LEVEL II SCOUR ANALYSIS FOR BRIDGE 50 (WALLTH00600050) on TOWN HIGHWAY 60, crossing OTTER CREEK, WALLINGFORD, VERMONT

Open-File Report 98-255

Prepared in cooperation with

VERMONT AGENCY OF TRANSPORTATION

and

FEDERAL HIGHWAY ADMINISTRATION

U.S. Department of the Interior
U.S. Geological Survey

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By MICHAEL A. IVANOFF

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Pembroke, New Hampshire

1998

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

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 50 (WALLTH00600050) ON TOWN HIGHWAY 60, CROSSING OTTER CREEK, WALLINGFORD, VERMONT

***By* Michael A. Ivanoff**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure WALLTH00600050 on Town Highway 60 crossing Otter Creek, Wallingford, Vermont (figures 1–8). A Level II study is a basic engineering analysis of the site, including a quantitative analysis of stream stability and scour (FHWA, 1993). Results of a Level I scour investigation also are included in appendix E of this report. A Level I investigation provides a qualitative geomorphic characterization of the study site. Information on the bridge, gleaned from Vermont Agency of Transportation (VTAOT) files, was compiled prior to conducting Level I and Level II analyses and is found in appendix D.

The site is in the Taconic section of the New England physiographic province in south-central Vermont. The 103-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is forest.

In the study area, Otter Creek has an incised, straight channel with a slope of approximately 0.004 ft/ft, an average channel top width of 70 ft and an average bank height of 4 ft. The channel bed material ranges from gravel to boulders with a median grain size (D_{50}) of 94.5 mm (0.310 ft). The geomorphic assessment at the time of the Level I and Level II site visit on September 26, 1995, indicated that the reach was laterally unstable. There is anabranching up- and downstream with bedrock along the left bank and flow channels with random bars across the channel.

The Town Highway 60 crossing of Otter Creek is a 72-ft-long, one-lane bridge consisting of one 70-foot steel thru-truss span (Vermont Agency of Transportation, written communication, March 22, 1995). The opening length of the structure parallel to the bridge face is 67 ft. The bridge is supported by vertical, concrete abutments with wingwalls. The channel is skewed approximately 25 degrees to the opening while the computed opening-skew-to-roadway is 5 degrees.

A scour hole 7.5 ft deeper than the mean thalweg depth was observed along the downstream channel during the Level I assessment. The scour protection measures at the site include type-2 stone fill (less than 36 inches diameter) along the left abutment, upstream left bank, upstream left wingwall, downstream left wingwall, and downstream left bank. Type-3 stone fill (less than 48 inches diameter) was observed along the right abutment. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

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

Computed contraction scour for all modelled flows was zero feet. Abutment scour ranged from 7.9 to 17.9 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 Davis, 1995, p. 46). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Wallingford, VT. Quadrangle, 1:24,000, 1986

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 WALLTH00600050 ***Stream*** Otter Creek

County Rutland ***Road*** TH 60 ***District*** 3

Description of Bridge

Bridge length 72.0 ***ft*** ***Bridge width*** 12.3 ***ft*** ***Max span length*** 70.0 ***ft***

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

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

Stone fill on abutment? No ***Date of inspection*** 9/26/95

Description of stone fill Type-2, along the entire base length of the left abutment and type-3, along the entire base length of the right abutment.

Brief description of piers/abutments Abutments and wingwalls are concrete.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 25

There is a mild channel bend in the upstream reach.

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

	Date of inspection	***Percent of channel blocked horizontally***	***Percent of channel blocked vertically***
Level I	9/26/95	0	0
Level II	9/26/95	0	0

Potential for debris Moderate. There is some debris caught on the banks and trees leaning over the channel upstream.

Describe any features near or at the bridge that may affect flow (include observation date) A 6 ft diameter culvert was observed on 9/26/95 through the right road embankment, which has little affect at high flow.

Description of the Geomorphic Setting

General topography The channel is located within a moderate relief valley with a steep valley wall on the left bank and a flood plain on the right bank.

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

Date of inspection 9/26/95

DS left: Steep channel bank and valley wall.

DS right: Steep channel bank and a narrow, irregular flood plain.

US left: Steep channel bank and valley wall.

US right: Mildly sloped channel bank and an irregular flood plain.

Description of the Channel

Average top width 70 ft ***Average depth*** 4 ft

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

Perennial, straight and anabranched stream with semi-alluvial channel boundaries.

9/26/95

Vegetative co Trees and brush.

DS left: Trees and brush.

DS right: Trees and brush.

US left: Trees and brush.

US right: Yes

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

None as of 9/26/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 103 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

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

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

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

USGS gage description Otter Creek at Center Rutland

USGS gage number 04282000

Gage drainage area 307 ***mi²***

Is there a lake/p No

Calculated Discharges

Q100 6,460 ***ft³/s*** ***Q500*** 7,970 ***ft³/s***

The 100- and 500-year discharges are based on a drainage area relationship [(103/307)exp 0.67] with the 100- and 500-year discharges determined for the downstream (04282000, Otter Creek at Center Rutland) gage for the period of record from 1928 to 1993. The 100- and 500- year discharges at the gage were developed using a Log-Pearson Type-III analysis of the peak-flow data (Interagency Advisory Committee on Water Data, 1982). The values used were within a range defined by flood frequency curves developed from several empirical methods (Benson, 1962; Johnson and Tasker, 1974; FHWA, 1983; Potter, 1957a&b; Talbot, 1887).

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

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

Datum tie between USGS survey and VTAOT plans None

Description of reference marks used to determine USGS datum. RM1 is a chiseled “X” on top of the downstream end of the right abutment bridge seat (elev. 498.29 ft, arbitrary survey datum). RM2 is a chiseled “X” on top of the upstream end of the left abutment bridge seat (elev. 498.59 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	-58	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	8	1	Road Grade section
APPRO	83	2	Modelled Approach section (Templated from APTEM)
APTEM	95	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 0.040 to 0.060, and overbank "n" values ranged from 0.055 to 0.060.

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 0.0013 ft/ft, which was estimated from the 100-year flood profile from the Flood Insurance Study for the Town of Wallingford, VT (Federal Emergency Management Agency, 1980).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.0352 ft/ft) to establish the modelled approach section (APPRO), one bridge length upstream of the upstream face as recommended by Shearman and others (1986). This location provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 501.0 ***ft***
Average low steel elevation 498.8 ***ft***

100-year discharge 6,460 ***ft³/s***
Water-surface elevation in bridge opening 498.0 ***ft***
Road overtopping? Yes ***Discharge over road*** 1,500 ***ft³/s***
Area of flow in bridge opening 629 ***ft²***
Average velocity in bridge opening 7.9 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.9 ***ft/s***

Water-surface elevation at Approach section with bridge 499.3
Water-surface elevation at Approach section without bridge 497.4
Amount of backwater caused by bridge 1.9 ***ft***

500-year discharge 7,970 ***ft³/s***
Water-surface elevation in bridge opening 499.2 ***ft***
Road overtopping? Yes ***Discharge over road*** 2,790 ***ft³/s***
Area of flow in bridge opening 686 ***ft²***
Average velocity in bridge opening 7.6 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.1 ***ft/s***

Water-surface elevation at Approach section with bridge 500.1
Water-surface elevation at Approach section without bridge 499.2
Amount of backwater caused by bridge 0.9 ***ft***

Incipient overtopping discharge 3,720 ***ft³/s***
Water-surface elevation in bridge opening 495.7 ***ft***
Area of flow in bridge opening 479 ***ft²***
Average velocity in bridge opening 7.8 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.7 ***ft/s***

Water-surface elevation at Approach section with bridge 497.0
Water-surface elevation at Approach section without bridge 496.5
Amount of backwater caused by bridge 0.5 ***ft***

Scour Analysis Summary

Special Conditions or Assumptions Made in Scour Analysis

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

Contraction scour for the 100-year and incipient roadway-overtopping discharges was computed by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20). At this site, the 500-year discharge resulted in unsubmerged orifice flow. Contraction scour at bridges with orifice flow is best estimated by use of the Chang pressure-flow scour equation (oral communication, J. Sterling Jones, October 4, 1996). Thus, contraction scour for this discharge was computed by use of the Chang equation (Richardson and Davis, 1995, p. 145-146).

For comparison, contraction scour for the 500-year discharge was also computed by use of the Laursen clear-water contraction scour equation and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). The results are presented in appendix F.

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

The effect of scour on the stone fill embankment material is uncertain so the depth of scour at the wall is unknown. Therefore, the elevation at the toe of the stone fill at the left abutment was used to compute the elevation of scour. The resulting scour elevation for the 100- and 500-year discharges was depicted at the left abutment wall and for the entire embankment in figure 8.

Scour Results

Contraction scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.0	0.0
Depth to armoring	0.2	0.1	0.2
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-year discharge	500-year discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	11.2	11.7	7.9
Right abutment	16.2	17.9	11.6
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-year discharge	500-year discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	1.5	1.1	1.4
Right abutment	1.5	1.1	1.4
Piers:	--	--	--
Pier 1	--	--	--
Pier 2	--	--	--

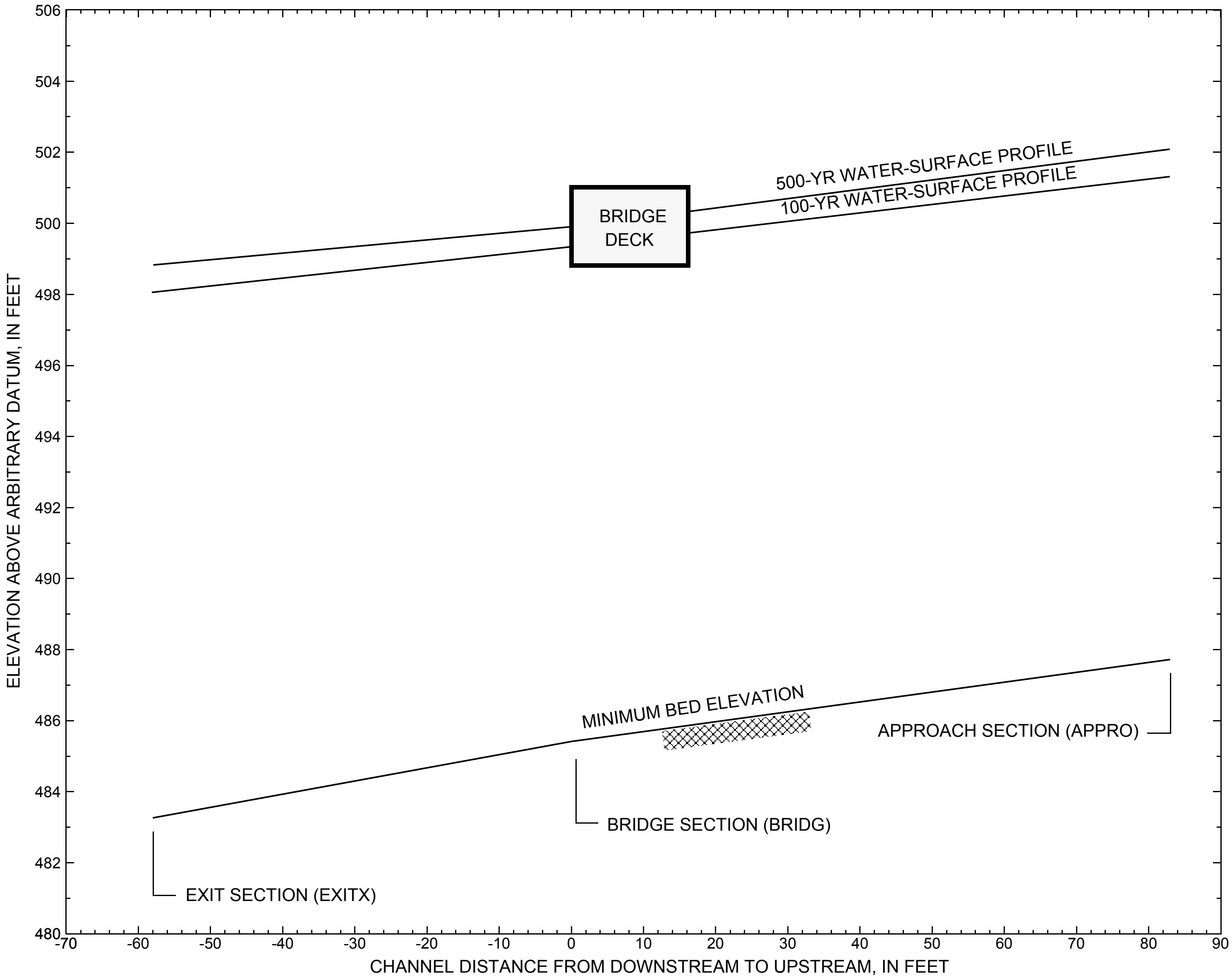

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure WALLTH00600050 on Town Highway 60, crossing Otter Creek, Wallingford, Vermont.

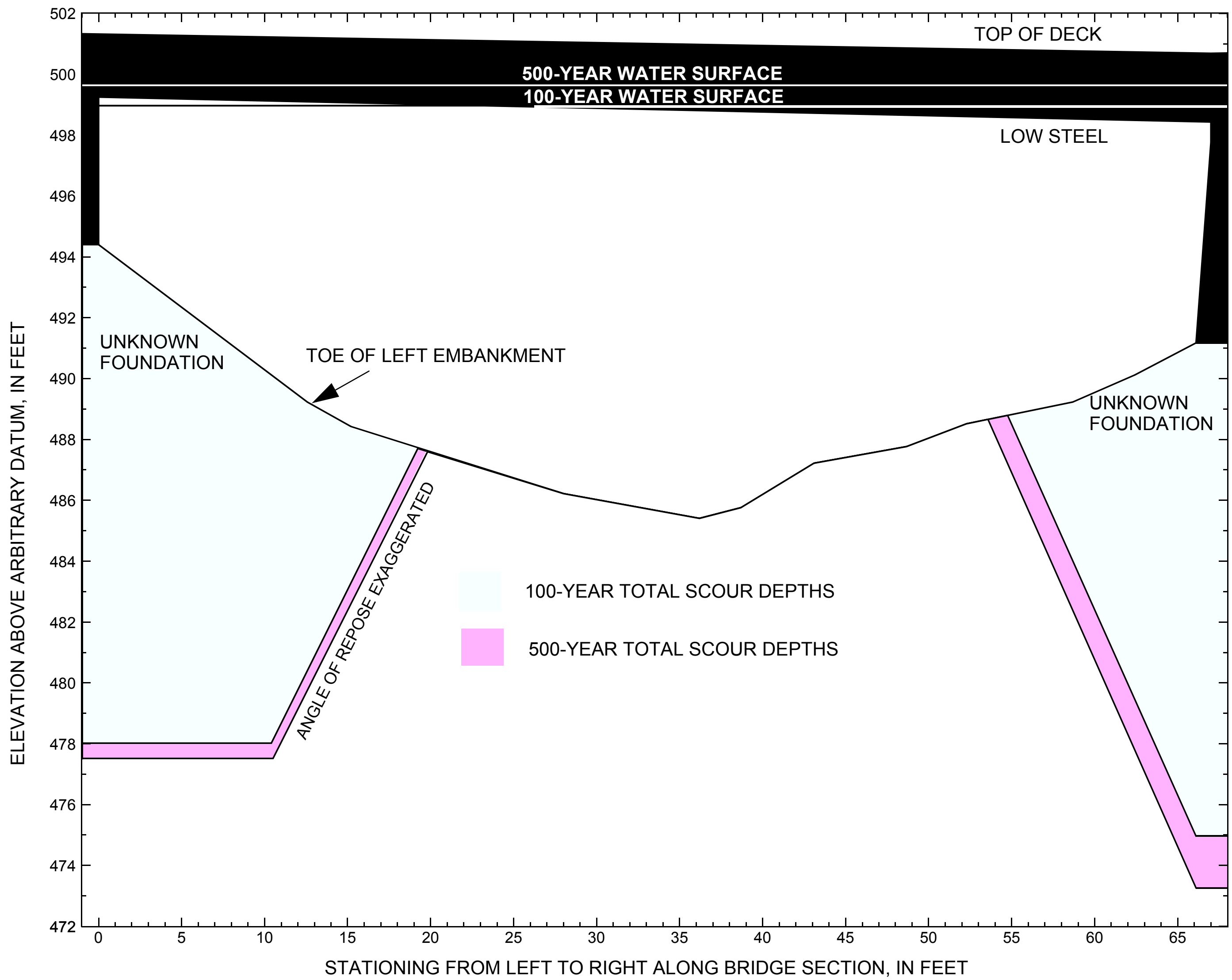

Figure 8. Scour elevations for the 100- and 500-year discharges at structure WALLTH00600050 on Town Highway 60, crossing Otter Creek, Wallingford, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure WALLTH00600050 on Town Highway 60, crossing Otter Creek, Wallingford, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year discharge is 6,460 cubic-feet per second											
Left abutment	0.0	--	499.2	--	494.4	0.0	--	--	--	478.0	--
Toe of left embankment	12.6	--	--	--	489.2	0.0	11.2	--	11.2	478.0	--
Right abutment	67.0	--	498.4	--	491.2	0.0	16.2	--	16.2	475.0	--

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 WALLTH00600050 on Town Highway 60, crossing Otter Creek, Wallingford, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing/pile elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year discharge is 7,790 cubic-feet per second											
Left abutment	0.0	--	499.2	--	494.4	0.0	--	--	--	477.5	--
Toe of left embankment	12.6	--	--	--	489.2	0.0	11.7	--	11.7	477.5	--
Right abutment	67.0	--	498.4	--	491.2	0.0	17.9	--	17.9	473.3	--

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, 1986, Wallingford, 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 wall050.wsp
T2        Hydraulic analysis for structure WALLTH00600050   Date: 07-NOV-97
T3        Bridge 50 on Elm St. Town Highway 60 over Otter Creek Wallingford, VT
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q          6460.0    7970.0    3720.0
SK         0.0013    0.0013    0.0013
*
XS   EXITX    -58
GR          -26.9, 510.37    -21.2, 500.77    -17.0, 498.08
GR          -12.6, 497.82     -4.0, 492.17      0.0, 489.22      1.8, 488.20
GR           11.3, 483.82     17.8, 483.26     24.6, 483.27     30.9, 484.46
GR           38.5, 486.39     42.1, 488.05     47.3, 488.47     54.4, 489.22
GR           57.6, 489.99     59.3, 492.02     84.3, 494.10    110.0, 493.58
GR          130.8, 493.20    134.1, 489.95    136.8, 489.40    141.2, 489.57
GR          142.7, 489.81    144.3, 490.46    148.3, 492.90    160.4, 492.14
GR          167.3, 490.30    175.6, 489.48    184.7, 491.18    188.7, 492.90
GR          201.6, 494.60    224.7, 495.18    329.5, 495.28    423.2, 497.10
GR          520.8, 500.61    599.3, 503.30    668.8, 505.94    720.6, 507.21
N           0.055        0.055    0.055    0.06
SA                  59.3      130.8    201.6
*
XS   FULLV      0  * * *   0.0292
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.84       5.0
GR            0.0, 499.25      0.0, 498.64      0.1, 494.40      4.2, 492.86
GR           12.6, 489.22     15.2, 488.42     28.0, 486.22     36.2, 485.41
GR           38.7, 485.76     43.1, 487.22     48.7, 487.77     52.3, 488.52
GR           58.7, 489.23     62.4, 490.11     66.1, 491.17     67.0, 497.76
GR           67.0, 498.43      0.0, 499.25
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      26.9 * *     67.2      4.5
N           0.040
*
*             SRD    EMBWID   IPAVE
XR   RDWAY      8      12.3     2
GR         -133.2, 510.47    -92.6, 507.46    -43.2, 503.43      0.0, 501.32
GR           66.3, 500.69     81.7, 500.55    117.6, 499.16    201.7, 497.66
GR          242.3, 496.72    310.6, 497.59    415.8, 500.61    499.3, 503.30
GR          568.8, 505.94    620.6, 507.21
*
XT   APTEM     95            0.
GR          -26.9, 510.37    -21.2, 500.77    -17.0, 498.08    -10.3, 496.78
GR            0.0, 495.09      8.3, 489.42     10.7, 489.24     14.1, 488.79
GR           27.3, 488.42     32.6, 488.14     42.5, 488.63     47.8, 488.29
GR           54.7, 488.76     61.2, 489.23     64.9, 489.92     70.2, 492.55
GR           88.8, 494.54    109.5, 495.57    127.8, 494.88    145.6, 493.67
GR          157.8, 494.93    157.8, 490.29    169.0, 490.13    179.7, 489.40
GR          186.4, 490.89    196.3, 495.32    217.6, 495.84    293.6, 497.12
GR          450.9, 501.75    515.7, 505.48    568.9, 505.91    606.4, 507.41
*
AS   APPRO   83 * * * 0.0352
GT
N           0.060         0.055      0.055       0.055
SA                 88.8         157.8     196.3
*
HP 1 BRIDG   497.98 1 497.98
HP 2 BRIDG   497.98 * * 4962
HP 2 RDWAY   497.97 * * 1498
HP 1 APPRO   499.31 1 499.31
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File wall050.wsp
      Hydraulic analysis for structure WALLTH00600050   Date: 07-NOV-97
      Bridge 50 on Elm St. Town Highway 60 over Otter Creek Wallingford, VT
         *** RUN DATE & TIME: 02-25-98  16:39
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     629.  93999.    67.    78.                        10956.
   497.98          629.  93999.    67.    78.  1.00     0.    67.  10956.

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

        WSEL     LEW     REW    AREA        K        Q    VEL
      497.98     0.0    67.0   628.9   93999.    4962.   7.89

X STA.         0.0       12.6       15.9       18.6       21.3       23.7
  A(I)            75.9       30.1       27.5       27.1       26.4
  V(I)            3.27       8.23       9.02       9.16       9.39

X STA.        23.7       26.0       28.3       30.4       32.5       34.6
  A(I)            25.7       26.0       25.3       25.4       25.9
  V(I)            9.65       9.52       9.81       9.76       9.59

X STA.        34.6       36.6       38.7       40.9       43.3       45.8
  A(I)            25.1       25.6       26.2       26.2       26.9
  V(I)            9.90       9.70       9.48       9.46       9.23

X STA.        45.8       48.4       51.2       54.3       57.5       67.0
  A(I)            26.7       27.7       28.9       29.1       71.3
  V(I)            9.28       8.96       8.59       8.54       3.48

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.

        WSEL     LEW     REW    AREA        K        Q    VEL
      498.97   128.3   358.7   277.5    8340.    1498.   5.40

X STA.       128.3      184.7      197.5      207.5      215.7      222.7
  A(I)            28.5       14.3       13.3       12.7       12.0
  V(I)            2.63       5.24       5.61       5.92       6.27

X STA.       222.7      228.8      234.4      239.6      244.4      248.8
  A(I)            11.4       11.2       11.0       10.9        9.5
  V(I)            6.57       6.67       6.83       6.89       7.92

X STA.       248.8      252.9      257.9      263.0      268.5      274.5
  A(I)             8.8       10.4       10.3       10.9       11.1
  V(I)            8.47       7.22       7.26       6.90       6.73

X STA.       274.5      280.7      287.5      295.1      303.7      358.7
  A(I)            11.2       11.7       12.4       13.1       43.0
  V(I)            6.67       6.40       6.06       5.73       1.74

  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      83.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     905.  90560.   108.   112.                        14831.
             2     343.  26991.    69.    69.                         4334.
             3     343.  36407.    39.    44.                         5813.
             4     452.  22088.   186.   186.                         3992.
   499.31         2042. 176047.   402.   411.  1.18   -20.   382.  24094.

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      83.

        WSEL     LEW     REW    AREA        K        Q    VEL
      499.31   -19.6   382.4  2042.1  176047.    6460.   3.16

X STA.       -19.6       13.7       20.2       26.7       32.8       39.2
  A(I)           175.8       71.0       73.6       69.8       73.1
  V(I)            1.84       4.55       4.39       4.63       4.42

X STA.        39.2       45.8       52.3       59.3       67.7       82.5
  A(I)            73.8       72.9       77.1       82.4      100.0
  V(I)            4.38       4.43       4.19       3.92       3.23

X STA.        82.5      106.0      131.8      150.3      164.8      172.7
  A(I)           116.8      117.3      104.8      105.1       76.5
  V(I)            2.77       2.75       3.08       3.07       4.22

X STA.       172.7      179.7      187.8      211.1      248.8      382.4
  A(I)            71.0       75.4      116.8      139.0      249.8
  V(I)            4.55       4.28       2.77       2.32       1.29
```

WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File wall050.wsp
        Hydraulic analysis for structure WALLTH00600050   Date: 07-NOV-97
        Bridge 50 on Elm St. Town Highway 60 over Otter Creek Wallingford, VT
           *** RUN DATE & TIME: 02-25-98  16:39
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     686.   71504.     0.   147.                    ********
   499.25          686.   71504.     0.   147.  1.00     0.    67.********

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       499.25     0.0    67.0   686.3   71504.    5183.   7.55

X STA.         0.0       10.6       14.1       17.2       19.9       22.5
  A(I)            72.5       33.7       32.3       30.9       29.3
  V(I)            3.57       7.68       8.01       8.39       8.83

X STA.        22.5       25.0       27.3       29.6       31.8       34.1
  A(I)            30.3       28.8       28.6       28.7       29.2
  V(I)            8.55       8.99       9.06       9.02       8.89

X STA.        34.1       36.2       38.4       40.7       43.2       45.9
  A(I)            28.5       28.4       29.6       29.6       30.3
  V(I)            9.08       9.13       8.75       8.74       8.56

X STA.        45.9       48.7       51.8       55.1       58.6       67.0
  A(I)            31.6       32.0       32.6       33.7       65.6
  V(I)            8.21       8.10       7.96       7.69       3.95

    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.
     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     676.   86888.    41.   106.                      15638.
   498.75          676.   86888.    41.   106.  1.00     0.    67.  15638.

    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =       8.
         WSEL     LEW     REW    AREA        K        Q    VEL
       499.63   105.5   381.7   446.0   16219.    2791.   6.26

X STA.       105.5      160.2      177.6      190.6      201.4      211.1
  A(I)            39.1       24.1       21.6       20.1       20.1
  V(I)            3.57       5.80       6.46       6.94       6.94

X STA.       211.1      219.5      226.9      233.8      240.3      245.7
  A(I)            19.2       18.2       18.2       18.2       15.6
  V(I)            7.28       7.67       7.65       7.67       8.94

X STA.       245.7      250.7      256.7      263.1      269.6      276.6
  A(I)            14.1       16.6       17.1       17.0       17.6
  V(I)            9.89       8.41       8.15       8.21       7.92

X STA.       276.6      284.1      292.1      300.9      310.5      381.7
  A(I)            18.2       18.5       19.6       20.2       72.7
  V(I)            7.68       7.53       7.11       6.90       1.92

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      83.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     991.  104467.   110.   113.                      16902.
             2     397.   34519.    69.    69.                       5408.
             3     374.   41943.    39.    44.                       6603.
             4     609.   33252.   213.   213.                       5847.
   500.10         2371.  214181.   430.   440.  1.17   -21.   409.  29169.

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      83.

         WSEL     LEW     REW    AREA        K        Q    VEL
       500.10   -20.8   409.2  2370.7  214181.    7970.   3.36

X STA.       -20.8       13.2       20.5       27.3       34.1       41.1
  A(I)           197.0       85.5       82.6       82.8       84.9
  V(I)            2.02       4.66       4.83       4.81       4.69

X STA.        41.1       48.1       55.2       63.1       75.1       93.8
  A(I)            84.3       85.5       89.5      106.5      121.5
  V(I)            4.72       4.66       4.45       3.74       3.28

X STA.        93.8      118.9      139.7      158.4      168.3      176.3
  A(I)           132.1      120.7      121.0      102.0       85.6
  V(I)            3.02       3.30       3.29       3.91       4.66

X STA.       176.3      184.1      198.6      228.0      263.8      409.2
  A(I)            83.7      108.3      140.9      150.8      305.4
  V(I)            4.76       3.68       2.83       2.64       1.30
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        U.S. Geological Survey WSPRO Input File wall050.wsp
        Hydraulic analysis for structure WALLTH00600050   Date: 07-NOV-97
        Bridge 50 on Elm St. Town Highway 60 over Otter Creek Wallingford, VT
           *** RUN DATE & TIME: 02-25-98  16:39

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

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     478.   62015.    66.    74.                       7288.
   495.72          478.   62015.    66.    74.  1.00     0.    67.   7288.


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

         WSEL     LEW     REW    AREA         K        Q    VEL
       495.72     0.1    66.7   478.4   62015.    3720.   7.78

X STA.         0.1       14.4       17.4       20.1       22.6       24.9
  A(I)            59.6       22.5       21.0       20.7       20.2
  V(I)            3.12       8.26       8.85       8.97       9.20

X STA.        24.9       27.0       29.0       31.1       33.0       34.9
  A(I)            19.3       19.3       19.5       19.0       19.4
  V(I)            9.64       9.64       9.53       9.78       9.60

X STA.        34.9       36.8       38.7       40.8       43.1       45.5
  A(I)            19.5       19.1       19.8       20.3       20.4
  V(I)            9.56       9.71       9.41       9.14       9.10

X STA.        45.5       48.1       50.9       54.0       57.5       66.7
  A(I)            20.9       21.8       21.9       24.0       50.1
  V(I)            8.90       8.53       8.48       7.76       3.71

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =      83.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     654.   54997.   102.   105.                       9392.
             2     180.    9218.    69.    69.                       1648.
             3     252.   21804.    39.    44.                       3665.
             4     107.    2923.   106.   106.                        611.
   496.95         1193.   88942.   316.   324.  1.17   -13.   302.  12175.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =      83.

         WSEL     LEW     REW    AREA         K        Q    VEL
       496.95   -13.4   302.2  1193.4   88942.    3720.   3.12

X STA.       -13.4       14.6       19.7       24.4       29.3       33.9
  A(I)           110.5       43.6       42.0       43.5       42.5
  V(I)            1.68       4.27       4.43       4.27       4.37

X STA.        33.9       38.6       43.7       48.6       53.8       59.0
  A(I)            42.6       45.0       43.9       46.0       44.1
  V(I)            4.37       4.14       4.24       4.05       4.22

X STA.        59.0       64.3       76.4      116.1      146.0      163.1
  A(I)            42.4       64.8      104.0       83.3       73.8
  V(I)            4.38       2.87       1.79       2.23       2.52

X STA.       163.1      169.8      175.8      181.3      188.2      302.2
  A(I)            48.4       44.5       43.0       47.2      138.4
  V(I)            3.85       4.18       4.33       3.94       1.34
```

```
        U.S. Geological Survey WSPRO Input File wall050.wsp
        Hydraulic analysis for structure WALLTH00600050   Date: 07-NOV-97
        Bridge 50 on Elm St. Town Highway 60 over Otter Creek Wallingford, VT
           *** RUN DATE & TIME: 02-25-98  16:39

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

EXITX:XS   ******   -15.    2066.  0.21 *****  498.16  493.48   6460.  497.95
      -58. ******   447.  179022.  1.38 ***** *******    0.31    3.13

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                             "FULLV"     KRATIO =  0.61

FULLV:FV      58.   -10.    1322.  0.52  0.12  498.43 *******   6460.  497.91
        0.    58.   378.  110042.  1.40  0.15   -0.01    0.55    4.89
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      83.   -18.    1696.  0.27  0.23  498.68 *******   6460.  498.41
       83.    83.   352.  138128.  1.18  0.00    0.02    0.34    3.81
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   499.71       0.00     497.40     496.72

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   497.98     499.08     499.32     498.84

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

 ===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                        YU/Z,WSIU,WS = 1.08     499.61     499.75

 ===270 REJECTED 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      58.     0.     629.  1.21  0.19  499.19  494.05   4962.  497.98
        0.    58.    67.   93941.  1.25  0.84    0.00    0.51    7.89

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  0.894 ******  498.84 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL      ERR       Q    WSEL
   RDWAY:RG       8.    71.  0.09  0.18  499.42     0.00   1498.  498.97

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:      0.    72.   -37.    35.   2.1   1.4   7.6   9.6   2.7   3.1
   RT:   1498.   230.   128.   359.   2.2   1.2   5.9   5.4   1.7   3.1

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

APPRO:AS      56.   -20.    2044.  0.18  0.23  499.50  494.35   6460.  499.31
       83.    71.   382.  176212.  1.18  0.08    0.00    0.27    3.16

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.819  0.681   56237.    36.   103. ********

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS      -58.   -15.   447.   6460.  179022.    2066.    3.13  497.95
   FULLV:FV        0.   -10.   378.   6460.  110042.    1322.    4.89  497.91
   BRIDG:BR        0.     0.    67.   4962.   93941.     629.    7.89  497.98
   RDWAY:RG        8.*******     0.   1498.       0.*********    2.00  498.97
   APPRO:AS       83.   -20.   382.   6460.  176212.    2044.    3.16  499.31

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      36.   103.   56237.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS     493.48    0.31  483.26  510.37************  0.21  498.16  497.95
   FULLV:FV   ********    0.55  484.95  512.06  0.12  0.15  0.52  498.43  497.91
   BRIDG:BR     494.05    0.51  485.41  499.25  0.19  0.84  1.21  499.19  497.98
   RDWAY:RG   ***************  496.72  510.47  0.09******  0.18  499.42  498.97
   APPRO:AS     494.35    0.27  487.72  509.95  0.23  0.08  0.18  499.50  499.31
```

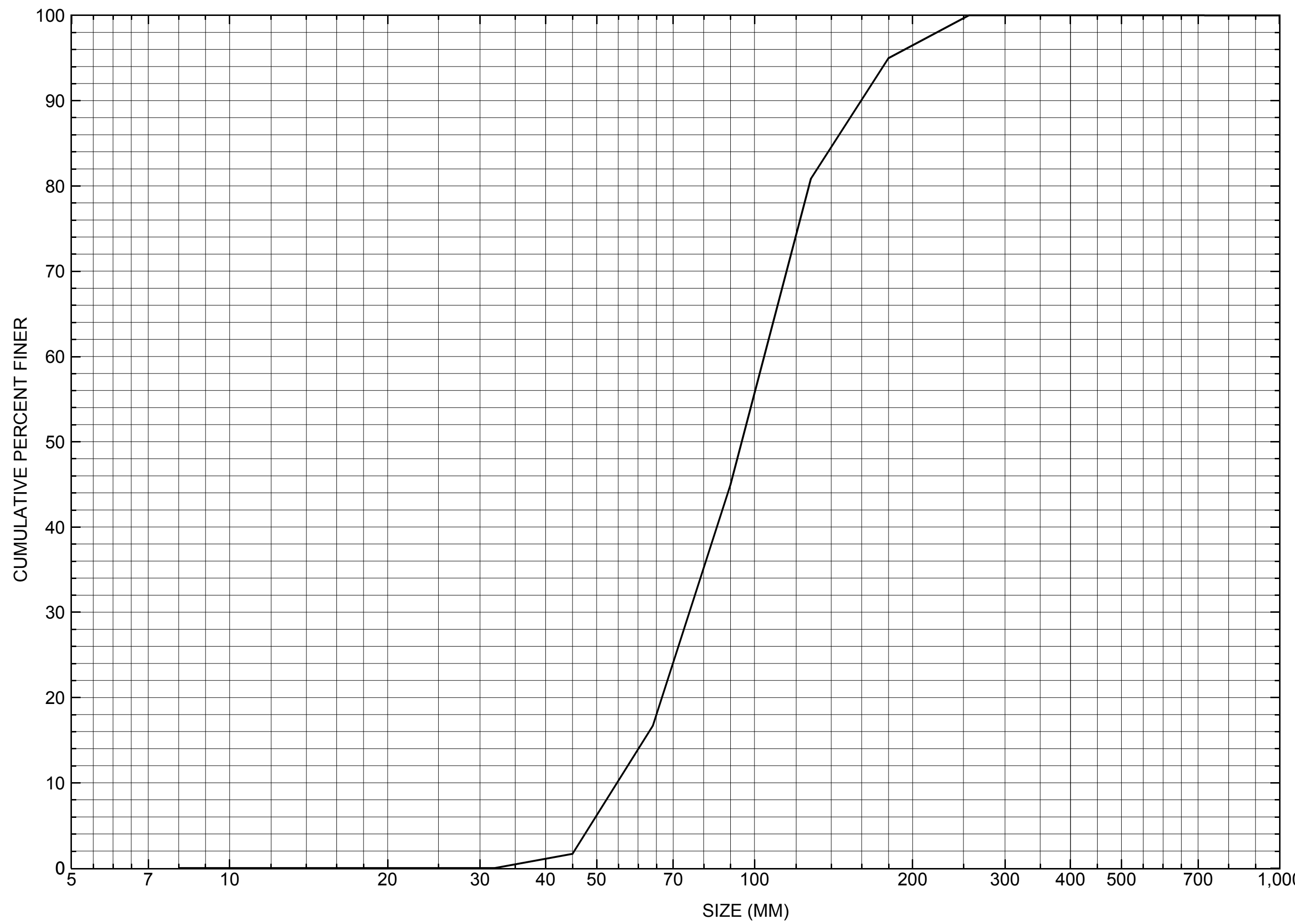
WSPRO OUTPUT FILE (continued)

```
        U.S. Geological Survey WSPRO Input File wall050.wsp
        Hydraulic analysis for structure WALLTH00600050   Date: 07-NOV-97
        Bridge 50 on Elm St. Town Highway 60 over Otter Creek Wallingford, VT
           *** RUN DATE & TIME: 02-25-98  16:39

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

EXITX:XS   ******   -18.    2461.  0.22 *****  499.00  494.49   7970.  498.78
      -58. ******   470.  220837.  1.33 ***** *******    0.29    3.24

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "FULLV"     KRATIO =  0.64

FULLV:FV      58.   -11.    1666.  0.51  0.12  499.26 *******   7970.  498.75
        0.    58.   421.  140665.  1.42  0.14   -0.01    0.51    4.78
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      83.   -19.    1991.  0.29  0.22  499.48 *******   7970.  499.18
       83.    83.   378.  170319.  1.18  0.00    0.00    0.34    4.00
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   501.11       0.00     498.09     496.72

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   499.02     499.98     500.25     498.84

 ===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      58.     0.     686.  0.89 *****  500.14  494.24   5183.  499.25
        0. ******    67.   71504.  1.00 ***** *******    0.42    7.55

     TYPE PPCD FLOW       C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****    5.  0.373 ******  498.84 ****** ****** ******

    XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG       8.    71.  0.10  0.21  500.21    0.00    2791.  499.63

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:     0.    68.   -37.    31.   2.1   1.4   7.5   9.7   2.7   3.1
   RT:  2791.   276.   106.   382.   2.9   1.6   6.9   6.3   2.2   3.1

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

APPRO:AS      56.   -21.    2370.  0.21  0.21  500.30  495.34   7970.  500.10
       83.    73.   409.  214092.  1.17  0.10    0.00    0.27    3.36

  FIRST USER DEFINED TABLE.

    XSID:CODE     SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -58.   -18.   470.   7970.  220837.    2461.    3.24  498.78
   FULLV:FV       0.   -11.   421.   7970.  140665.    1666.    4.78  498.75
   BRIDG:BR       0.     0.    67.   5183.    71504.     686.    7.55  499.25
   RDWAY:RG       8.*******     0.   2791.        0.*********    2.00  499.63
   APPRO:AS      83.   -21.   409.   7970.  214092.    2370.    3.36  500.10

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN     YMAX    HF     HO   VHD      EGL    WSEL
   EXITX:XS    494.49    0.29  483.26  510.37************  0.22  499.00  498.78
   FULLV:FV  ********    0.51  484.95  512.06  0.12  0.14  0.51  499.26  498.75
   BRIDG:BR    494.24    0.42  485.41  499.25************  0.89  500.14  499.25
   RDWAY:RG  ****************  496.72  510.47  0.10******  0.21  500.21  499.63
   APPRO:AS    495.34    0.27  487.72  509.95  0.21  0.10  0.21  500.30  500.10
```

```
        U.S. Geological Survey WSPRO Input File wall050.wsp
        Hydraulic analysis for structure WALLTH00600050   Date: 07-NOV-97
        Bridge 50 on Elm St. Town Highway 60 over Otter Creek Wallingford, VT
           *** RUN DATE & TIME: 02-25-98  16:39

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

EXITX:XS   ******   -10.    1240.  0.19 *****  496.20  491.34   3720.  496.01
      -58. ******   367.  103160.  1.38 ***** *******    0.34    3.00

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

FULLV:FV      58.    -7.     760.  0.48  0.13  496.46 *******   3720.  495.98
        0.    58.   199.   61829.  1.28  0.14   -0.01    0.51    4.90
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS      83.   -11.    1051.  0.22  0.24  496.71 *******   3720.  496.48
       83.    83.   281.   76639.  1.16  0.00    0.01    0.35    3.54
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   496.95       0.00     495.72     496.72

 ===260 ATTEMPTING FLOW CLASS 4 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      58.     0.     479.  1.07  0.17  496.80  492.96   3720.  495.72
        0.    58.    67.   62070.  1.14  0.42    0.00    0.55    7.77

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  0.936 ******  498.84 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD      EGL      ERR       Q    WSEL
   RDWAY:RG       8.        <<<<<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      56.   -13.    1195.  0.18  0.24  497.13  492.65   3720.  496.95
       83.    68.   302.   89070.  1.17  0.10    0.01    0.31    3.11

       M(G)   M(K)      KQ   XLKQ   XRKQ    OTEL
      0.772  0.499   44546.    21.    88. ********


  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS     -58.   -10.   367.   3720.  103160.    1240.    3.00  496.01
   FULLV:FV       0.    -7.   199.   3720.   61829.     760.    4.90  495.98
   BRIDG:BR       0.     0.    67.   3720.   62070.     479.    7.77  495.72
   RDWAY:RG       8.**************      0.       0.       0.    2.00********
   APPRO:AS      83.   -13.   302.   3720.   89070.    1195.    3.11  496.95

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      21.    88.   44546.


 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    491.34    0.34  483.26  510.37************  0.19  496.20  496.01
   FULLV:FV  ********    0.51  484.95  512.06  0.13  0.14  0.48  496.46  495.98
   BRIDG:BR    492.96    0.55  485.41  499.25  0.17  0.42  1.07  496.80  495.72
   RDWAY:RG  ****************  496.72  510.47  0.12******  0.18  497.01********
   APPRO:AS    492.65    0.31  487.72  509.95  0.24  0.10  0.18  497.13  496.95
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure WALLTH00600050, in Wallingford, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number WALLTH00600050

General Location Descriptive

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

Date *(MM/DD/YY)* 03 / 22 / 95

Highway District Number *(I - 2; nn)* 03

County *(FIPS county code; I - 3; nnn)* 021

Town *(FIPS place code; I - 4; nnnnn)* 75850

Mile marker *(I - 11; nnn.nnn)* 000000

Waterway *(I - 6)* Otter Creek

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

Route Number TH060

Vicinity *(I - 9)* 0.1 mile to jct with Creek Rd

Topographic Map Wallingford

Hydrologic Unit Code: 02010002

Latitude *(I - 16; nnnn.n)* 43284

Longitude *(i - 17; nnnnn.n)* 72588

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10112500501125

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

Maximum span length *(I - 48; nnnn)* 0070

Year built *(I - 27; YYYY)* 1919

Structure length *(I - 49; nnnnnn)* 000072

Average daily traffic, ADT *(I - 29; nnnnnn)* 000030

Deck Width *(I - 52; nn.n)* 123

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

Channel & Protection *(I - 61; n)* 5

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

Waterway adequacy *(I - 71; n)* 7

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

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

Structure type *(I - 43; nnn)* 310

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 067.1

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

Vertical clearance from streambed (*nnn.n ft*) 010.6

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

Waterway of full opening (*nnn.n ft^2*) 711.1

Comments:

The structural inspection report of 10/3/94 indicates the structure is a steel (pony) thru-truss type bridge with a timber deck. The abutment walls and wingwalls are "laid-up" stone. There is no wingwall on the one downstream end of the right abutment. The face of the right abutment wall has a random vertical settlement crack at the centerline of the bridge. Originally, the report indicates there was a concrete footing along the bottom of the right abutment and its wingwall. However, most of the concrete of the footing has spalled off, with deep voided sections along the bottom. Its one wingwall is broken into three distinct sections reportedly, and settlement has been a problem. The left abutment has a few random fine cracks and small leaks indicated. **(Continued, page 33)**

Bridge Hydrologic Data

Is there hydrologic data available? **Y** *if No, type ctrl-n h* VTAOT Drainage area *(mi²)*: **102.0**

Terrain character: -

Stream character & type: -

Streambed material: -

Discharge Data *(cfs)*: $Q_{2.33}$ - Q_{10} **7000** Q_{25} **10000**

Q_{50} **12500** Q_{100} **14500** 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: **The channel of Otter Creek here divides into two parts. This bridge is reportedly over the main channel during lower flows. The other bridge serves as an overflow structure, which is mainly active during high discharge periods.**

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*)	-	**9.1**	**11.7**	**13.2**	**14.0**
Velocity (*ft / sec*)	-	-	-	-	-

Long term stream bed changes: -

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

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

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

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

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

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

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

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

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

Comments:

Additionally, a vertical crack has developed in the wall near the centerline of the bridge. Some boulder fill is noted in front of each abutment and there is some stone fill on the streambanks up- and downstream on the left abutment side of the channel. Gravel bars and debris accumulation problems are noted as minor. The hydraulics section folder on this bridge had very little information available.

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **102.60** mi^2 Lake/pond/swamp area **0.78** mi^2

Watershed storage *(ST)* **0.8** %

Bridge site elevation **571** ft Headwater elevation **3051** ft

Main channel length **21.349** mi

10% channel length elevation **571** ft 85% channel length elevation **835** ft

Main channel slope *(S)* **16.49** ft / mi

Watershed Precipitation Data

Average site precipitation - in Average headwater precipitation - in

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

Average seasonal snowfall *(Sn)* - ft

Bridge Plan Data

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

Project Number -

Minimum channel bed elevation: -

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

Benchmark location description:

NO BENCHMARK INFORMATION

Reference Point (*MSL, Arbitrary, Other*): -

Datum (*NAD27, NAD83, Other*): -

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

If 1: Footing Thickness - Footing bottom elevation: -

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

If 3: Footing bottom elevation: -

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

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

Briefly describe material at foundation bottom elevation or around piles:

NO FOUNDATION MATERIAL INFORMATION

Comments:

NO PLANS.

Cross-sectional Data

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

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

Comments: **This cross section is taken from a HEC-2 input file.**

Station	124	134	146	159	171	195	-	-	-	-	-
Feature	LAB	-	-	-	-	RAB	-	-	-	-	-
Low chord elevation	565	565	565	565	565	565	-	-	-	-	-
Bed elevation	561	555.3	553.5	552	553	557.8	-	-	-	-	-
Low chord to bed	4	9.7	11.5	13	12	7.2	-	-	-	-	-
Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments: -

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: CG Date: 02/21/96
Computerized by: CG Date: 02/21/96
Reviewd by: MAI Date: 01/29/98

Structure Number WALLTH00600050

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* M. Ivanoff Date *(MM/DD/YY)* 09 / 26 / 1996
2. Highway District Number 03 Mile marker 0
County Rutland (021) Town Wallingford (75850)
Waterway *(I - 6)* Otter Creek Road Name Elm Street
Route Number TH 60 Hydrologic Unit Code: 02010002
3. Descriptive comments:
The site is located 0.1 mile from the junction of Elm Street with Creek Road.

B. Bridge Deck Observations

4. Surface cover... LBUS 6 RBUS 6 LBDS 6 RBDS 6 Overall 6
(2b us,ds,lb,rb: 1- Urban; 2- Suburban; 3- Row crops; 4- Pasture; 5- Shrub- and brushland; 6- Forest; 7- Wetland)
5. Ambient water surface... US 1 UB 1 DS 1 *(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 72.0 *(feet)* Span length 70.0 *(feet)* Bridge width 12.3 *(feet)*

Road approach to bridge:

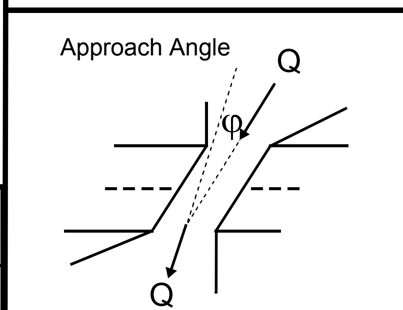
8. LB 2 RB 1 *(0 even, 1- lower, 2- higher)*
9. LB 2 RB 2 *(1- Paved, 2- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left -- US right --

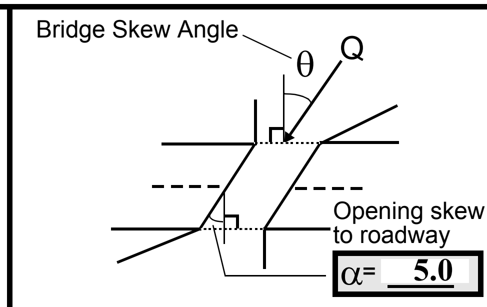
	Protection		13.Erosion	14.Severity
	11.Type	12.Cond.		
LBUS	5	1	2	1
RBUS	5	1	2	1
RBDS	5	1	0	0
LBDS	5	1	0	0

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: 25 16. Bridge skew: 25





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 40 feet US *(US, UB, DS)* to 0 feet DS
Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 0
Range? 12 feet US *(US, UB, DS)* to 60 feet US

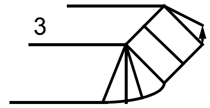
Impact Severity: 0- none to very slight; 1- Slight; 2- Moderate; 3- Severe

18. Bridge Type: **1a**

1a- Vertical abutments with wingwalls

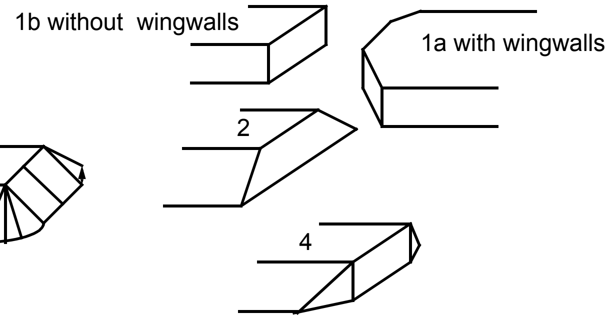
1b- Vertical abutments without wingwalls

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



3- Spill through abutments

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



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

7. The bridge dimension values are from the VTAOT database. The measured bridge length is 72 ft, span length is 68.5 ft, and bridge width is 12 ft.
11. Wood cribbing is in place along both sides of the road approaches.
17. Impact zone 2 is along the channel and at high flow impacts the road approach embankment.

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
87.0	**5.5**			**4.5**	**4**	**4**	**436**	**435**	**1**	**1**

23. Bank width **35.0** 24. Channel width **10.0** 25. Thalweg depth **89.0** 29. Bed Material **43**

30 .Bank protection type: LB **2** RB **0** 31. Bank protection condition: LB **1** RB **-**

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

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

27. The left bank material consists of cobbles and gravel. There is bedrock underneath the cobbles and gravel. This bedrock extends 200 ft upstream and along the high left embankment. The right bank is made up of cobbles and gravel with some boulders. The boulders may have been placed, as the structural inspection of 1994 noted stones along the up- and downstream banks.
29. The bed material consists of cobbles and gravel.
30. The left bank protection extends 20 ft upstream from the bridge face.

33. Point/Side bar present? **Y** *(Y or N. if N type ctrl-n pb)* 34. Mid-bar distance: **155** 35. Mid-bar width: **33**

36. Point bar extent: **100** feet **US** *(US, UB)* to **200** feet **US** *(US, UB, DS)* positioned **0** %LB to **70** %RB

37. Material: **43**

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

This side bar consists of cobbles and gravel.

Another bar has formed mid-channel from 240 ft to 350 ft upstream with a mid-bar width of 50 ft. It is vegetated with 30 ft tall trees.

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: **40** 42. Cut bank extent: **90** feet **US** *(US, UB)* to **25** feet **uS** *(US, UB, DS)*

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

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

This is a steepened bank 4 ft above the edge of water exposing some roots.

45. Is channel scour present? **Y** *(Y or if N type ctrl-n cs)* 46. Mid-scour distance: **230**

47. Scour dimensions: Length **40** Width **25** Depth : **4** Position **0** %LB to **45** %RB

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

At 220 ft upstream bedrock lines the left channel bank to the bed with a 4 ft deep pool. Bedrock is exposed at the base of the pool.

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

Roaring brook enters on the right bank 350 ft upstream.

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
56.5		1.0		2	7	7	-

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

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

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

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

547

The right abutment has a mix of boulders and rough concrete blocks extending into the channel.

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? 1___ *(Y or N)* Ice Blockage Potential N____ *(1- Low; 2- Moderate; 3- High)*

70. Debris and Ice Comments:

1

Debris has accumulated along the right bank up to the road approach. There are trees leaning over the upstream channel.

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	0	0	90.0
RABUT	1	0	80			2	3	66.5

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

0.5

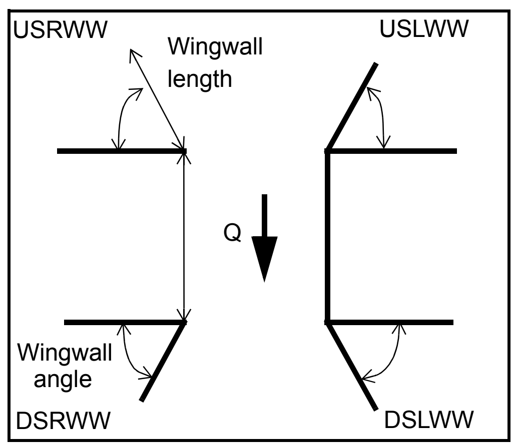
1

The right abutment has random voids below the base of the wall, exposing stones. Settlement at the upstream end of the wingwall near the old wingwall was evident.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						66.5	
USRWW:	Y		1		0	4.0	
DSLWW:	-		-		Y	17.0	
DSRWW:	1		5		1	15.5	

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



82. **Bank / Bridge Protection**:

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

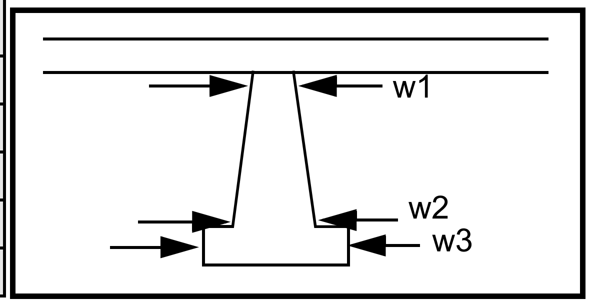
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

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				**60.0**	**12.0**	**75.0**
Pier 2			**5.5**	**11.0**	**45.0**	-
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**The**	**ment**	**nearly**	**tled.**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**upst**	**wing**	**par-**		***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**ream**	**wall**	**allel**		***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**right**	**and**	**to**		***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**wing**	**a**	**the**		*Y- yes; N- no*
91. Attack ∠ (BF)	**wall**	**newe**	**right**		
92. Pushed	**con-**	**r**	**abut**		*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**sists**	**wing**	**ment**		
95. Cross-members	**of**	**wall**	**;**		***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**the**	**exte**	**both**		***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**older**	**ndin**	**have**	**N**	
98. Exposure depth	**abut**	**g**	**set-**	-	

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 - Thalweg depth - Bed Material -

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

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

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

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

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

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

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

Point bar extent: __NO__ feet __PI__ *(US, UB, DS)* to __ERS__ feet ____ *(US, UB, DS)* positioned ____ %LB to _____ %RB

Material: _____

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

Is a cut-bank present? _____ *(Y or if N type ctrl-n cb)* Where? __4__ *(LB or RB)* Mid-bank distance: __4__

Cut bank extent: __63__ feet __32__ *(US, UB, DS)* to __0__ feet __1__ *(US, UB, DS)*

Bank damage: __34__ *(**1**- eroded and/or creep; **2**- slip failure; **3**- block failure)*

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

2
0
1
-

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

Scour dimensions: Length __bank__ Width __pro-__ Depth: __tec-__ Positioned __tion__ %LB to __beg__ %RB

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

ins 20 ft upstream of the bridge and extends 90 ft downstream of the bridge.

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

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

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

Confluence comments (eg. confluence name):

F. Geomorphic Channel Assessment

107. Stage of reach evolution _____

__1__- Constructed
__2__- Stable
__3__- Aggraded
__4__- Degraded
__5__- Laterally unstable
__6__- Vertically and laterally unstable

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

N

-

NO DROP STRUCTURE

Y

110

25

30

DS

109. G. Plan View Sketch

- 14

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:	WALLTH00600050	Town:	Wallingford
Road Number:	TH 60 Elm Street	County:	Rutland
Stream:	Otter Creek		

Initials MAI   Date: 1/7/98   Checked: EMB

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	6460	7970	3720
Main Channel Area, ft2	905	991	654
Left overbank area, ft2	0	0	0
Right overbank area, ft2	1138	1380	539
Top width main channel, ft	108	110	102
Top width L overbank, ft	0	0	0
Top width R overbank, ft	299	321	214
D50 of channel, ft	0.3102	0.3102	0.3102
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	8.4	9.0	6.4
y1, average depth, LOB, ft	ERR	ERR	ERR
y1, average depth, ROB, ft	3.8	4.3	2.5
Total conveyance, approach	176047	214181	88942
Conveyance, main channel	90560	104467	54997
Conveyance, LOB	0	0	0
Conveyance, ROB	85486	109714	33945
Percent discrepancy, conveyance	0.0006	0.0000	0.0000
Qm, discharge, MC, cfs	3323.1	3887.4	2300.3
Ql, discharge, LOB, cfs	0.0	0.0	0.0
Qr, discharge, ROB, cfs	3136.9	4082.6	1419.7
Vm, mean velocity MC, ft/s	3.7	3.9	3.5
Vl, mean velocity, LOB, ft/s	ERR	ERR	ERR
Vr, mean velocity, ROB, ft/s	2.8	3.0	2.6
Vc-m, crit. velocity, MC, ft/s	10.8	10.9	10.3
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)

Bridge Section	Q100	Q500	Other Q
(Q) total discharge, cfs	6460	7970	3720
(Q) discharge thru bridge, cfs	4962	5183	3720
Main channel conveyance	93999	71504	62015
Total conveyance	93999	71504	62015
Q2, bridge MC discharge,cfs	4962	5183	3720
Main channel area, ft2	629	686	478
Main channel width (normal), ft	66.7	66.7	66.3
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	66.7	66.7	66.3
y_bridge (avg. depth at br.), ft	9.43	10.28	7.21
Dm, median (1.25*D50), ft	0.38775	0.38775	0.38775
y2, depth in contraction,ft	6.52	6.77	5.12
ys, scour depth (y2-ybridge), ft	**-2.91**	-3.52	**-2.09**

Pressure Flow Scour (contraction scour for orifice flow conditions)

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

	Q100	Q500	OtherQ
Q, total, cfs	6460	7970	3720
Q, thru bridge MC, cfs	4962	5183	3720
Vc, critical velocity, ft/s	10.81	10.95	10.34
Va, velocity MC approach, ft/s	3.67	3.92	3.52
Main channel width (normal), ft	66.7	66.7	66.3
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	66.7	66.7	66.3
qbr, unit discharge, ft2/s	74.4	77.7	56.1
Area of full opening, ft2	629.0	686.0	478.0
Hb, depth of full opening, ft	9.43	10.28	7.21
Fr, Froude number, bridge MC	0	0.42	0
Cf, Fr correction factor (<=1.0)	0.00	1.00	0.00
**Area at downstream face, ft2	N/A	676.1	N/A
**Hb, depth at downstream face, ft	N/A	10.14	N/A
**Fr, Froude number at DS face	ERR	0.42	ERR

**Cf, for downstream face (<=1.0)	N/A	1.00	N/A
Elevation of Low Steel, ft	0	498.84	0
Elevation of Bed, ft	0.00	488.56	-7.21
Elevation of Approach, ft	0	500.1	0
Friction loss, approach, ft	0	0.21	0
Elevation of WS immediately US, ft	0.00	499.89	0.00
ya, depth immediately US, ft	0.00	11.33	7.21
Mean elevation of deck, ft	0	501	0
w, depth of overflow, ft (>=0)	0.00	0.00	0.00
Cc, vert contrac correction (<=1.0)	ERR	0.98	1.00
**Cc, for downstream face (<=1.0)	ERR	0.972831	ERR
Ys, scour w/Chang equation, ft	N/A	**-3.01**	N/A
Ys, scour w/Umbrell equation, ft	N/A	-3.56	N/A

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

**Ys, scour w/Chang equation, ft	N/A	-2.84	N/A
**Ys, scour w/Umbrell equation, ft	ERR	-3.41	ERR

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

y2, from Laursen's equation, ft	6.52	6.77	5.12
WSEL at downstream face, ft	--	498.75	--
Depth at downstream face, ft	N/A	10.14	N/A
Ys, depth of scour (Laursen), ft	N/A	-3.37	N/A

Armoring

Dc=[(1.94*V^2)/(5.75*log(12.27*y/D90))^2]/[0.03*(165-62.4)]

Depth to Armoring=3*(1/Pc-1)

(Federal Highway Administration, 1993)

Downstream bridge face property	100-yr	500-yr	Other Q
Q, discharge thru bridge MC, cfs	4962	5183	3720
Main channel area (DS), ft2	629	676.1	478
Main channel width (normal), ft	66.7	66.7	66.3
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	66.7	66.7	66.3
D90, ft	0.5236	0.5236	0.5236
D95, ft	0.5906	0.5906	0.5906
Dc, critical grain size, ft	0.2159	0.1985	0.2326
Pc, Decimal percent coarser than Dc	0.810	0.857	0.748
Depth to armoring, ft	**0.15**	**0.10**	**0.24**

Abutment Scour

Froehlich's Abutment Scour

Ys/Y1 = 2.27*K1*K2*(a'/Y1)^0.43*Fr1^0.61+1

(Richardson and others, 1995, p. 48, eq. 28)

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	6460	7970	3720	6460	7970	3720
a', abut.length blocking flow, ft	19.9	21.1	13.7	42.5	42.5	42.9
Ae, area of blocked flow ft2	105.06	122.26	54.07	239.58	273.16	139.19
Qe, discharge blocked abut.,cfs	193.02	247.3	91.01	--	--	--
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.57	2.02	1.68	2.80	3.01	2.58

ya, depth of f/p flow, ft	5.28	5.79	3.95	5.64	6.43	3.24

--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	95	95	95	85	85	85
K2	1.01	1.01	1.01	0.99	0.99	0.99
Fr, froude number f/p flow	0.168	0.148	0.149	0.245	0.250	0.277
ys, scour depth, ft	**11.18**	**11.70**	**7.91**	**16.16**	**17.91**	**11.56**

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)	19.9	21.1	13.7	42.5	42.5	42.9
y1 (depth f/p flow, ft)	5.28	5.79	3.95	5.64	6.43	3.24
a'/y1	3.77	3.64	3.47	7.54	6.61	13.22
Skew correction (p. 49, fig. 16)	1.01	1.01	1.01	0.98	0.98	0.98
Froude no. f/p flow	0.17	0.15	0.15	0.25	0.25	0.28
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	Other Q	Q100	Q500	Other Q
Fr, Froude Number	0.51	0.42	0.55	0.51	0.42	0.55
y, depth of flow in bridge, ft	9.43	10.14	7.21	9.43	10.14	7.21
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	**1.52**	**1.11**	**1.35**	**1.52**	**1.11**	**1.35**
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR