pembroke, New Hampshire

1997

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 39 (ANDOVT00110039) ON STATE ROUTE 11, CROSSING THE MIDDLE BRANCH WILLIAMS RIVER, ANDOVER, VERMONT

By **Ronda L. Burns and Emily C. Wild**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure ANDOVT00110039 on State Route 11 crossing the Middle Branch Williams River, Andover, 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 section of the New England physiographic province in southern Vermont. The 5.75-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest on the upstream left bank and downstream right bank. The surface cover on the upstream right and downstream left banks is brush.

In the study area, the Middle Branch Williams River has an incised, sinuous channel with a slope of approximately 0.01 ft/ft, an average channel top width of 58 ft and an average bank height of 8 ft. The channel bed material ranges from sand to boulder with a median grain size (D_{50}) of 96.8 mm (0.317 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 9, 1996, indicated that the reach was laterally unstable.

The State Route 11 crossing of the Middle Branch Williams River is a 43-ft-long, two-lane bridge consisting of one 41-foot concrete-beam span and two additional steel beams on the upstream face (Vermont Agency of Transportation, written communication, March 29, 1995). 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 45 degrees.

The only scour protection measures at the site was type-2 stone fill (less than 36 inches diameter) at the upstream end of the upstream right wingwall and type-3 stone fill (less than 48 inches diameter) along the entire base length of the upstream left wingwall. 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 0.8 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 8.9 to 11.2 ft. The worst-case abutment scour occurred at the incipient-overtopping discharge. Additional information on scour depths and depths to armoring are included in the section titled “Scour Results”. Scoured-streambed elevations, based on the calculated scour depths, are presented in tables 1 and 2. A cross-section of the scour computed at the bridge is presented in figure 8. Scour depths were calculated assuming an infinite depth of erosive material and a homogeneous particle-size distribution.

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

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

NORTH

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

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

LEVEL II SUMMARY

Structure Number ANDOVT00110039 ***Stream*** Middle Branch Williams River

County Windham ***Road*** VT11 ***District*** 2

Description of Bridge

Bridge length 43 ***ft*** ***Bridge width*** 32.5 ***ft*** ***Max span length*** 41 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 09/09/97

Type-2, around the upstream end of the upstream right wingwall and type-3 along the base of the upstream left wingwall.

Abutments and wingwalls are concrete.

Y 45

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

The channel bends mildly in the upstream reach and in the downstream 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	09/09/97	0	0
Level II	09/09/97	0	0

Potential for debris Moderate. In the upstream reach there are some very large trees down in the middle of the channel.

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

None (09/09/97).

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 09/09/97

DS left: Steep valley wall

DS right: Steep valley wall

US left: Steep valley wall

US right: Steep valley wall

Description of the Channel

Average top width 58 ***ft*** ***Average depth*** 8.0 ***ft***

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

Sinuous and unstable with semi-alluvial channel boundaries and no flood plain.

09/09/97

Vegetative co

DS left: Small trees and brush

DS right: Trees

US left: Trees

US right: Short grass and brush.

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

The channel bends both upstream and downstream where it widens and there are wide point bars. There is moderate fluvial erosion on the downstream right bank and cut banks on the upstream left and downstream right banks.

None (09/09/97).

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 5.75 ***mi***^{2}

Percentage of drainage area in physiographic provinces: (approximate)

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

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 -- ***mi***^{2}

Is there a lake/p No

Calculated Discharges

Q100 1,980 ***ft***^{3}***/s*** ***Q500*** 2,900 ***ft***^{3}***/s***

The 100- and 500-year discharges are based on a drainage area relationship [(5.8/14.8)exp 0.68] with the drainage area above the Andover Branch confluence with the Middle Branch Williams River in Chester. This drainage area is 14.8 square miles and has flood frequency estimates available in the Flood Insurance Study for the town of Chester (Federal Emergency Management Agency, February 1982). 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 Subtract 50.9 ft. from the USGS survey to obtain VTAOT plans' datum.

Description of reference marks used to determine USGS datum. RM11 is a chiseled X on top of the downstream end of the right abutment (elev. 446.50 ft, arbitrary survey datum). RM12 is a chiseled X on top of the upstream end of the left abutment (elev. 446.22 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	-32	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	21	1	Road Grade section
APPRO	67	2	Modelled Approach section (Templated from APTEM)
APTEM	113	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 0.100.

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 0.0143 ft/ft which was calculated from surveyed points downstream.

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0079 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 446.5 *ft*
Average low steel elevation 442.9 *ft*

100-year discharge 1,980 *ft³/s*
Water-surface elevation in bridge opening 443.1 *ft*
Road overtopping? N *Discharge over road* - *ft³/s*
Area of flow in bridge opening 218 *ft²*
Average velocity in bridge opening 9.1 *ft/s*
Maximum WSPRO tube velocity at bridge 10.8 *ft/s*

Water-surface elevation at Approach section with bridge 445.3
Water-surface elevation at Approach section without bridge 440.5
Amount of backwater caused by bridge 4.8 *ft*

500-year discharge 2,900 *ft³/s*
Water-surface elevation in bridge opening 443.1 *ft*
Road overtopping? Y *Discharge over road* 462 *ft³/s*
Area of flow in bridge opening 218 *ft²*
Average velocity in bridge opening 11.2 *ft/s*
Maximum WSPRO tube velocity at bridge 13.2 */s*

Water-surface elevation at Approach section with bridge 447.6
Water-surface elevation at Approach section without bridge 441.7
Amount of backwater caused by bridge 5.9 *ft*

Incipient overtopping discharge 2,250 *ft³/s*
Water-surface elevation in bridge opening 443.1 *ft*
Area of flow in bridge opening 218 *ft²*
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 446.6
Water-surface elevation at Approach section without bridge 440.9
Amount of backwater caused by bridge 5.7 *ft*

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

Scour depths were computed using the general guidelines described in Hydraulic Engineering Circular 18 (Richardson and 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.

The 100-year, 500-year and incipient road-overflow discharges resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Therefore, contraction scour for all discharges was computed by use of the Chang equation (Richardson and others, 1995, p. 145-146). For comparison, estimates of contraction scour were also computed by use of the Laursen clear-water contraction scour equation and presented in Appendix F. In this case, the 500-year model resulted in the worst case contraction scour with a scour depth of 0.8 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.

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	0.0	0.8	0.3
Depth to armoring	1.1	4.2	2.5
Left overbank	--	--	--
Right overbank	--	--	--
Local scour:			
Abutment scour			
Left abutment	9.5	11.0	11.2
Right abutment	10.6	8.9	10.8
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	2.5	3.5	3.2
Right abutment	2.5	3.5	3.2
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

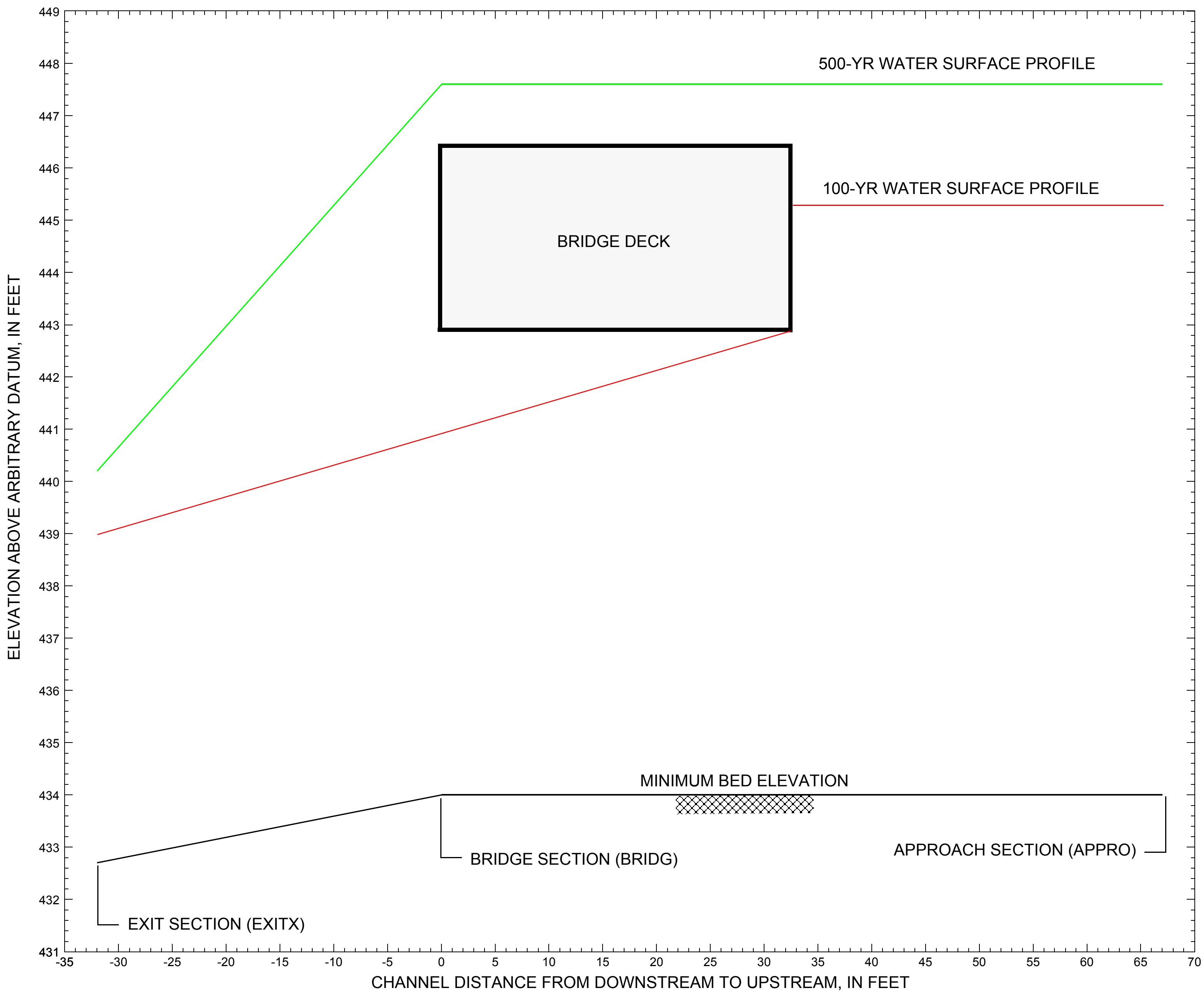

Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure ANDOVT00110039 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

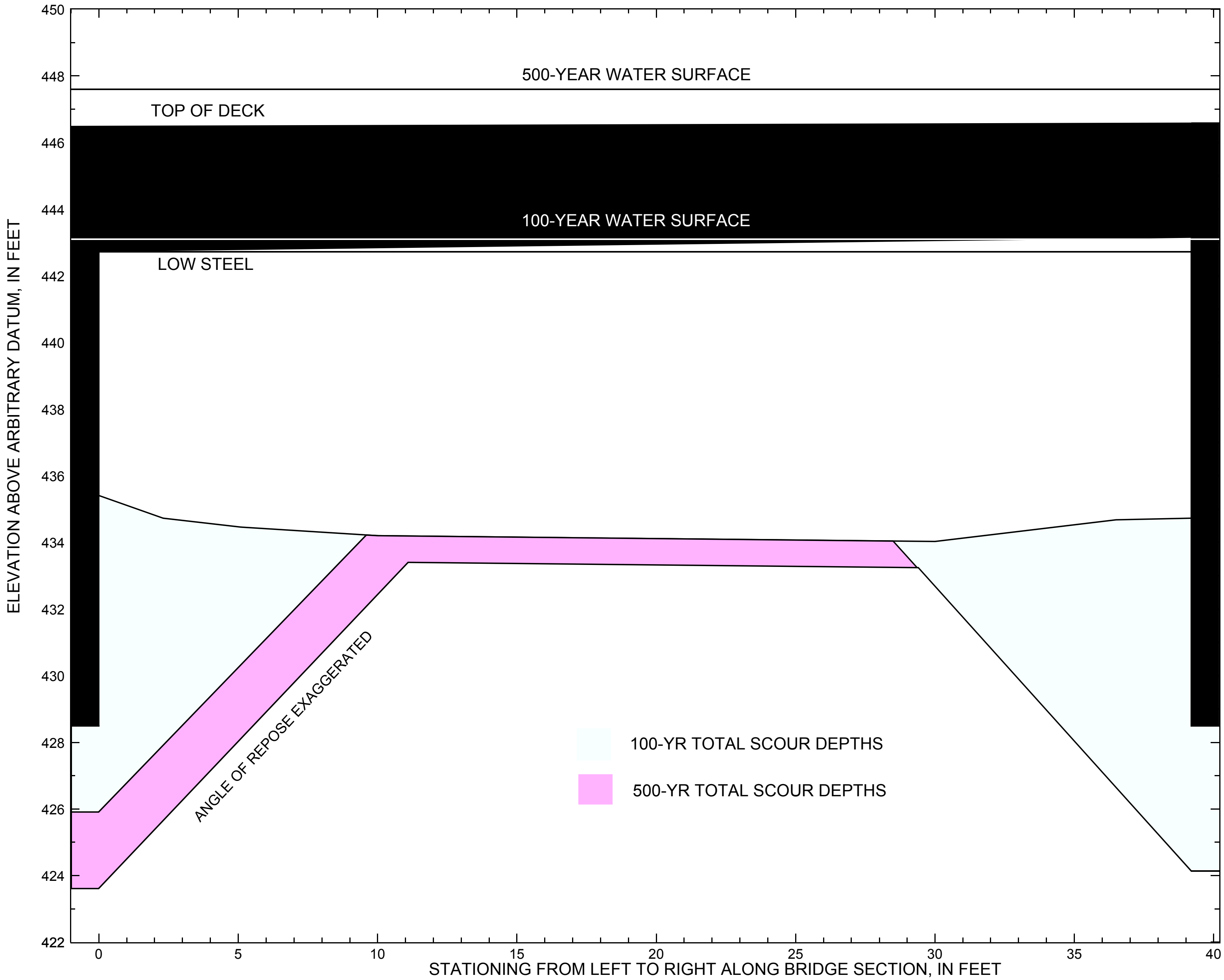

Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure ANDOVT00110039 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure ANDOVT00110039 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

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

Description	Station[1]	VTAOT minimum bridge seat 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 1,980 cubic-feet per second											
Left abutment	0.0	391.8	442.7	428.4	435.4	0.0	9.5	--	9.5	425.9	-2.5
Right abutment	39.2	--	443.1	428.4	434.7	0.0	10.6	--	10.6	424.1	-4.3

1.Measured along the face of the most constricting side of the bridge.

2.Arbitrary datum for this study.

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure ANDOVT00110039 on State Route 11, crossing the Middle Branch Williams River, Andover, Vermont.

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

Description	Station[1]	VTAOT minimum bridge seat 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 2,900 cubic-feet per second											
Left abutment	0.0	391.8	442.7	428.4	435.4	0.8	11.0	--	11.8	423.6	-4.8
Right abutment	39.2	--	443.1	428.4	434.7	0.8	8.9	--	9.7	425.0	-3.4

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, 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 ando039.wsp
T2        Hydraulic analysis for structure ANDOVT00110039   Date: 07-FEB-97
T3        VT11 crossing Middle Branch of Williams River in Andover, VT       RLB
*
J1         * * 0.005
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           1980.0   2900.0   2250.0
SK          0.0143   0.0143   0.0143
*
XS   EXITX    -32           0.
GR         -253.1, 455.15    -75.6, 445.13    -53.2, 445.92    -23.0, 445.52
GR           -9.9, 439.30      0.0, 434.52     15.5, 433.60     17.4, 432.81
GR           25.5, 432.65     29.7, 433.05     36.9, 433.31     41.8, 438.01
GR           55.5, 438.18     95.7, 460.34
*
N           0.035        0.060        0.100
SA                 -23.0        41.8
*
XS   FULLV      0  * * *   0.0214
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    442.93      50.0
GR            0.0, 442.72      0.0, 435.41      2.3, 434.73      5.1, 434.46
GR           10.0, 434.20     17.9, 434.15     30.0, 434.03     36.5, 434.38
GR           36.5, 434.68     39.2, 434.73     39.2, 443.14      0.0, 442.72
*
*         BRTYPE  BRWDTH        WWANGL    WWWID
CD           1      51.8 * *     69.3      6.5
N           0.045
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     21      32.5     1
GR          -20.5, 455.61    -20.5, 446.48      0.0, 446.48     38.6, 446.58
GR          152.5, 448.92    398.2, 463.12
*
XT   APTEM    113           0.
GR          -63.1, 456.52    -32.6, 452.65    -20.5, 445.26     -5.5, 444.95
GR            0.0, 442.31      3.3, 438.27     11.1, 435.84     19.5, 435.03
GR           20.7, 434.50     24.1, 434.37     27.2, 434.61     29.7, 435.06
GR           33.2, 436.64     39.5, 441.35     45.6, 445.76     54.6, 447.37
GR          127.4, 448.95    363.8, 463.05
*
AS   APPRO     67  * * * 0.0079
GT
N           0.100         0.060      0.045
SA                  -5.5        45.6
*
HP 1 BRIDG    443.14 1 443.14
HP 2 BRIDG    443.14 * * 1980
HP 1 APPRO    445.25 1 445.25
HP 2 APPRO    445.25 * * 1980
*
HP 1 BRIDG    443.14 1 443.14
HP 2 BRIDG    443.14 * * 2432
HP 2 RDWAY    447.64 * *  462
HP 1 APPRO    447.64 1 447.64
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
        U.S. Geological Survey WSPRO Input File ando039.wsp
        Hydraulic analysis for structure ANDOVT00110039   Date: 07-FEB-97
        VT11 crossing Middle Branch of Williams River in Andover, VT       RLB
           *** RUN DATE & TIME: 04-01-97  14:07
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      218     15868      0     67                            0
   443.14           218     15868      0     67  1.00      0     39        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       443.14     0.0    39.2   217.7   15868.    1980.   9.10

X STA.         0.0        3.7        6.0        7.9        9.8       11.6
  A(I)            18.9       11.8       10.7       10.4        9.7
  V(I)            5.25       8.38       9.27       9.56      10.21

X STA.        11.6       13.3       15.0       16.7       18.3       20.0
  A(I)             9.7        9.6        9.3        9.3        9.3
  V(I)           10.20      10.29      10.61      10.70      10.66

X STA.        20.0       21.6       23.3       24.9       26.5       28.2
  A(I)             9.3        9.4        9.2        9.4        9.6
  V(I)           10.59      10.55      10.76      10.56      10.31

X STA.        28.2       29.9       31.6       33.5       35.7       39.2
  A(I)             9.8       10.0       10.9       12.2       19.3
  V(I)           10.05       9.93       9.09       8.15       5.14

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      67.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1        8        72     16     16                           31
             2      382     33558     51     57                         5930
   445.25           389     33630     66     73  1.03    -20     45     5258

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      67.

         WSEL     LEW     REW    AREA        K        Q    VEL
       445.25   -21.1    45.4   389.4   33630.    1980.   5.09

X STA.       -21.1        4.1        6.9        9.1       11.1       12.8
  A(I)            42.2       22.6       19.7       18.5       17.0
  V(I)            2.35       4.37       5.04       5.36       5.82

X STA.        12.8       14.4       16.1       17.6       19.0       20.5
  A(I)            16.2       16.4       15.8       15.3       15.7
  V(I)            6.10       6.05       6.27       6.48       6.32

X STA.        20.5       21.9       23.2       24.6       26.0       27.4
  A(I)            15.1       15.2       15.4       15.2       16.1
  V(I)            6.54       6.51       6.41       6.50       6.14

X STA.        27.4       29.0       30.7       32.7       35.6       45.4
  A(I)            16.8       17.9       19.8       23.3       35.1
  V(I)            5.88       5.53       4.99       4.25       2.82
```

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        U.S. Geological Survey WSPRO Input File ando039.wsp
        Hydraulic analysis for structure ANDOVT00110039   Date: 07-FEB-97
        VT11 crossing Middle Branch of Williams River in Andover, VT       RLB
           *** RUN DATE & TIME: 04-01-97  14:07
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      218     15868      0     67                            0
   443.14           218     15868      0     67  1.00      0     39        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       443.14     0.0    39.2   217.7   15868.    2432.  11.17

X STA.         0.0        3.7        6.0        7.9        9.8       11.6
  A(I)            18.9       11.8       10.7       10.4        9.7
  V(I)            6.45      10.29      11.38      11.75      12.54

X STA.        11.6       13.3       15.0       16.7       18.3       20.0
  A(I)             9.7        9.6        9.3        9.3        9.3
  V(I)           12.52      12.64      13.03      13.14      13.09

X STA.        20.0       21.6       23.3       24.9       26.5       28.2
  A(I)             9.3        9.4        9.2        9.4        9.6
  V(I)           13.01      12.96      13.22      12.97      12.67

X STA.        28.2       29.9       31.6       33.5       35.7       39.2
  A(I)             9.8       10.0       10.9       12.2       19.3
  V(I)           12.35      12.20      11.16      10.01       6.31

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      21.

         WSEL     LEW     REW    AREA        K        Q    VEL
       447.64   -20.5    90.2    94.0    2077.     462.   4.92

X STA.       -20.5      -16.5      -13.3      -10.0       -6.7       -3.4
  A(I)             4.6        3.8        3.8        3.8        3.8
  V(I)            5.04       6.11       6.01       6.10       6.09

X STA.        -3.4       -0.2        3.1        6.4        9.8       13.2
  A(I)             3.8        3.8        3.8        3.9        3.8
  V(I)            6.12       6.05       6.07       5.97       6.02

X STA.        13.2       16.7       20.2       23.7       27.4       31.0
  A(I)             3.9        3.9        3.9        4.0        3.9
  V(I)            5.91       5.96       5.94       5.79       5.91

X STA.        31.0       34.7       38.4       43.4       53.8       90.2
  A(I)             4.0        4.0        5.0        8.9       13.6
  V(I)            5.83       5.80       4.61       2.58       1.70

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      67.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       50      1344     19     20                          449
             2      504     53147     51     58                         8975
             3       22       510     38     38                           96
   447.64           576     55001    109    116  1.18    -24     84     6915

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      67.

         WSEL     LEW     REW    AREA        K        Q    VEL
       447.64   -25.0    83.8   575.6   55001.    2900.   5.04

X STA.       -25.0        0.1        4.4        7.1        9.3       11.4
  A(I)            74.0       36.5       27.7       25.3       24.2
  V(I)            1.96       3.97       5.23       5.73       5.99

X STA.        11.4       13.3       15.0       16.8       18.5       20.2
  A(I)            23.2       22.2       22.2       21.5       21.9
  V(I)            6.25       6.54       6.52       6.74       6.63

X STA.        20.2       21.7       23.3       24.9       26.5       28.1
  A(I)            21.5       21.0       21.6       21.3       22.5
  V(I)            6.75       6.92       6.71       6.81       6.44

X STA.        28.1       29.9       32.0       34.4       38.1       83.8
  A(I)            23.4       25.1       27.6       33.1       59.8
  V(I)            6.18       5.77       5.25       4.39       2.43
```

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        U.S. Geological Survey WSPRO Input File ando039.wsp
        Hydraulic analysis for structure ANDOVT00110039   Date: 07-FEB-97
        VT11 crossing Middle Branch of Williams River in Andover, VT       RLB
           *** RUN DATE & TIME: 04-01-97  14:07
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      218     15868      0     67                            0
   443.14           218     15868      0     67  1.00      0     39        0

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       443.14     0.0    39.2   217.7   15868.    2250.  10.34

X STA.         0.0        3.7        6.0        7.9        9.8       11.6
  A(I)            18.9       11.8       10.7       10.4        9.7
  V(I)            5.97       9.52      10.53      10.87      11.60

X STA.        11.6       13.3       15.0       16.7       18.3       20.0
  A(I)             9.7        9.6        9.3        9.3        9.3
  V(I)           11.59      11.69      12.05      12.15      12.11

X STA.        20.0       21.6       23.3       24.9       26.5       28.2
  A(I)             9.3        9.4        9.2        9.4        9.6
  V(I)           12.04      11.99      12.23      12.00      11.72

X STA.        28.2       29.9       31.6       33.5       35.7       39.2
  A(I)             9.8       10.0       10.9       12.2       19.3
  V(I)           11.43      11.28      10.32       9.26       5.84

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      67.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1       30       608     18     18                          216
             2      449     43802     51     58                         7541
             3        4        86      7      7                           16
   446.56           482     44496     75     82  1.10    -22     52     6589

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      67.

         WSEL     LEW     REW    AREA        K        Q    VEL
       446.56   -23.2    52.1   481.9   44496.    2250.   4.67

X STA.       -23.2        2.3        5.5        8.0       10.1       12.0
  A(I)            61.1       28.1       24.1       22.0       21.0
  V(I)            1.84       4.01       4.67       5.11       5.35

X STA.        12.0       13.7       15.5       17.1       18.7       20.3
  A(I)            19.6       19.8       19.1       18.5       18.8
  V(I)            5.73       5.69       5.90       6.10       5.99

X STA.        20.3       21.7       23.2       24.7       26.2       27.8
  A(I)            18.6       18.1       18.7       18.4       19.5
  V(I)            6.05       6.20       6.01       6.10       5.77

X STA.        27.8       29.4       31.3       33.5       36.7       52.1
  A(I)            19.8       22.0       23.7       27.9       43.1
  V(I)            5.67       5.12       4.74       4.04       2.61
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       U.S. Geological Survey WSPRO Input File ando039.wsp
       Hydraulic analysis for structure ANDOVT00110039   Date: 07-FEB-97
       VT11 crossing Middle Branch of Williams River in Andover, VT       RLB
          *** RUN DATE & TIME: 04-01-97  14:07

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

EXITX:XS   ******     -8      256  1.00 *****  439.99  437.73    1980  438.99
       -31 ******     57    16557  1.08 ***** *******    0.72    7.75

FULLV:FV       32     -8      239  1.13  0.50  440.55 *******    1980  439.42
         0     32     57    15177  1.06  0.06    0.00    0.79    8.28
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.95     440.52     440.34

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   438.92     462.69    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   438.92     462.69     440.34

APPRO:AS       67      1      172  2.05  1.56  442.57  440.34    1980  440.52
        67     67     39    11097  1.00  0.46    0.00    0.95   11.49
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
          WS3,WSIU,WS1,LSEL =   440.07     443.67     443.90     442.93

 ===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       32      0      218  1.28 *****  444.42  440.05    1978  443.14
         0 ******     39    15868  1.00 ***** *******    0.68    9.09

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.489  0.000  442.93 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      21.        <<<<<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       15    -20      389  0.42  0.14  445.66  440.34    1980  445.25
        67     18     45    33596  1.03  1.34    0.00    0.38    5.09

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   445.13

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

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -32.    -9.    57.   1980.   16557.     256.    7.75  438.99
   FULLV:FV       0.    -9.    57.   1980.   15177.     239.    8.28  439.42
   BRIDG:BR       0.     0.    39.   1978.   15868.     218.    9.09  443.14
   RDWAY:RG      21.**************       0.******************    1.00********
   APPRO:AS      67.   -21.    45.   1980.   33596.     389.    5.09  445.25

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    437.73    0.72  432.65  460.34************  1.00  439.99  438.99
   FULLV:FV  ********    0.79  433.33  461.02  0.50  0.06  1.13  440.55  439.42
   BRIDG:BR    440.05    0.68  434.03  443.14************  1.28  444.42  443.14
   RDWAY:RG  ****************  446.48  463.12************  0.20  448.03********
   APPRO:AS    440.34    0.38  434.01  462.69  0.14  1.34  0.42  445.66  445.25
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        U.S. Geological Survey WSPRO Input File ando039.wsp
        Hydraulic analysis for structure ANDOVT00110039   Date: 07-FEB-97
        VT11 crossing Middle Branch of Williams River in Andover, VT       RLB
           *** RUN DATE & TIME: 04-01-97  14:07

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

EXITX:XS   ******    -11      341  1.26 *****  441.49  438.99    2900  440.23
       -31 ******     59    24233  1.12 ***** *******    0.73    8.51

FULLV:FV       32    -10      322  1.41  0.49  442.05 *******    2900  440.65
         0     32     59    22462  1.11  0.07    0.00    0.78    9.01
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
              FNTEST,FR#,WSEL,CRWS =  0.80    1.04     441.57     441.73

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                   WSLIM1,WSLIM2,DELTAY =   440.15     462.69    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                   WSLIM1,WSLIM2,CRWS =   440.15     462.69     441.73

 ===130 CRITICAL WATER-SURFACE ELEVATION  A _ S _ S _ U _ M _ E _ D  !!!!!
              ENERGY EQUATION  N_O_T  B_A_L_A_N_C_E_D  AT SECID "APPRO"
                   WSBEG,WSEND,CRWS =   441.73     462.69     441.73

APPRO:AS       67      0      219  2.72 *****  444.44  441.73    2900  441.73
        67     67     41    15697  1.00 ***** *******    1.00   13.22
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   441.73     446.21     446.46     442.93

 ===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       32      0      218  1.94 *****  445.08  440.91    2432  443.14
         0 ******     39    15868  1.00 ***** *******    0.84   11.18

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.500  0.000  442.93 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      21.    35.  0.10  0.47  448.01    0.00    462.  447.64

              Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    228.    40.   -21.    20.   1.2   1.1   5.6   4.9   1.5   3.0
   RT:    234.    70.    20.    90.   1.1   0.7   4.8   4.9   1.0   3.1

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

APPRO:AS       15    -24      575  0.47  0.18  448.10  441.73    2900  447.64
        67     22     84    54975  1.18  1.40    0.00    0.42    5.04

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -32.   -12.    59.   2900.   24233.     341.    8.51  440.23
   FULLV:FV      0.   -11.    59.   2900.   22462.     322.    9.01  440.65
   BRIDG:BR      0.     0.    39.   2432.   15868.     218.   11.18  443.14
   RDWAY:RG      21.*******   228.    462.*********      0.    1.00  447.64
   APPRO:AS      67.   -25.    84.   2900.   54975.     575.    5.04  447.64

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

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    438.99    0.73  432.65  460.34************  1.26  441.49  440.23
   FULLV:FV  ********    0.78  433.33  461.02  0.49  0.07  1.41  442.05  440.65
   BRIDG:BR    440.91    0.84  434.03  443.14************  1.94  445.08  443.14
   RDWAY:RG  ****************  446.48  463.12  0.10******  0.47  448.01  447.64
   APPRO:AS    441.73    0.42  434.01  462.69  0.18  1.40  0.47  448.10  447.64
```

WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File ando039.wsp
        Hydraulic analysis for structure ANDOVT00110039   Date: 07-FEB-97
        VT11 crossing Middle Branch of Williams River in Andover, VT       RLB
           *** RUN DATE & TIME: 04-01-97  14:07

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

EXITX:XS   ******     -9      282  1.08 *****  440.47  438.11    2250  439.38
       -31 ******     58    18814  1.09 ***** *******    0.72    7.99

FULLV:FV       32     -9      264  1.22  0.50  441.03 *******    2250  439.81
         0     32     57    17306  1.08  0.07    0.00    0.78    8.51
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===125 FR# EXCEEDS FNTEST AT SECID "APPRO":  TRIALS CONTINUED.
             FNTEST,FR#,WSEL,CRWS =  0.80    0.98     440.85     440.78

 ===110 WSEL NOT FOUND AT SECID "APPRO":  REDUCED DELTAY.
                  WSLIM1,WSLIM2,DELTAY =   439.31     462.69    0.50

 ===115 WSEL NOT FOUND AT SECID "APPRO":  USED WSMIN = CRWS.
                  WSLIM1,WSLIM2,CRWS =   439.31     462.69     440.78

APPRO:AS       67      1      185  2.29  1.59  443.15  440.78    2250  440.86
        67     67     39    12317  1.00  0.54    0.00    0.98   12.15
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   440.57     444.45     444.67     442.93

 ===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       32      0      218  1.65 *****  444.79  440.57    2242  443.14
         0 ******     39    15868  1.00 ***** *******    0.77   10.30

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   2.  0.498  0.000  442.93 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      21.        <<<<<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       15    -22      482  0.37  0.13  446.93  440.78    2250  446.56
        67     18     52    44470  1.10  1.36    0.00    0.34    4.67

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
     ****** ****** ******** ****** ******   446.47

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW      Q        K     AREA     VEL    WSEL
   EXITX:XS     -32.   -10.    58.   2250.   18814.     282.    7.99  439.38
   FULLV:FV      0.   -10.    57.   2250.   17306.     264.    8.51  439.81
   BRIDG:BR      0.     0.    39.   2242.   15868.     218.   10.30  443.14
   RDWAY:RG     21.**************      0.       0.       0.    1.00********
   APPRO:AS     67.   -23.    52.   2250.   44470.     482.    4.67  446.56

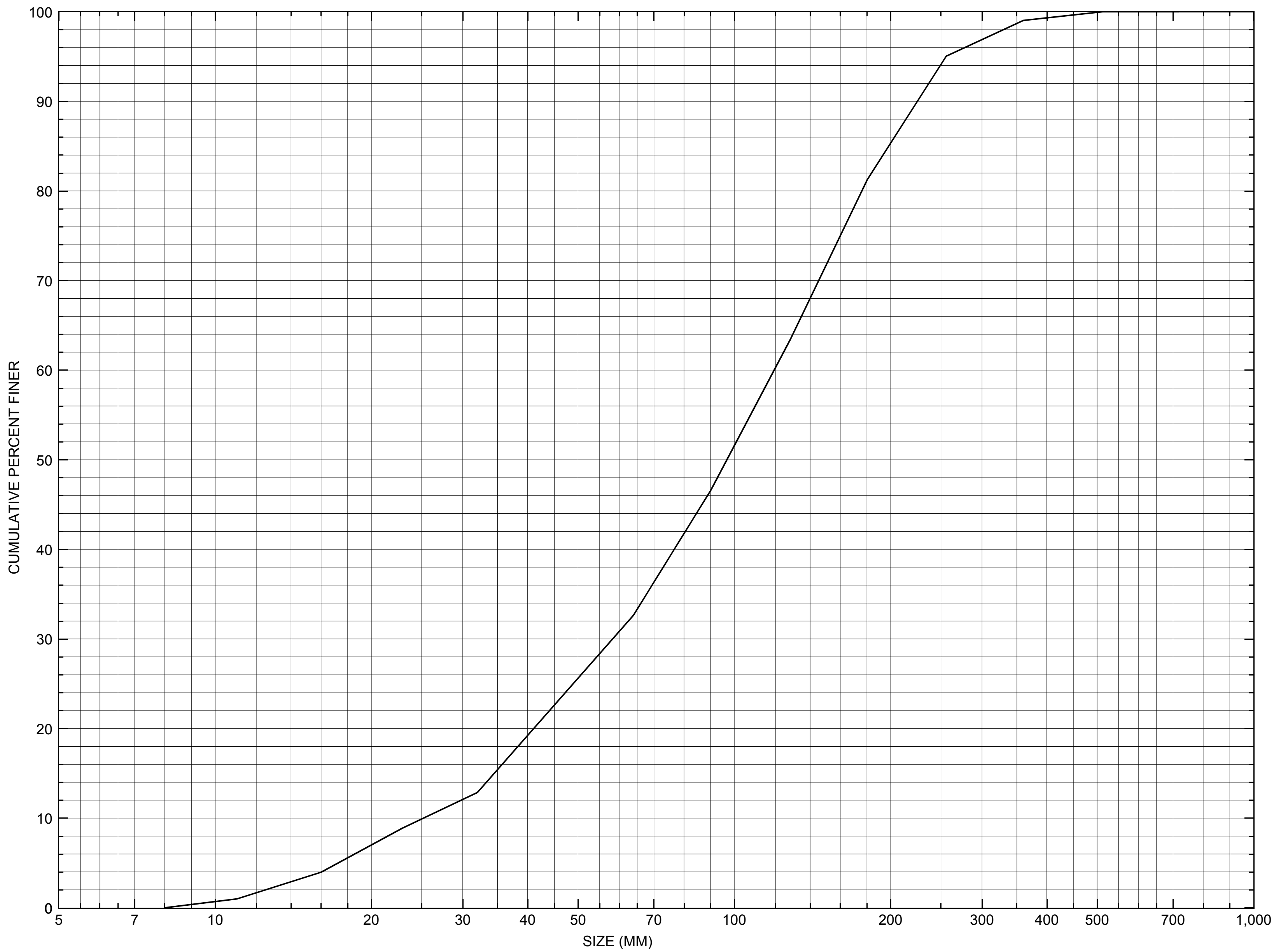
    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS  ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD     EGL    WSEL
   EXITX:XS    438.11    0.72  432.65  460.34************  1.08  440.47  439.38
   FULLV:FV  ********    0.78  433.33  461.02  0.50  0.07  1.22  441.03  439.81
   BRIDG:BR    440.57    0.77  434.03  443.14************  1.65  444.79  443.14
   RDWAY:RG  ****************  446.48  463.12************  0.37  446.84********
   APPRO:AS    440.78    0.34  434.01  462.69  0.13  1.36  0.37  446.93  446.56
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure ANDOVT00110039, in Andover, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number ANDOVT00110039

General Location Descriptive

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

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

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

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

Town *(FIPS place code; I - 4; nnnnn)* 01300

Mile marker *(I - 11; nnn.nnn)* 001670

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

Road Name *(I - 7)*: -

Route Number VT 11

Vicinity *(I - 9)* 3.0 MI E JCT VT 121

Topographic Map Andover

Hydrologic Unit Code: 01080107

Latitude *(I - 16; nnnn.n)* 43153

Longitude *(i - 17; nnnnn.n)* 72432

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 20001600391401

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

Maximum span length *(I - 48; nnnn)* 0041

Year built *(I - 27; YYYY)* 1929

Structure length *(I - 49; nnnnnn)* 000043

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

Deck Width *(I - 52; nn.n)* 325

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

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

Opening skew to Roadway *(I - 34; nn)* 45

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

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

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

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

Year Reconstructed *(I - 106)* 1973

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

Clear span (*nnn.n ft*) _______

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

Vertical clearance from streambed (*nnn.n ft*) 8.0

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

Waterway of full opening (*nnn.n ft*^{2}) _______

Comments:

The structural inspection report of 11/10/94 indicates the structure is a concrete T-beam type bridge with an asphalt road surface. The concrete footing is exposed on the upstream end at the newer portion of the abutment. The left abutment has some minor scaling along the flow lines. The upstream right wingwall is in good condition. The downstream right wingwall has some moderate scaling along the flow line and the top of the wingwall is cracked off. The upstream left wingwall has some minor cracks and stains. The downstream left wingwall has some heavy spalling and heavily corroded reinforcement bar exposed 12 feet from the end. There is a crack, approximately 4 inches wide in the downstream **(Continued, page 33)**

Bridge Hydrologic Data

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

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} (ft^3/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 (ft^2): -

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

Comments:
left wingwall. Some areas show signs of movement. The left abutment footing is not in view. The channel alignment is straight through the skewed structure with a slight turn approximately 50 feet downstream. The channel bed consists of stone and gravel. There is some heavy stone riprap along the upstream right abutment end, and some stone and free-poured concrete at the upstream end of the left abutment. The wings have some course gravel and vegetation in front of them.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **5.75** mi^2 Lake and pond area **0** mi^2
Watershed storage *(ST)* **0** %
Bridge site elevation **1200** ft Headwater elevation **2894** ft
Main channel length **5.03** mi
10% channel length elevation **1240** ft 85% channel length elevation **2106** ft
Main channel slope *(S)* **229.72** 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** / **1972**

Project Number **BMA 6308** Minimum channel bed elevation: **383.0**

Low superstructure elevation: USLAB **391.75** DSLAB **392.78** USRAB **-** DSRAB **393.04**

Benchmark location description:

Chiseled 'X' in the concrete step to church located 115 feet left bankward from the left abutment and 58 feet perpendicular from roadway centerline in upstream direction, elevation 392.21.

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

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

If 1: Footing Thickness **2.0** Footing bottom elevation: **377.5***

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

If 3: Footing bottom elevation: ______

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

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

Briefly describe material at foundation bottom elevation or around piles:

Plans show "bottom of footings foundation: boulder"

Comments:

***The base of the new upstream right wing wall is 381.0 with a top elevation of 395.56. The original structure remained during the rehabilitation in 1972 which included only widening the deck on the upstream side. Other elevation points: 1) point on the top streamward edge of the upstream right wingwall where it meets the right abutment, elevation 395.56; 2) the point at the upstream end of the upstream left wingwall on the top streamward corner of the concrete, elevation 391.0. The footings on the widened section are shown with a bottom elevation about 3.5 feet higher than those on the original bridge set at 377.5. The bed elevation on the original structure is shown at 383.0.**

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: **RB** Date: **10/01/96**
Computerized by: **RB** Date: **10/01/96**
Reviewd by: **RB** Date: **03/31/97**

Structure Number **ANDOVT00110039**

A. General Location Descriptive

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

2. Highway District Number **02**
Mile marker **001670**
County **027**
Town **ANDOVER 01300**
Waterway *(I - 6)* **MIDDLE BR. WILLIAMS RIVER**
Road Name **-**
Route Number **VT 11**
Hydrologic Unit Code: **01080107**

3. Descriptive comments:
Located 3.0 miles east of the junction with VT 121 and approximately 0.1 miles west of Lyman Brook junction with the Middle Branch of the Williams River at ANDO040.

B. Bridge Deck Observations

4. Surface cover... LBUS **6** RBUS **5** LBDS **5** 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 **2** 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 **43** *(feet)* Span length **41** *(feet)* Bridge width **32.5** *(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)*

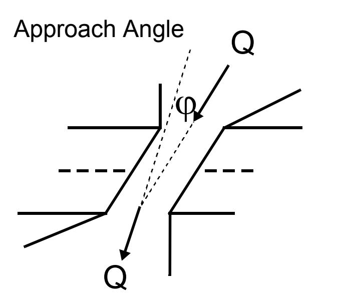
10. Embankment slope (*run / rise in feet / foot*):
US left **11:4:1** US right **12:9:1**

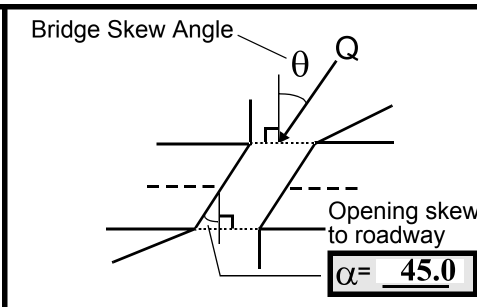
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	0	-	0	-
RBUS	0	-	0	-
RBDS	0	-	2	1
LBDS	0	-	2	2

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

Channel approach to bridge (BF):

15. Angle of approach: **20** 16. Bridge skew: **45**





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **165** feet **US** *(US, UB, DS)* to **0** feet **US**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **1**
Range? **46** feet **DS** *(US, UB, DS)* to **150** feet **DS**

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

18. Bridge Type: 1

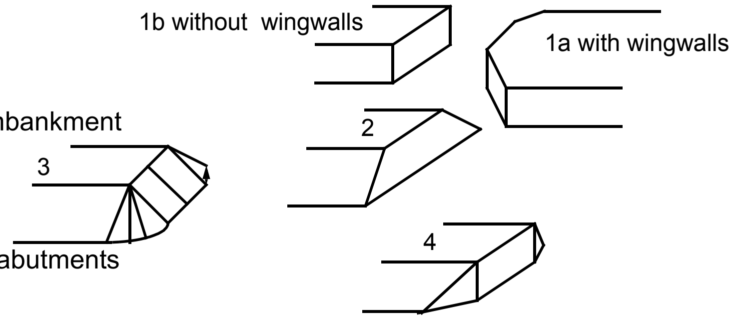
1a- Vertical abutments with wingwalls

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 left bank US a dirt driveway runs parallel to the channel. On the right bank US and the left bank DS, VT 11 runs parallel to the channel. The right bank DS is all forested.

7. Values are from the VT AOT files. Measured bridge length is 46 ft. US and 44 ft. DS, clear span length is 43.5 ft. US and 42 ft. DS, and the bridge width is 31.6 ft.

13. The road wash on the right bank DS is minor with the back side of the DS right wingwall being eroded a bit. On the left bank DS the road wash has eroded asphalt and the DS left wingwall. A large section of the DS left wingwall is hanging over the channel by rebar.

18. The US right wingwall is type 1a and the US left wingwall slopes to 1 ft. below the low chord and is type 4. The DS right wingwall is type 2 and the DS left wingwall is type 4.

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
67.0	9.0			9.0	3	3	435	435	1	1

23. Bank width 30.0 24. Channel width 35.0 25. Thalweg depth 51.0 29. Bed Material 453

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.):

26. From 50 ft. US to the US bridge face the percent vegetation on the US right bank is 0% to 25%.

33. Point/Side bar present? Y (Y or N. if N type ctrl-n pb) 34. Mid-bar distance: 75 35. Mid-bar width: 9.5

36. Point bar extent: 121 feet US (US, UB) to 8 feet US (US, UB, DS) positioned 0 %LB to 50 %RB

37. Material: 430

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

Vegetation on side bar is grass.

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

41. Mid-bank distance: 141 42. Cut bank extent: 165 feet US (US, UB) to 124 feet US (US, UB, DS)

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

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

Vegetation has slipped down the slope of the US left bank where it now protrudes into part of the channel, also the US right bank at this point is eroded and undermined.

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 small scour holes are behind the 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)		57 Angle (BF)		61. Material (BF)		62. Erosion (BF)	
LB	RB	LB	RB	LB	RB	LB	RB
22.0		0.5		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.):

4325

63. Some of the bed material under the bridge towards the left abutment is concrete. The bed is also tightly packed cobble and gravel with some sand and boulders.

The bridge deck was widened and two steel I beams were added to the US end. The US left wingwall extends underneath the bridge deck.

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

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

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

70. Debris and Ice Comments:

1

67. 68. There are many large trees along both banks. Between ANDO039 and ANDO038 some very large trees are down in the middle of the channel.

69. There are some small scars on the trees.

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		25	90	2	0	-	-	90.0
RABUT	1	0	90			2	2	27.5

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.):

0

0.7

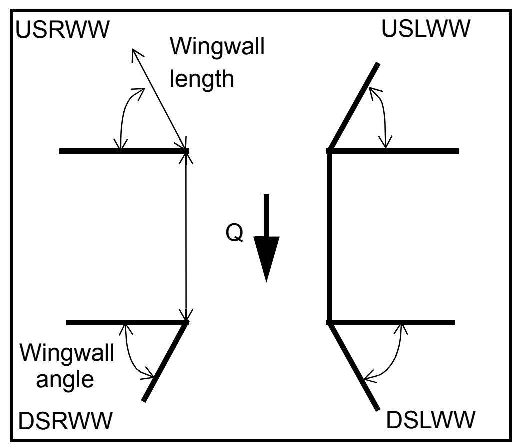
1

76. Only the US end of the right abutment footing is exposed. A point bar covers the footing from 5 ft. under the bridge to the DS bridge face.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						27.5	
USRWW:	Y		1		0	0.5	
DSLWW:	-		-		Y	44.5	
DSRWW:	1		2		0	48.5	

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



82. **Bank / Bridge Protection**:

Location	USLWW	USRWW	LABUT	RABUT	LB	RB	DSLWW	DSRWW
Type	1.2	0	Y	-	1	2	-	-
Condition	Y	-	1	-	1	2	-	-
Extent	1	-	0	3	2	0	0	-

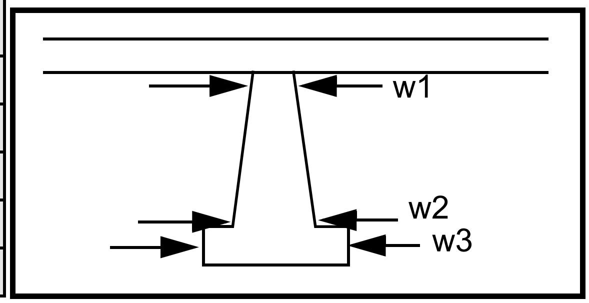
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

84. Are there piers? **80.** *(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				**120.0**	**11.5**	**15.0**
Pier 2				**27.0**	**15.0**	**31.0**
Pier 3			**-**	**135.0**	**13.0**	**-**
Pier 4	**-**	**-**	**-**	**-**	**-**	**-**



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

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
-		-		-	-	-	-	-	-	-

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.):
-
-
-
-
-
-
-
-
NO PIERS

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

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

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

2
3
432
345
1

106. Point/Side bar present? 2 (Y or N. if N type ctrl-n pb) Mid-bar distance: 435 Mid-bar width: 0

Point bar extent: 0 feet - (US, UB, DS) to - feet Th (US, UB, DS) positioned e %LB to be %RB

Material: d

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

material also consists of broken off pieces of concrete.

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

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

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

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

N

Is channel scour present? - (Y or if N type ctrl-n cs) Mid-scour distance: NO

Scour dimensions: Length DRO Width P Depth: STR Positioned UC %LB to TU %RB

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

RE

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

Confluence 1: Distance Y Enters on 2 (LB or RB) Type 17 (**1**- perennial; **2**- ephemeral)

Confluence 2: Distance 5 Enters on UB (LB or RB) Type 48 (**1**- perennial; **2**- ephemeral)

Confluence comments (eg. confluence name):

DS
50

F. Geomorphic Channel Assessment

107. Stage of reach evolution 100

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)*:

325

Vegetation on the point bar is grass. An additional point bar extends from 20 ft. DS to 145 ft. DS. The mid-bar distance is 82 ft. and the width is 21 ft. It is positioned 0% LB to 45% RB and the material is gravel, sand, and boulders.

Y
RB
82
46
DS
127
DS
1

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: ANDOVT00110039   Town: ANDOVER
Road Number: VT011   County: WINDHAM
Stream: MIDDLE 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	1980	2900	2250
Main Channel Area, ft2	382	504	449
Left overbank area, ft2	8	50	30
Right overbank area, ft2	0	22	4
Top width main channel, ft	51	51	51
Top width L overbank, ft	16	19	18
Top width R overbank, ft	0	38	7
D50 of channel, ft	0.317	0.317	0.317
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	7.5	9.9	8.8
y1, average depth, LOB, ft	0.5	2.6	1.7
y1, average depth, ROB, ft	ERR	0.6	0.6
Total conveyance, approach	33630	55001	44496
Conveyance, main channel	33558	53147	43802
Conveyance, LOB	72	1344	608
Conveyance, ROB	0	510	86
Percent discrepancy, conveyance	0.0000	0.0000	0.0000
Qm, discharge, MC, cfs	1975.8	2802.2	2214.9
Ql, discharge, LOB, cfs	4.2	70.9	30.7
Qr, discharge, ROB, cfs	0.0	26.9	4.3
Vm, mean velocity MC, ft/s	5.2	5.6	4.9
Vl, mean velocity, LOB, ft/s	0.5	1.4	1.0
Vr, mean velocity, ROB, ft/s	ERR	1.2	1.1
Vc-m, crit. velocity, MC, ft/s	10.7	11.2	11.0
Vc-l, crit. velocity, LOB, ft/s	ERR	ERR	ERR
Vc-r, crit. velocity, ROB, ft/s	ERR	ERR	ERR

Results

Live-bed(1) or Clear-Water(0) Contraction Scour?			
Main Channel	0	0	0
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

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	382	504	449
Main channel width, ft	51	51	51
y1, main channel depth, ft	7.49	9.88	8.80

Bridge Section	Q100	Q500	Qother
(Q) total discharge, cfs	1980	2900	2250
(Q) discharge thru bridge, cfs	1980	2432	2250
Main channel conveyance	15868	15868	15868
Total conveyance	15868	15868	15868
Q2, bridge MC discharge,cfs	1980	2432	2250
Main channel area, ft2	218	218	218
Main channel width (skewed), ft	25.2	25.2	25.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	25.2	25.2	25.2
y_bridge (avg. depth at br.), ft	8.65	8.65	8.65
Dm, median (1.25*D50), ft	0.39625	0.39625	0.39625
y2, depth in contraction,ft	6.79	8.10	7.58
ys, scour depth (y2-ybridge), ft	-1.86	-0.55	-1.07

ARMORING			
D90	0.739	0.739	0.739
D95	0.839	0.839	0.839
Critical grain size,Dc, ft	0.3379	0.5098	0.4364
Decimal-percent coarser than Dc	0.47	0.265	0.346
Depth to armoring,ft	1.14	4.24	2.47

Pressure Flow Scour (contraction scour for orifice flow conditions)

```
Hb+Ys=Cq*qbr/Vc          Cq=1/Cf*Cc           Cf=1.5*Fr^0.43 (<=1)
Chang Equation           Cc=SQRT[0.10(Hb/(ya-w)-0.56)]+0.79  (<=1)
(Richarson and others, 1995, p. 145-146)
```

	Q100	Q500	OtherQ
Q, total, cfs	1980	2900	2250
Q, thru bridge, cfs	1980	2432	2250
Total Conveyance, bridge	15868	15868	15868
Main channel(MC) conveyance, bridge	15868	15868	15868
Q, thru bridge MC, cfs	1980	2432	2250
Vc, critical velocity, ft/s	10.69	11.20	10.98
Vc, critical velocity, m/s	3.26	3.41	3.35
Main channel width (skewed), ft	25.2	25.2	25.2
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	25.2	25.2	25.2
qbr, unit discharge, ft2/s	78.6	96.5	89.3
qbr, unit discharge, m2/s	7.3	9.0	8.3
Area of full opening, ft2	218.0	218.0	218.0
Hb, depth of full opening, ft	8.65	8.65	8.65
Hb, depth of full opening, m	2.64	2.64	2.64
Fr, Froude number, bridge MC	0.68	0.84	0.77
Cf, Fr correction factor (<=1.0)	1.00	1.00	1.00
Elevation of Low Steel, ft	442.93	442.93	442.93
Elevation of Bed, ft	434.28	434.28	434.28
Elevation of Approach, ft	445.25	447.64	446.56
Friction loss, approach, ft	0.14	0.18	0.13
Elevation of WS immediately US, ft	445.11	447.46	446.43
ya, depth immediately US, ft	10.83	13.18	12.15
ya, depth immediately US, m	3.30	4.02	3.70
Mean elevation of deck, ft	446.529	446.529	446.529
w, depth of overflow, ft (>=0)	0.00	0.93	0.00
Cc, vert contrac correction (<=1.0)	0.94	0.91	0.91
Ys, depth of scour, ft	-0.87	0.81	0.25

Comparison of Chang and Laursen results (for unsubmerged orifice flow)

y2, from Laursen’s equation, ft	6.791669	8.100614	7.578143
Full valley WSEL, ft	439.42	440.65	439.81
Full valley depth, ft	5.140794	6.370794	5.530794
Ys, depth of scour (y2-yfullv), ft	1.650875	1.729821	2.047349

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	1980	2900	2250	1980	2900	2250
a', abut.length blocking flow, ft	28.1	32	30.2	13.2	51.6	19.9
Ae, area of blocked flow ft2	65.7	105.28	103.66	63.35	86.39	85
Qe, discharge blocked abut.,cfs	202.5	--	292.5	222.75	--	291.48
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	3.08	3.13	2.82	3.52	3.58	3.43
ya, depth of f/p flow, ft	2.34	3.29	3.43	4.80	1.67	4.27
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	0.82	0.82	0.82	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	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	0.355	0.267	0.268	0.283	0.417	0.292
ys, scour depth, ft	9.48	11.00	11.16	10.55	8.86	10.82

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)	28.1	32	30.2	13.2	51.6	19.9
y1 (depth f/p flow, ft)	2.34	3.29	3.43	4.80	1.67	4.27
a'/y1	12.02	9.73	8.80	2.75	30.82	4.66
Skew correction (p. 49, fig. 16)	1.00	1.00	1.00	1.00	0.72	1.00
Froude no. f/p flow	0.36	0.27	0.27	0.28	0.42	0.29
Ys w/ corr. factor K1/0.55:						
vertical	ERR	ERR	ERR	ERR	6.60	ERR
vertical w/ ww's	ERR	ERR	ERR	ERR	5.41	ERR
spill-through	ERR	ERR	ERR	ERR	3.63	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	0.68	0.84	0.77	0.68	0.84	0.77
(Fr from the characteristic V and y in contracted section--mc, bridge section)						
y, depth of flow in bridge, ft	8.65	8.65	8.65	8.65	8.65	8.65
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	2.47	ERR	3.17	2.47	ERR	3.17
Fr>0.8 (vertical abut.)	ERR	3.45	ERR	ERR	3.45	ERR
Fr<=0.8 (spillthrough abut.)	2.16	ERR	2.77	2.16	ERR	2.77
Fr>0.8 (spillthrough abut.)	ERR	3.05	ERR	ERR	3.05	ERR