LEVEL II SCOUR ANALYSIS FOR BRIDGE 4 (PROCTH00060004) on TOWN HIGHWAY 6, crossing OTTER CREEK, PROCTOR, VERMONT

Open-File Report 98-055

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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LEVEL II SCOUR ANALYSIS FOR BRIDGE 4 (PROCTH00060004) on TOWN HIGHWAY 6, crossing OTTER CREEK, PROCTOR, VERMONT

By MICHAEL A. IVANOFF AND LAURA MEDALIE

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Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
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Open-File Reports Unit
Box 25286
Denver, CO 80225-0286

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CONVERSION FACTORS, ABBREVIATIONS, AND VERTICAL DATUM

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

OTHER ABBREVIATIONS

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

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

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

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

LEVEL II SCOUR ANALYSIS FOR BRIDGE 4 (PROCTH00060004) ON TOWN HIGHWAY 6, CROSSING OTTER CREEK, PROCTOR, VERMONT

By **Michael A. Ivanoff and Laura Medalie**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure PROCTH00060004 on Town Highway 6 crossing Otter Creek, Proctor, 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 (Federal Highway Administration, 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 west-central Vermont. The 365-mi^2 drainage area is in a predominantly rural and forested basin. In the vicinity of the study site, the surface cover is pasture upstream and downstream of the bridge, while the immediate banks are covered by trees. The upstream left bank consists of forest.

In the study area, Otter Creek has an incised, sinuous channel with a slope of approximately 0.001 ft/ft, an average channel top width of 138 ft and an average bank height of 12 ft. The channel bed material ranges from silt/clay to sand with a median grain size (D_{50}) of 0.479 mm (0.00157 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 23, 1995, indicated that the reach was stable.

The Town Highway 6 crossing of Otter Creek is a 130-ft-long, one-lane covered bridge consisting of one 105-foot timber thru-truss span (Vermont Agency of Transportation, written communication, March 22, 1995). The opening length of the structure parallel to the bridge face is 94.7 ft. The bridge is supported by vertical, “laid-up” stone abutments with concrete caps. The channel is not skewed to the opening while 5 degrees was computed for the opening-skew-to-roadway.

A scour hole 4.5 ft deeper than the mean thalweg depth was observed along the left abutment during the Level I assessment. The scour protection measures at the site included type-1 stone fill (less than 12 inches diameter) at the upstream end of the right abutment and type-2 stone fill (less than 36 inches diameter) at the upstream end of the left abutment and along both upstream banks. Additional details describing conditions at the site are included in the Level II Summary and appendices D and E.

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

Contraction scour for all modelled flows ranged from 0.1 to 3.3 ft. The worst-case contraction scour occurred at the 100-year discharge. Abutment scour ranged from 7.8 to 16.8 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.

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.

Proctor, VT. Quadrangle, 1:24,000, 1944

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 PROCTH00060004 ***Stream*** Otter Creek

County Rutland ***Road*** TH 6 ***District*** 3

Description of Bridge

Bridge length 130 ***ft*** ***Bridge width*** 18.0 ***ft*** ***Max span length*** 105 ***ft***

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

Abutment type Vertical ***Embankment type*** Sloping

Stone fill on abutment? Yes ***Date of inspection*** 6/23/95

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

The left abutment is laid-up stone with a concrete facing on the lower portion, a concrete footing, and a concrete cap. The right abutment is laid-up stone with a concrete cap. There is a 4.5 ft deep scour hole in front of the left abutment.

Is bridge skewed to flood flow according to No ***survey?*** No ***Angle*** 0

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	6/23/95	0	0
Level II	6/23/95	0	0

Potential for debris Moderate. There are no trees along the upstream banks near the bridge, but the drainage basin is forested.

Describe any features near or at the bridge that may affect flow (include observation date) None, 6/23/95.

Description of the Geomorphic Setting

General topography The stream is located within a moderate relief valley with a flat to slightly irregular, wide flood plain.

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

Date of inspection 6/23/95

DS left: Steep channel bank to the overbank.

DS right: Steep channel bank to the flood plain.

US left: Steep channel bank to the overbank.

US right: Steep channel bank to the flood plain.

Description of the Channel

Average top width 138 *ft* ***Average depth*** 12 *ft*

Predominant bed material Silt/ Clay ***Bank material*** Sand

Perennial, sinuous but stable with alluvial channel boundaries.

6/23/95

Vegetative co Pasture with few trees.

DS left: Trees and brush with some pasture.

DS right: Trees and brush.

US left: Pasture with some row crops.

US right:

Do banks appear stable? Yes

There is some moderate fluvial erosion along the left and right banks both upstream and downstream of the bridge.

date of observation.

None noted, 6/23/95.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 365 ***mi***^{2}

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 ***mi***^{2}

Is there a lake/p No

Calculated Discharges

Q100 15,000 ***ft***^{3}***/s*** ***Q500*** 18,600 ***ft***^{3}***/s***

The 100- and 500-year discharges are interpolated from the 100- and 500-year discharges determined for the upstream (04282000, Otter Creek at Center Rutland) gage. The 100- and 500- year discharges at the gage was developed using a log-Pearson type-III analysis of annual peak-flow data (Interagency Advisory Committee on Water Data, 1982). These discharge values are within a range of several flood frequency curves based on 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 concrete post for the base of the guard rail along the upstream right abutment corner of the bridge (elev. 504.71 ft, arbitrary survey datum). RM2 is a chiseled X on top of the second wooden guard rail post upstream from the bridge near the left abutment (elev. 506.86 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	-125	1	Exit section
FULLV	0	2	Downstream Full-valley section (Templated from EXITX)
BRIDG	0	1	Bridge section
RDWAY	11	1	Road Grade section
APPRO	116	1	Approach section

[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 0.037 to 0.045, and overbank "n" values ranged from 0.050 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 the slope of the 100-year water surface profile from the Flood Insurance Study for the Town of Pittsford (Federal Emergency Management Agency, 1988).

The approach section (APPRO) was surveyed 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 505.4 ***ft***
Average low steel elevation 502.5 ***ft***

100-year discharge 15,100 ***ft³/s***
Water-surface elevation in bridge opening 500.1 ***ft***
Road overtopping? Yes ***Discharge over road*** 3,020 ***ft³/s***
Area of flow in bridge opening 1,680 ***ft²***
Average velocity in bridge opening 7.2 ***ft/s***
Maximum WSPRO tube velocity at bridge 9.1 ***ft/s***

Water-surface elevation at Approach section with bridge 501.5
Water-surface elevation at Approach section without bridge 501.2
Amount of backwater caused by bridge 0.3 ***ft***

500-year discharge 18,600 ***ft³/s***
Water-surface elevation in bridge opening 502.1 ***ft***
Road overtopping? Yes ***Discharge over road*** 7,960 ***ft³/s***
Area of flow in bridge opening 1,870 ***ft²***
Average velocity in bridge opening 5.7 ***ft/s***
Maximum WSPRO tube velocity at bridge 7.4 ***ft/s***

Water-surface elevation at Approach section with bridge 503.0
Water-surface elevation at Approach section without bridge 502.5
Amount of backwater caused by bridge 0.5 ***ft***

Incipient overtopping discharge 11,900 ***ft³/s***
Water-surface elevation in bridge opening 498.0 ***ft***
Area of flow in bridge opening 1,488 ***ft²***
Average velocity in bridge opening 8.0 ***ft/s***
Maximum WSPRO tube velocity at bridge 10.2 ***ft/s***

Water-surface elevation at Approach section with bridge 498.8
Water-surface elevation at Approach section without bridge 499.0
Amount of backwater caused by bridge N/A ***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.

Contraction scour for the 100-year, 500-year, and incipient roadway-overtopping discharges was computed by use of the Laursen live-bed contraction scour equation (Richardson and Davis, 1995, p. 30, equation 17). 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.

Abutment scour was computed by use of the HIRE equation (Richardson and Davis, 1995, p. 49, equation 29) because the HIRE equation is recommended when the length to depth ratio of the embankment blocking flow exceeds 25. Variables for the HIRE 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	3.3	0.3	0.1
Depth to armoring	N/A	N/A	N/A
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:			
Abutment scour			
Left abutment	11.5	12.3	9.4
Right abutment	13.8	16.8	7.8
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	1.9	1.3	1.4
Right abutment	1.9	1.3	1.4
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

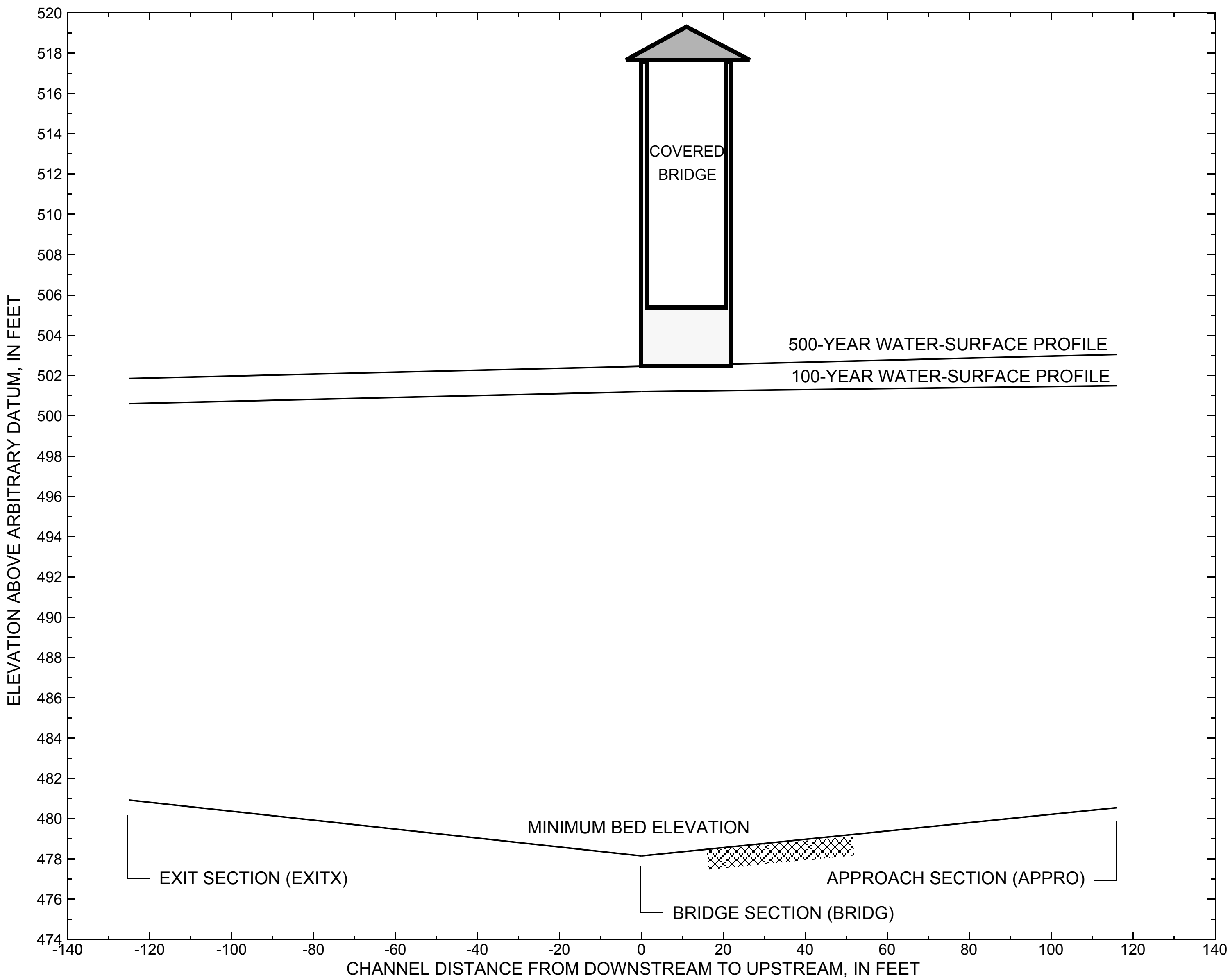

Figure 7. Water-surface profiles for the 100- and 500-year discharges at structure PROCTH00060004 on Town Highway 6, crossing Otter Creek, Proctor, Vermont.

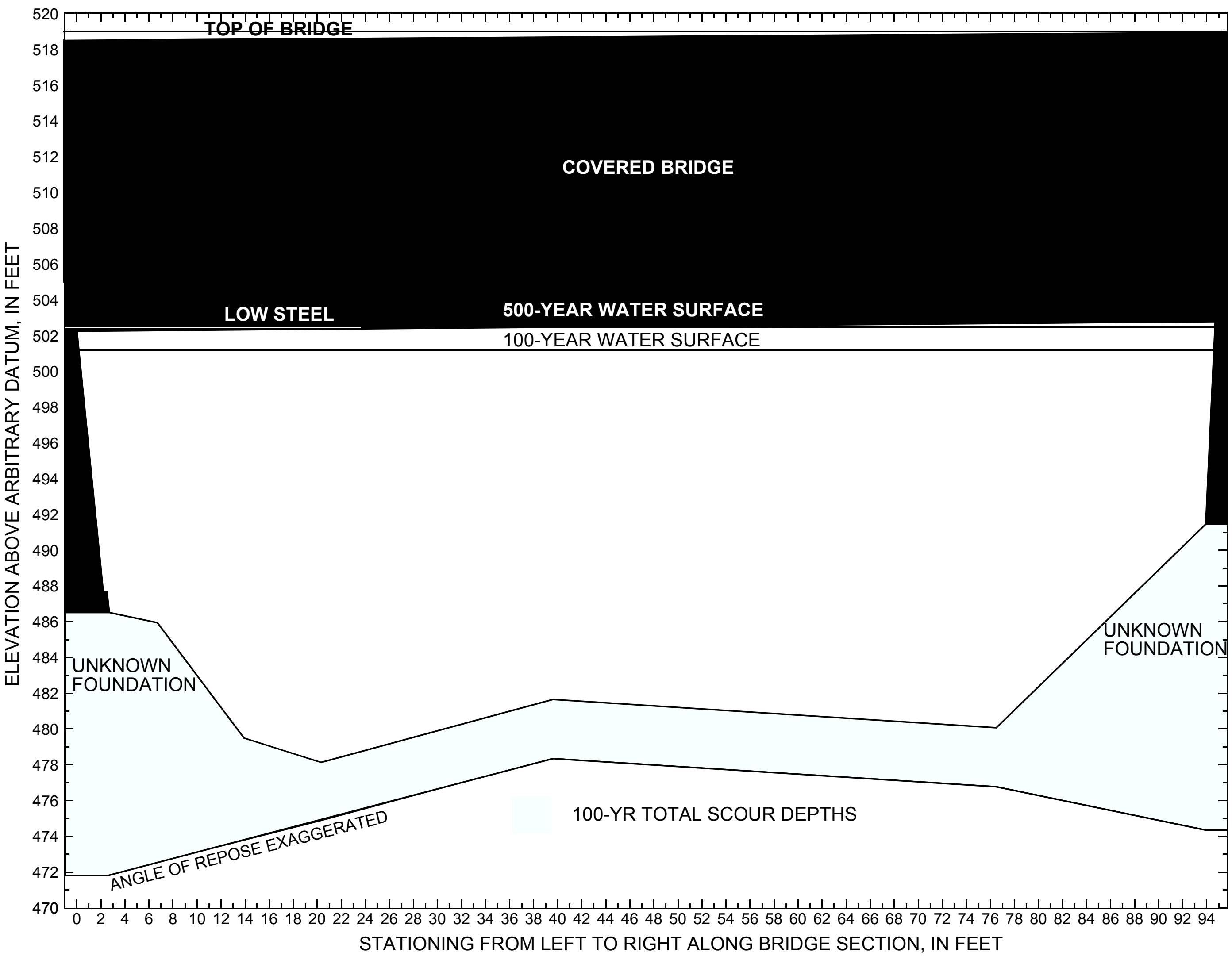

Figure 8. Scour elevations for the 100- and 500-year discharges at structure PROCTH00060004 on Town Highway 6, crossing Otter Creek, Proctor, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure PROCTH00060004 on Town Highway 6, crossing Otter Creek, Proctor, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-year. discharge is 15,100 cubic-feet per second											
Left abutment	0.0	--	502.2	--	486.5	3.3	11.5	--	14.8	471.7	--
Right abutment	94.7	--	502.8	--	491.4	3.3	13.8	--	17.1	474.3	--

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 PROCTH00060004 on Town Highway 6, crossing Otter Creek, Proctor, Vermont.
[VTAOT, Vermont Agency of Transportation; --, no data]

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-year. discharge is 18,600 cubic-feet per second											
Left abutment	0.0	--	502.2	--	486.5	0.3	12.3	--	12.6	473.9	--
Right abutment	94.7	--	502.8	--	491.4	0.3	16.8	--	17.1	474.3	--

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

SELECTED REFERENCES

Arcement, G.J., Jr., and Schneider, V.R., 1989, Guide for selecting Manning's roughness coefficients for natural channels and flood plains: U.S. Geological Survey Water-Supply Paper 2339, 38 p.

Barnes, H.H., Jr., 1967, Roughness characteristics of natural channels: U.S. Geological Survey Water-Supply Paper 1849, 213 p.

Benson, M. A., 1962, Factors Influencing the Occurrence of Floods in a Humid Region of Diverse Terrain: U.S. Geological Survey Water-Supply Paper 1580-B, 64 p.

Brown, S.A. and Clyde, E.S., 1989, Design of riprap revetment: Federal Highway Administration Hydraulic Engineering Circular No. 11, Publication FHWA-IP-89-016, 156 p.

Federal Highway Administration, 1983, Runoff estimates for small watersheds and development of sound design: Federal Highway Administration Report FHWA-RD-77-158.

Federal Highway Administration, 1993, Stream Stability and Scour at Highway Bridges: Participant Workbook: Federal Highway Administration Report FHWA-HI-91-011.

Federal Emergency Management Agency, 1988, Flood Insurance Study, Town of Pittsford, Rutland County, Vermont: Washington, D.C., July 1988.

Froehlich, D.C., 1989, Local scour at bridge abutments *in* Ports, M.A., ed., Hydraulic Engineering--Proceedings of the 1989 National Conference on Hydraulic Engineering: New York, American Society of Civil Engineers, p. 13-18.

Hayes, D.C.,1993, Site selection and collection of bridge-scour data in Delaware, Maryland, and Virginia: U.S. Geological Survey Water-Resources Investigation Report 93-4017, 23 p.

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood flow frequency: U.S. Geological Survey, Bulletin 17B of the Hydrology Subcommittee, 190 p.

Johnson, C.G. and Tasker, G.D.,1974, Progress report on flood magnitude and frequency of Vermont streams: U.S. Geological Survey Open-File Report 74-130, 37 p.

Lagasse, P.F., Schall, J.D., Johnson, F., Richardson, E.V., Chang, F., 1995, Stream Stability at Highway Structures: Federal Highway Administration Hydraulic Engineering Circular No. 20, Publication FHWA-IP-90-014, 144 p.

Laursen, E.M., 1960, Scour at bridge crossings: Journal of the Hydraulics Division, American Society of Civil Engineers, v. 86, no. HY2, p. 39-53.

Potter, W. D., 1957a, Peak rates of runoff in the Adirondack, White Mountains, and Maine woods area, Bureau of Public Roads

Potter, W. D., 1957b, Peak rates of runoff in the New England Hill and Lowland area, Bureau of Public Roads

Richardson, E.V. and Davis, S.R., 1995, Evaluating scour at bridges: Federal Highway Administration Hydraulic Engineering Circular No. 18, Publication FHWA-IP-90-017, 204 p.

Richardson, E.V., Simons, D.B., and Julien, P.Y., 1990, Highways in the river environment: Federal Highway Administration Publication FHWA-HI-90-016.

Ritter, D.F., 1984, Process Geomorphology: W.C. Brown Co., Debuque, Iowa, 603 p.

Shearman, J.O., 1990, User's manual for WSPRO--a computer model for water surface profile computations: Federal Highway Administration Publication FHWA-IP-89-027, 187 p.

Shearman, J.O., Kirby, W.H., Schneider, V.R., and Flippo, H.N., 1986, Bridge waterways analysis model; research report: Federal Highway Administration Publication FHWA-RD-86-108, 112 p.

Talbot, A.N., 1887, The determination of water-way for bridges and culverts.

U.S. Department of Housing and Urban Development, 1978, Flood Insurance Study, Town of Proctor, Rutland County, Vermont: Washington, D.C., June 1978.

U.S. Geological Survey, 1944, Proctor, 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 proc004.wsp
T2        Hydraulic analysis for structure PROCTH00060004   Date: 01-DEC-97
T3        Gorham Bridge 4 on Gorham Street TH 6 over Otter Creek Proctor, VT MAI
*
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q             15100.0   18600.0   11900.0
SK             0.0013    0.0013    0.0013
*
XS   EXITX   -125
GR         -264.8, 502.71   -230.2, 499.56    -21.7, 500.52      0.0, 496.43
GR            4.4, 489.36     13.0, 485.92     31.2, 483.42     64.7, 480.91
GR           86.7, 480.94    108.1, 482.99    114.2, 486.02    119.2, 487.31
GR          122.0, 495.47    129.7, 499.14    159.0, 499.44    174.5, 498.08
GR          202.7, 498.32    203.2, 499.04    289.8, 497.91    343.6, 497.46
GR          382.0, 502.32
N           0.057        0.045        0.060
SA                -21.7        129.7
*
XS   FULLV      0  * * *   0.0000
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    502.51       5.0
GR            0.0, 502.24      2.2, 487.67      2.5, 487.67      2.7, 486.52
GR            6.7, 485.94     13.9, 479.50     20.3, 478.14     39.6, 481.65
GR           76.5, 480.07     85.7, 485.99     93.9, 491.45     94.7, 502.78
GR            0.0, 502.24
*
*         BRTYPE  BRWDTH
CD           1      21.6
N           0.037
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     11      18.0      1
GR         -270.0, 516.50   -264.8, 502.71
GR         -219.4, 501.76   -149.0, 500.99    -85.0, 500.88      0.0, 505.08
GR           95.5, 505.62    180.3, 499.57    308.0, 498.47    752.4, 508.17
GR          913.6, 508.27
*
AS   APPRO   116
GR         -175.9, 516.53   -153.5, 500.72   -140.3, 501.30   -118.8, 500.81
GR         -105.6, 498.39    -40.7, 498.62    -16.8, 499.99      0.0, 493.63
GR            4.9, 487.38      7.7, 485.91     14.7, 480.54     17.9, 480.54
GR           28.4, 483.02     51.3, 483.32     56.7, 484.07     71.1, 483.79
GR           81.3, 484.04     88.6, 486.00     92.2, 487.80     97.3, 495.21
GR          108.4, 499.13    171.5, 497.88    319.8, 498.61    393.8, 496.25
GR          441.0, 495.20    614.3, 497.33    733.7, 504.46    767.2, 505.12
N           0.050        0.045        0.050
SA                -16.8        108.4
*
HP 1 BRIDG   500.11 1 500.11
HP 2 BRIDG   500.11 * * 12084
HP 2 RDWAY   501.19 * * 3016
HP 1 APPRO   501.49 1 501.49
HP 2 APPRO   501.49 * * 15100
*
HP 1 BRIDG   502.08 1 502.08
HP 2 BRIDG   502.08 * * 10639
HP 2 RDWAY   502.45 * * 7961
```

APPENDIX B:

WSPRO OUTPUT FILE

WSPRO OUTPUT FILE

```
      U.S. Geological Survey WSPRO Input File proc004.wsp
      Hydraulic analysis for structure PROCTH00060004   Date: 01-DEC-97
      Gorham Bridge 4 on Gorham Street TH 6 over Otter Creek Proctor, VT MAI
         *** RUN DATE & TIME: 12-12-97  10:16
  CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1    1682.  393887.    94.   120.                       40419.
 500.11         1682.  393887.    94.   120.  1.00     0.    95.  40419.

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

       WSEL     LEW     REW    AREA        K        Q    VEL
     500.11     0.3    94.5  1682.2  393887.   12084.   7.18

X STA.        0.3       15.0       18.1       21.2       24.3       27.5
  A(I)           220.3       66.6       66.3       66.7       67.5
  V(I)            2.74       9.07       9.11       9.06       8.96

X STA.       27.5       31.0       34.5       38.3       42.2       46.1
  A(I)            70.4       69.3       71.8       71.6       72.0
  V(I)            8.58       8.72       8.42       8.44       8.39

X STA.       46.1       49.9       53.7       57.4       61.0       64.7
  A(I)            71.3       72.0       70.9       69.6       70.3
  V(I)            8.47       8.40       8.52       8.68       8.59

X STA.       64.7       68.2       71.7       75.1       78.8       94.5
  A(I)            69.2       68.9       67.4       72.3      207.8
  V(I)            8.73       8.76       8.96       8.36       2.91

  VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.

       WSEL     LEW     REW    AREA        K        Q    VEL
     501.19  -167.3   432.6   484.1   16564.    3016.   6.23

X STA.     -167.3      188.7      202.1      213.8      224.7      234.9
  A(I)            51.4       23.4       21.7       21.4       20.8
  V(I)            2.93       6.44       6.94       7.05       7.25

X STA.      234.9      244.7      253.8      262.6      271.0      278.9
  A(I)            20.9       20.1       20.2       19.9       19.2
  V(I)            7.22       7.50       7.45       7.59       7.85

X STA.      278.9      286.2      293.5      300.6      307.2      314.1
  A(I)            18.2       18.7       18.7       17.8       18.3
  V(I)            8.27       8.07       8.07       8.46       8.24

X STA.      314.1      321.4      329.5      338.9      350.4      432.6
  A(I)            18.3       19.0       20.1       22.0       73.8
  V(I)            8.23       7.95       7.49       6.86       2.04

      U.S. Geological Survey WSPRO Input File proc004.wsp
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      Gorham Bridge 4 on Gorham Street TH 6 over Otter Creek Proctor, VT MAI
         *** RUN DATE & TIME: 12-12-97  10:16
  CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     116.

   WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
           1     287.   13914.   138.   138.                        2350.
           2    1795.  330090.   125.   137.                       38576.
           3    2293.  171623.   576.   576.                       25963.
 501.49         4375.  515627.   839.   851.  1.70  -155.   684.  43529.

  VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     116.

       WSEL     LEW     REW    AREA        K        Q    VEL
     501.49  -154.6   684.0  4374.8  515627.   15100.   3.45

X STA.     -154.6       10.5       16.4       21.7       27.7       33.9
  A(I)           507.0      117.9      109.8      116.0      112.9
  V(I)            1.49       6.41       6.87       6.51       6.69

X STA.       33.9       40.2       46.7       53.2       60.1       66.9
  A(I)           116.1      118.3      117.8      122.8      118.9
  V(I)            6.50       6.38       6.41       6.15       6.35

X STA.       66.9       73.3       80.1       87.2      192.0      317.0
  A(I)           112.5      119.0      119.7      434.7      400.3
  V(I)            6.71       6.34       6.31       1.74       1.89

X STA.      317.0      400.4      449.7      498.7      553.8      684.0
  A(I)           343.5      291.6      287.7      289.1      419.0
  V(I)            2.20       2.59       2.62       2.61       1.80
```

WSPRO OUTPUT FILE (continued)

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        U.S. Geological Survey WSPRO Input File proc004.wsp
        Hydraulic analysis for structure PROCTH00060004   Date: 01-DEC-97
        Gorham Bridge 4 on Gorham Street TH 6 over Otter Creek Proctor, VT MAI
           *** RUN DATE & TIME: 12-12-97  10:16
    CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1    1868.  458756.    94.   124.                       47168.
   502.08         1868.  458756.    94.   124.  1.00     0.    95.  47168.


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

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.08     0.0    94.7  1867.5  458756.   10639.   5.70

X STA.         0.0       15.2       18.3       21.4       24.6       27.8
  A(I)           254.2       72.9       72.3       74.8       73.2
  V(I)            2.09       7.30       7.36       7.11       7.27

X STA.        27.8       31.3       34.8       38.5       42.4       46.3
  A(I)            76.6       75.6       78.6       78.7       79.2
  V(I)            6.94       7.03       6.77       6.76       6.72

X STA.        46.3       50.0       53.8       57.5       61.1       64.7
  A(I)            78.4       79.0       77.8       76.3       77.1
  V(I)            6.78       6.73       6.84       6.97       6.90

X STA.        64.7       68.3       71.7       75.1       79.0       94.7
  A(I)            75.8       75.4       73.7       82.1      235.7
  V(I)            7.02       7.05       7.21       6.48       2.26


    VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      11.

         WSEL     LEW     REW    AREA        K        Q    VEL
       502.45  -252.4   490.3  1068.0   44411.    7961.   7.45

X STA.      -252.4     -142.5      -97.5      177.8      193.1      207.3
  A(I)            96.6       67.9       95.7       44.4       43.2
  V(I)            4.12       5.86       4.16       8.96       9.21

X STA.       207.3      220.7      233.4      245.8      257.6      268.7
  A(I)            42.6       41.8       42.0       41.2       39.8
  V(I)            9.35       9.52       9.48       9.67      10.01

X STA.       268.7      279.0      289.3      299.0      308.5      318.1
  A(I)            38.0       38.9       37.5       37.4       37.3
  V(I)           10.48      10.24      10.62      10.64      10.66

X STA.       318.1      328.7      340.5      353.8      370.0      490.3
  A(I)            38.4       40.0       41.6       45.5      158.1
  V(I)           10.36       9.94       9.58       8.75       2.52

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     116.

     WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
             1     502.   34913.   140.   141.                        5399.
             2    1989.  391679.   125.   137.                       44997.
             3    3205.  291246.   602.   602.                       41976.
   503.04         5696.  717837.   867.   880.  1.56  -157.   710.  66394.


    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     116.

         WSEL     LEW     REW    AREA        K        Q    VEL
       503.04  -156.8   709.9  5696.4  717837.   18600.   3.27

X STA.      -156.8        3.8       14.2       20.6       27.7       35.2
  A(I)           652.1      189.1      144.5      148.6      149.2
  V(I)            1.43       4.92       6.43       6.26       6.23

X STA.        35.2       42.9       50.8       58.9       67.5       75.5
  A(I)           153.4      156.2      156.2      163.4      154.4
  V(I)            6.06       5.96       5.95       5.69       6.02

X STA.        75.5       83.2      121.4      208.9      297.3      377.5
  A(I)           146.3      330.4      423.5      420.5      409.8
  V(I)            6.36       2.81       2.20       2.21       2.27

X STA.       377.5      427.0      470.1      516.6      568.7      709.9
  A(I)           343.6      331.0      334.8      342.8      546.4
  V(I)            2.71       2.81       2.78       2.71       1.70
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   CROSS-SECTION PROPERTIES:  ISEQ =  3;  SECID = BRIDG;  SRD =       0.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1    1488.  328573.    93.   116.                       33692.
  498.03         1488.  328573.    93.   116.  1.00     1.    94.  33692.


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

        WSEL     LEW     REW    AREA        K        Q    VEL
      498.03     0.6    94.4  1487.5  328573.   11900.   8.00

X STA.         0.6       14.9       18.0       21.0       24.1       27.3
  A(I)           187.9       59.8       59.7       58.3       61.0
  V(I)            3.17       9.95       9.96      10.21       9.76

X STA.        27.3       30.6       34.2       37.9       41.9       45.9
  A(I)            60.9       62.9       63.3       65.0       65.4
  V(I)            9.78       9.46       9.39       9.15       9.10

X STA.        45.9       49.7       53.5       57.2       60.8       64.5
  A(I)            63.5       64.1       63.2       62.2       62.9
  V(I)            9.37       9.28       9.41       9.57       9.46

X STA.        64.5       68.0       71.5       74.9       78.6       94.4
  A(I)            61.9       61.8       60.5       64.9      178.3
  V(I)            9.61       9.63       9.84       9.16       3.34


   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPRO;  SRD =     116.

    WSEL  SA#     AREA        K   TOPW   WETP  ALPH    LEW    REW     QCR
            1      17.     200.    69.    69.                          48.
            2    1456.  238064.   121.   133.                       28661.
            3     787.   31272.   511.   511.                        5542.
  498.76         2260.  269536.   701.   713.  1.67  -108.   638.  17792.


   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPRO;  SRD =     116.

        WSEL     LEW     REW    AREA        K        Q    VEL
      498.76  -107.6   638.2  2259.8  269536.   11900.   5.27

X STA.      -107.6       13.9       17.5       21.0       24.8       29.0
  A(I)           220.0       65.5       63.0       65.6       67.0
  V(I)            2.70       9.08       9.44       9.08       8.87

X STA.        29.0       33.3       37.6       41.9       46.4       50.9
  A(I)            67.0       67.7       67.8       69.1       68.9
  V(I)            8.88       8.79       8.78       8.61       8.64

X STA.        50.9       55.4       60.1       64.8       69.3       74.1
  A(I)            69.2       69.3       69.3       67.8       70.4
  V(I)            8.60       8.59       8.58       8.78       8.45

X STA.        74.1       78.6       83.4      391.4      486.8      638.2
  A(I)            67.6       70.7      355.4      299.3      299.3
  V(I)            8.80       8.42       1.67       1.99       1.99
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        U.S. Geological Survey WSPRO Input File proc004.wsp
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 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******  -242.    2787.  0.65 *****  501.25  491.18  15100.  500.60
      -125. ******   368.  418670.  1.42 ***** *******    0.53    5.42

FULLV:FV     125.  -244.    2912.  0.61  0.16  501.41 *******  15100.  500.80
        0.   125.   370.  433021.  1.46  0.00    0.01    0.51    5.19
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     116.  -154.    4113.  0.36  0.13  501.54 *******  15100.  501.18
      116.   116.   679.  479905.  1.72  0.00   -0.01    0.38    3.67

         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   501.75       0.00     499.29     498.47
 ===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    -125.     0.    1682.  1.51 -0.20  501.62  489.94  12084.  500.11
        0.  -125.    95.  393883.  1.88  0.57    0.00    0.41    7.18

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  0.730 ******  502.51 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.    98.  0.08  0.31  501.73    0.00   3016.  501.19

            Q    WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    178.    88.  -167.   -79.   0.3   0.2   4.0   9.3   0.8   3.0
   RT:   2838.   275.   158.   433.   2.7   1.7   6.9   6.1   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      94.  -155.    4375.  0.31  0.17  501.80  493.37  15100.  501.49
      116.   132.   684.  515710.  1.70  0.02    0.00    0.35    3.45

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.887  0.458  279532.    19.   113. ********


  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -125.  -242.   368.  15100.  418670.    2787.    5.42  500.60
   FULLV:FV       0.  -244.   370.  15100.  433021.    2912.    5.19  500.80
   BRIDG:BR       0.     0.    95.  12084.  393883.    1682.    7.18  500.11
   RDWAY:RG      11.*******   178.   3016.       0.*********    1.00  501.19
   APPRO:AS     116.  -155.   684.  15100.  515710.    4375.    3.45  501.49

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      19.   113.  279532.


 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD      EGL    WSEL
   EXITX:XS    491.18    0.53  480.91  502.71************  0.65  501.25  500.60
   FULLV:FV  ********    0.51  480.91  502.71  0.16  0.00  0.61  501.41  500.80
   BRIDG:BR    489.94    0.41  478.14  502.78 -0.20  0.57  1.51  501.62  500.11
   RDWAY:RG  ****************  498.47  516.50  0.08******  0.31  501.73  501.19
   APPRO:AS    493.37    0.35  480.54  516.53  0.17  0.02  0.31  501.80  501.49
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 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******  -255.    3568.  0.68 *****  502.54  492.41  18600.  501.85
      -125. ******   378.  515718.  1.61 ***** *******    0.49    5.21

FULLV:FV     125.  -258.    3700.  0.64  0.16  502.70 *******  18600.  502.06
        0.   125.   380.  533663.  1.63  0.00    0.01    0.47    5.03
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     116.  -156.    5234.  0.32  0.12  502.82 *******  18600.  502.50
      116.   116.   701.  643577.  1.60  0.00    0.00    0.32    3.55

         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   503.86       0.00     500.13     498.47
 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.
 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   502.08     502.90     503.04     502.51
 ===245 ATTEMPTING FLOW CLASS 2 (5) SOLUTION.
 ===250 INSUFFICIENT HEAD FOR PRESSURE FLOW.
                        YU/Z,WSIU,WS = 1.03     503.11     503.22
 ===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    -125.     0.    1867.  1.07 -0.18  503.14  489.23  10639.  502.08
        0.  -125.    95.  458672.  2.11  0.78    0.00    0.33    5.70

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   4.  0.688 ******  502.51 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.    98.  0.07  0.26  503.25    0.00   7961.  502.45

               Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:   1547.   199.  -252.   -53.   1.6   1.0   6.3   7.4   1.8   3.1
   RT:   6414.   350.   140.   490.   4.0   2.5   8.5   7.5   3.2   3.1

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

APPRO:AS      94.  -157.    5693.  0.26  0.14  503.30  494.87  18600.  503.04
      116.   136.   710.  717332.  1.56  0.01    0.00    0.28    3.27

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.890  0.592  292774.    26.   121. ********

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXITX:XS    -125.  -255.   378.  18600.  515718.    3568.    5.21  501.85
   FULLV:FV       0.  -258.   380.  18600.  533663.    3700.    5.03  502.06
   BRIDG:BR       0.     0.    95.  10639.  458672.    1867.    5.70  502.08
   RDWAY:RG      11.******* 1547.   7961.******************    1.00  502.45
   APPRO:AS     116.  -157.   710.  18600.  717332.    5693.    3.27  503.04

    XSID:CODE   XLKQ   XRKQ       KQ
   APPRO:AS      26.   121.  292774.

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXITX:XS    492.41    0.49  480.91  502.71************  0.68  502.54  501.85
   FULLV:FV  ********    0.47  480.91  502.71  0.16  0.00  0.64  502.70  502.06
   BRIDG:BR    489.23    0.33  478.14  502.78 -0.18  0.78  1.07  503.14  502.08
   RDWAY:RG  **************** 498.47  516.50  0.07******  0.26  503.25  502.45
   APPRO:AS    494.87    0.28  480.54  516.53  0.14  0.01  0.26  503.30  503.04
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        U.S. Geological Survey WSPRO Input File proc004.wsp
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 XSID:CODE   SRDL    LEW     AREA   VHD    HF     EGL    CRWS       Q    WSEL
       SRD   FLEN    REW        K  ALPH    HO     ERR     FR#     VEL

EXITX:XS   ******   -12.    1969.  0.62 *****  499.31  489.97  11900.  498.69
      -125. ******   353.  329787.  1.09 ***** *******    0.43    6.04

FULLV:FV     125.   -13.    2028.  0.60  0.16  499.48 *******  11900.  498.88
        0.   125.   355.  336436.  1.12  0.00    0.01    0.43    5.87
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

APPRO:AS     116.  -109.    2457.  0.63  0.17  499.67 *******  11900.  499.04
      116.   116.   643.  286372.  1.73  0.02    0.00    0.61    4.84

        <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   498.76       0.00     498.03     498.47
 ===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    -125.     1.    1488.  1.17 -0.21  499.20  489.85  11900.  498.03
        0.  -125.    94.  328653.  1.18  0.10    0.00    0.38    8.00

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****    4.  0.922 ******  502.51 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      11.        <<<<<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      94.  -108.    2259.  0.72  0.25  499.48  491.95  11900.  498.76
      116.   118.   638.  269431.  1.67  0.03   -0.01    0.67    5.27

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.875  0.066  252136.     7.   101. ********


   FIRST USER DEFINED TABLE.

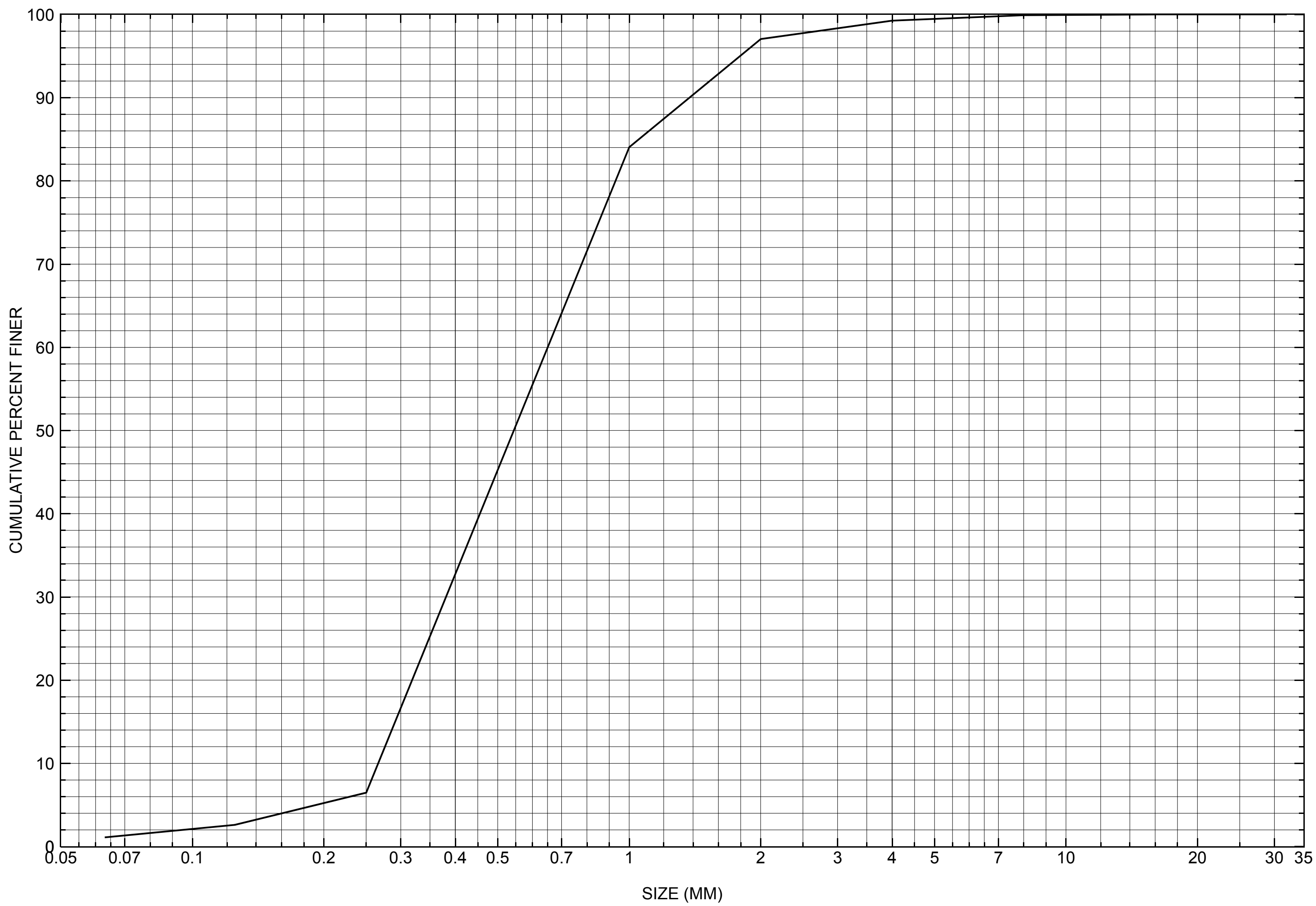
    XSID:CODE    SRD    LEW    REW       Q        K      AREA     VEL    WSEL
   EXITX:XS    -125.   -12.   353.  11900.  329787.    1969.    6.04  498.69
   FULLV:FV       0.   -13.   355.  11900.  336436.    2028.    5.87  498.88
   BRIDG:BR       0.     1.    94.  11900.  328653.    1488.    8.00  498.03
   RDWAY:RG      11.**************       0.       0.       0.    1.00********
   APPRO:AS     116.  -108.   638.  11900.  269431.    2259.    5.27  498.76

  SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXITX:XS    489.97    0.43  480.91  502.71************  0.62  499.31  498.69
   FULLV:FV  ********    0.43  480.91  502.71  0.16  0.00  0.60  499.48  498.88
   BRIDG:BR    489.85    0.38  478.14  502.78 -0.21  0.10  1.17  499.20  498.03
   RDWAY:RG  ****************  498.47  516.50  0.19******  0.72  499.28********
   APPRO:AS    491.95    0.67  480.54  516.53  0.25  0.03  0.72  499.48  498.76
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution from a sieve analysis of a bulk sample taken from the channel approach of structure PROCTH00060004, in Proctor, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number PROCTH00060004

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)* 57250

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

Waterway *(I - 6)* Otter Creek

Road Name *(I - 7)*: -

Route Number TH006

Vicinity *(I - 9)* At the town line with Pittsford

Topographic Map Proctor

Hydrologic Unit Code: 02010002

Latitude *(I - 16; nnnn.n)* 43408

Longitude *(i - 17; nnnnn.n)* 72023

Select Federal Inventory Codes

FHWA Structure Number *(I - 8)* 10111800041118

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

Maximum span length *(I - 48; nnnn)* 0105

Year built *(I - 27; YYYY)* 1841

Structure length *(I - 49; nnnnnn)* 000130

Average daily traffic, ADT *(I - 29; nnnnnn)* 000600

Deck Width *(I - 52; nn.n)* 180

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

Channel & Protection *(I - 61; n)* 6

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)* Y48

Structure type *(I - 43; nnn)* 710

Year Reconstructed *(I - 106)* 0000

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

Clear span (*nnn.n ft*) 088.6

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

Vertical clearance from streambed (*nnn.n ft*) 019.5

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

Waterway of full opening (*nnn.n ft*^{2}) 1727.

Comments:

The structural inspection report of 11/14/94 indicates the structure is a timber thru-truss type covered bridge. The abutment walls are "laid-up" stone with concrete caps. The lower half of the left abutment has concrete facing on the stone wall and a concrete footing. The right abutment reportedly has random voids overall where some stones have cracked or broken and fallen out. Many of the stones that remain are noted as cracked. Likewise, on the left abutment where the stones are visible on the face of the wall, a few are reported as cracked. A few boulders are noted as evident at the ends of the abutments and along the channel banks. Bank erosion is reported evident from previous flooding. The report indicates the type of foundation is boulders at the base of each stone abutment wall.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

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

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* 364.88 mi^2
Lake/pond/swamp area 4.69 mi^2
Watershed storage *(ST)* 1.4 %
Bridge site elevation 360 ft
Headwater elevation 3051 ft
Main channel length 45.66 mi
10% channel length elevation 470 ft
85% channel length elevation 679 ft
Main channel slope *(S)* 6.1 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*)? **Other**

Comments: **U.S. Department of Housing and Urban Development, Flood Insurance Study, Town of Proctor, VT, June 1978.**
This cross section is taken from a HEC-2 input file. The measurements are in feet.

Station	291	336	394	-	-	-	-	-	-	-	-
Feature	LAB	-	RAB	-	-	-	-	-	-	-	-
Low chord elevation	366.3	366.4	366.5	-	-	-	-	-	-	-	-
Bed elevation	352.2	339.7	352.2	-	-	-	-	-	-	-	-
Low chord to bed	14.1	26.7	14.3	-	-	-	-	-	-	-	-
Station	-	-	-	-	-	-	-	-	-	-	-
Feature	-	-	-	-	-	-	-	-	-	-	-
Low chord elevation	-	-	-	-	-	-	-	-	-	-	-
Bed elevation	-	-	-	-	-	-	-	-	-	-	-
Low chord to bed	-	-	-	-	-	-	-	-	-	-	-

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

Comments: -
-

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: **RB** Date: **2/16/96**
Computerized by: **RB** Date: **2/16/96**
Reviewd by: **MAI** Date: **12/17/97**

Structure Number **PROCTH00060004**

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* **L. Medalie** Date *(MM/DD/YY)* **06** / **23** / 19**95**

2. Highway District Number **03** Mile marker **0000**

County **Rutland (021)** Town **Proctor (57250)**

Waterway *(I - 6)* **Otter Creek** Road Name **Gorham Road**

Route Number **TH006** Hydrologic Unit Code: **02010002**

3. Descriptive comments:

The site is the Gorham covered bridge at the town line with Pittsford.

B. Bridge Deck Observations

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

5. Ambient water surface... US **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 **130** *(feet)* Span length **105** *(feet)* Bridge width **18.0** *(feet)*

Road approach to bridge:

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

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

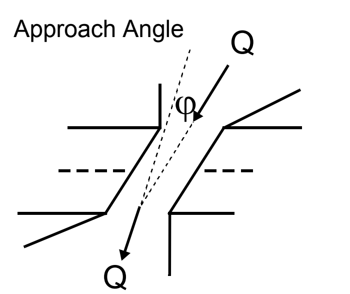
10. Embankment slope (*run / rise in feet / foot*):
US left **--** US right **--**

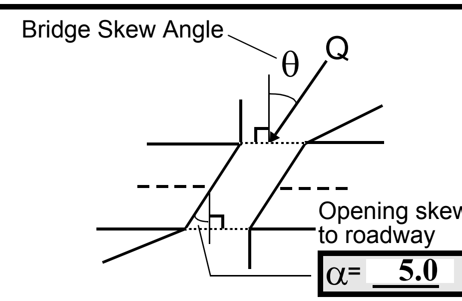
	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	1	1	2	1
RBUS	1	1	0	-
RBDS	1	1	0	-
LBDS	0	-	0	-

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

Channel approach to bridge (BF):

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





17. Channel impact zone 1: Exist? **Y** *(Y or N)*
Where? **RB** *(LB, RB)* Severity **2**
Range? **40** feet **US** *(US, UB, DS)* to **150** feet **DS**

Channel impact zone 2: Exist? **Y** *(Y or N)*
Where? **LB** *(LB, RB)* Severity **1**
Range? **10** feet **DS** *(US, UB, DS)* to **190** feet **DS**

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

18. Bridge Type: **1b**

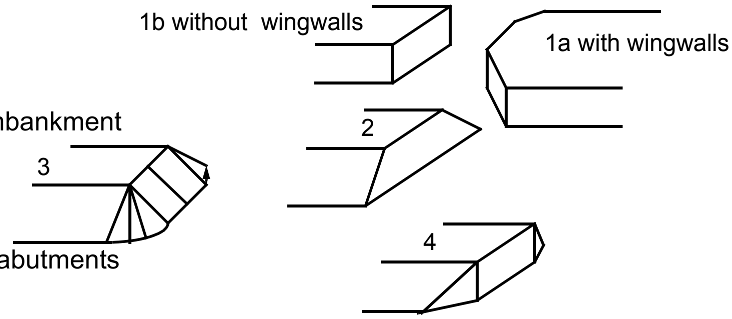
1a- Vertical abutments with wingwalls

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 116 feet.
11. The right bank US protection consists of 3 boulders and the rest is gravel (15-30 cm).
4. The left bank US is an 80 foot wide strip of pasture, then a paved road, and then the forest.
The right bank US is a triangle of pasture 200 feet US of the bridge with row crops beyond that.
The right bank DS is forest, then a paved road, and then pasture.
13. On the left bank US is a thin gully of road wash just at the end of the bridge before the guard rail.
17. At impact zone 2, along the downstream left bank, the channel widens 15 feet along the left bank to create some eddying effects.

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
0.0	**12.5**			**11.5**	**1**	**1**	**2**	**2**	**2**	**2**

23. Bank width **30.0** 24. Channel width **35.0** 25. Thalweg depth **125.0** 29. Bed Material **1**

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

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

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

26. There are no trees on the immediate left bank and up to 25% on the right bank but it is only a thin strip of trees.
30. The left bank protection from 0-100 feet US is large concrete blocks. Over 100 feet US, the bank protection consists of smaller stones (type 1). The right bank protection extends 40 feet US of the bridge, except for an occasional isolated boulder or rock pile further US.
At 250 feet US there is a large stump in the streambed about 15 feet from the right bank.

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

36. Point bar extent: - feet - (US, UB) to - feet - (US, UB, DS) positioned - %LB to - %RB

37. Material: -

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

NO POINT BARS

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

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

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

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

NO CUT BANKS

Stream incision has created almost vertical banks on both sides of the stream. This is not a cut bank because up to 1000 feet US the stream section is straight.

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

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

A very small confluence on the right bank about 200 feet US cuts through the bank from pasture runoff.

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
87.5		3.0		2	7	7	0

58. Bank width (BF) - 59. Channel width (Amb) - 60. Thalweg depth (Amb) 90.0 63. Bed Material 1

*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.):

1

61. Both abutment walls are laid-up stone with concrete caps. The right abutment has 8 feet of vertical stone above natural sand then topped by concrete. The left abutment has a concrete face with a footing at the streambed below the laid-up stone and is capped by concrete. There are some signs of erosion and cracks in the right abutment.

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

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

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

70. Debris and Ice Comments:

1

There are not many trees along the banks US of the bridge, but the drainage basin is forested. A debris accumulation is located 1000 feet DS of the bridge as noted in the DS assessment.

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		0	90	2	2	4.5	1	90.0
RABUT	1	0	90			2	0	94.5

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.):

-

-

2

77. The right abutment material is laid-up stone over sand and topped by concrete.

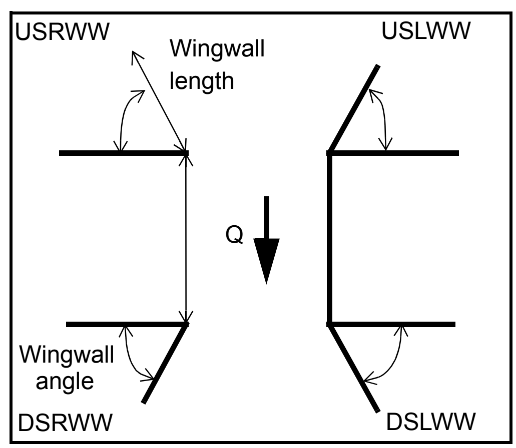
75. The scour hole described in the DS assessment is present under the bridge close to both abutments. Since it is continuous, it is not described separately here. The abutments are not undermined.

76. The left abutment footing exposure ranges from 1 foot US to 3 feet DS.

80. Wingwalls:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						94.5	
USRWW:	N		-		-	8.0	
DSLWW:	-		-		N	21.5	
DSRWW:	-		-		-	22.0	

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



82. Bank / Bridge Protection:

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

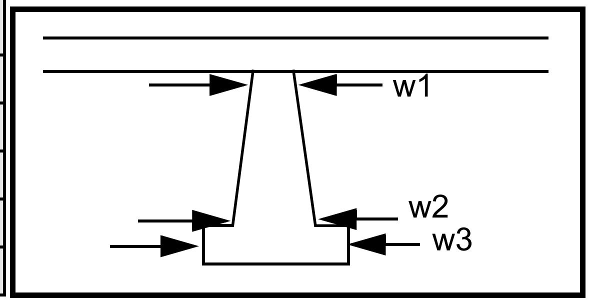
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

Piers:

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

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



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	**e left**	**under**	**size is**	**there**	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	**and**	**the**	**vari-**	**is**	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	**right**	**brid**	**able,**	**almo**	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	**abut**	**ge**	**most**	**st no**	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	**ment**	**from**	**ly 1-**	**pro-**	*Y- yes; N- no*
91. Attack ∠ (BF)	**pro-**	**the**	**2**	**tec-**	
92. Pushed	**tec-**	**US**	**feet.**	**tion,**	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	**tion**	**end.**	**On**	**only**	
95. Cross-members	**only**	**Also,**	**the**	**very**	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	**exte**	**pro-**	**DS**	**spar**	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	**nds 4**	**tec-**	**left**	**se**	
98. Exposure depth	**feet**	**tion**	**bank**	**stone**	

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

s, less than 12 inches.

N

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.):
-
-
-
-
-
-
-
-
-
-
-
-
-
-
-

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: -_____ feet -____ *(US, UB, DS)* to -_____ 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? N_____ *(Y or if N type ctrl-n cb)* Where? O_____ *(LB or RB)* Mid-bank distance: PIE_

Cut bank extent: RS___ 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.):

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

Scour dimensions: Length 4_____ Width 2_____ Depth: 2_____ Positioned 2___ %LB to 2___ %RB

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

1
0
0
-

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

Confluence 1: Distance e is a Enters on larg_ *(LB or RB)* Type e_____ *(**1**- perennial; **2**- ephemeral)*

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

Confluence comments (eg. confluence name):

mulation across the width of the stream 1000 feet DS from the bridge. It appears to be from trees along the eroded banks that have slumped. This debris is catching subsequent debris.

F. Geomorphic Channel Assessment

107. Stage of reach evolution Th___

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)*:

e DS thalweg is 4 feet approximately at midstream, though further than 1 bridge length, the channel gets shallower. Depths are highly variable.

109. G. Plan View Sketch

N

point bar (pb)	debris	flow (Q)	stone wall
cut-bank (cb)	rip rap or stone fill	cross-section	other wall
scour hole		ambient channel	

APPENDIX F:

SCOUR COMPUTATIONS

SCOUR COMPUTATIONS

Structure Number: PROCTH00060004 Town: Proctor
Road Number: TH 6 County: Rutland
Stream: Otter Creek

Initials MAI Date: 12/12/97 Checked: ECW

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	15100	18600	11900
Main Channel Area, ft2	1795	1989	1456
Left overbank area, ft2	287	502	17
Right overbank area, ft2	2293	3205	787
Top width main channel, ft	125	125	121
Top width L overbank, ft	138	140	69
Top width R overbank, ft	576	602	511
D50 of channel, ft	0.001568	0.001568	0.001568
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	14.4	15.9	12.0
y1, average depth, LOB, ft	2.1	3.6	0.2
y1, average depth, ROB, ft	4.0	5.3	1.5
Total conveyance, approach	515627	717837	269536
Conveyance, main channel	330090	391679	238064
Conveyance, LOB	13914	34913	200
Conveyance, ROB	171623	291246	31272
Percent discrepancy, conveyance	0.0000	-0.0001	0.0000
Qm, discharge, MC, cfs	9666.6	10148.9	10510.5
Ql, discharge, LOB, cfs	407.5	904.6	8.8
Qr, discharge, ROB, cfs	5025.9	7546.5	1380.7
Vm, mean velocity MC, ft/s	5.4	5.1	7.2
Vl, mean velocity, LOB, ft/s	1.4	1.8	0.5
Vr, mean velocity, ROB, ft/s	2.2	2.4	1.8
Vc-m, crit. velocity, MC, ft/s	2.0	2.1	2.0
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	1	1	1
Left Overbank	N/A	N/A	N/A
Right Overbank	N/A	N/A	N/A

Live-Bed Contraction Scour

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

	Approach			Bridge		
Characteristic	100 yr	500 yr	Other Q	100 yr	500 yr	Other Q
Q1, discharge, cfs	15100	18600	11900	12084	10639	11900
Total conveyance	515627	717837	269536	393887	458756	328573
Main channel conveyance	330090	391679	238064	393887	458756	328573
Main channel discharge	9667	10149	10511	12084	10639	11900
Area - main channel, ft2	1795	1989	1456	1682.2	1867.5	1487.5
(W1) channel width, ft	125	125	121	93.8	94.3	93.4
(Wp) cumulative pier width, ft	0	0	0	0	0	0
W1, adjusted bottom width(ft)	125	125	121	93.8	94.3	93.4
D50, ft	0.001568	0.001568	0.001568			
w, fall velocity, ft/s (p. 32)	0.2734	0.2734	0.2734			
y, ave. depth flow, ft	14.36	15.91	12.03	17.93	19.80	15.93
S1, slope EGL	0.00112	0.001034	0.001638			
P, wetted perimeter, MC, ft	137	137	133			
R, hydraulic Radius, ft	13.102	14.518	10.947			
V*, shear velocity, ft/s	0.687	0.695	0.760			
V*/w	2.514	2.543	2.779			
Bed transport coeff., k1, (0.59 if V*/w<0.5; 0.64 if .5<V*/w<2; 0.69 if V*/w>2.0 p. 33)						
k1	0.69	0.69	0.69			
y2,depth in contraction, ft	21.20	20.13	16.00			
ys, scour depth, ft (y2-y_bridge)	**3.26**	**0.32**	**0.08**			

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	12084	10639	11900
Main channel area (DS), ft2	1682.2	1867.5	1487.5
Main channel width (normal), ft	93.8	94.3	93.4
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	93.8	94.3	93.4
D90, ft	0.0039	0.0039	0.0039
D95, ft	0.0054	0.0054	0.0054
Dc, critical grain size, ft	0.0436	0.0269	0.0552
Pc, Decimal percent coarser than Dc	0.000	0.000	0.000

Depth to armoring, ft	**N/A**	**N/A**	**N/A**

Abutment Scour

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

	Left Abutment			Right Abutment		
Characteristic	100 yr Q	500 yr Q	Other Q	100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	15100	18600	11900	15100	18600	11900
a', abut.length blocking flow, ft	155.1	157	108.4	589.7	615.4	544
Ae, area of blocked flow ft2	453.92	523.12	196.28	1990.35	2548.47	941.54
Qe, discharge blocked abut.,cfs	--	--	530.85	--	--	1764.14
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	1.49	1.43	2.70	2.15	2.39	1.87
ya, depth of f/p flow, ft	2.93	3.33	1.81	3.38	4.14	1.73
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	1	1	1
--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	0.150	0.125	0.354	0.186	0.180	0.251
ys, scour depth, ft	14.52	14.56	14.58	28.48	32.30	21.62

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)	155.1	157	108.4	589.7	615.4	544
y1 (depth f/p flow, ft)	2.93	3.33	1.81	3.38	4.14	1.73
a'/y1	53.00	47.12	59.87	174.72	148.61	314.31
Skew correction (p. 49, fig. 16)	1.01	1.01	1.01	0.98	0.98	0.98
Froude no. f/p flow	0.15	0.13	0.35	0.19	0.18	0.25
Ys w/ corr. factor K1/0.55:						
vertical	**11.51**	**12.33**	**9.45**	**13.85**	**16.81**	**7.8**4
vertical w/ ww's	9.43	10.11	7.75	11.36	13.79	6.43

spill-through	6.33	6.78	5.20	7.62	9.25	4.31

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	0.41	0.33	0.38	0.41	0.33	0.38
y, depth of flow in bridge, ft	17.93	19.80	15.93	17.93	19.80	15.93
Median Stone Diameter for riprap at:	left abutment			right abutment, ft		
Fr<=0.8 (vertical abut.)	**1.86**	**1.33**	**1.42**	**1.86**	**1.33**	**1.42**
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR