LEVEL II SCOUR ANALYSIS FOR BRIDGE 29 (FERRTH00260029) on TOWN HIGHWAY 26, crossing LITTLE OTTER CREEK, FERRISBURG, VERMONT

U.S. Geological Survey
Open-File Report 98-022

Prepared in cooperation with
VERMONT AGENCY OF TRANSPORTATION
and

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

science for a changing world

LEVEL II SCOUR ANALYSIS FOR BRIDGE 29 (FERRTH00260029) on TOWN HIGHWAY 26, crossing LITTLE OTTER CREEK, FERRISBURG, VERMONT

By ERICK M. BOEHMLER AND ROBERT H. FLYNN

U.S. Geological Survey
Open-File Report 98-022

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

Pembroke, New Hampshire

1998

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

U.S. GEOLOGICAL SURVEY
Thomas Casadevall, Acting Director

For additional information write to:

District Chief
U.S. Geological Survey
361 Commerce Way
Pembroke, NH 03275-3718

Copies of this report may be purchased from:

U.S. Geological Survey
Branch of Information Services
Open-File Reports Unit
Box 25286
Denver, CO 80225-0286

CONTENTS

FIGURES

TABLES

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 29 (FERRTH00260029) ON TOWN HIGHWAY 26, CROSSING LITTLE OTTER CREEK, FERRISBURG, VERMONT

By **Erick M. Boehmler and Robert H. Flynn**

INTRODUCTION AND SUMMARY OF RESULTS

This report provides the results of a detailed Level II analysis of scour potential at structure FERRTH00260029 on Town Highway 26 crossing Little Otter Creek, Ferrisburg, 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 Champlain section of the St. Lawrence Valley physiographic province in northwestern Vermont. The 37.9-mi^2 drainage area is in a predominantly rural and forested basin with pasture on the valley bottom in many places. In the vicinity of the study site, the surface cover is pasture except for the upstream right bank, which is forested.

In the study area, Little Otter Creek has an incised, sinuous channel with a slope of approximately 0.001 ft/ft, an average channel top width of 64 ft and an average bank height of 3 ft. The predominant channel bed material is cobbles with a median grain size (D_{50}) of 106 mm (0.348 ft). The geomorphic assessment at the time of the Level I and Level II site visit on June 20, 1996, indicated that the reach was stable.

The Town Highway 26 crossing of Little Otter Creek is a 33-ft-long, one-lane bridge consisting of one 31-foot steel-beam span (Vermont Agency of Transportation, written communication, June 14, 1996). The opening length of the structure parallel to the bridge face is 28.9 ft. The bridge is supported by vertical, concrete abutments with wingwalls only on the right abutment. The channel is skewed approximately 10 degrees to the opening while the opening-skew-to-roadway is 15 degrees.
A scour hole 1.5 feet deeper than the average thalweg depth was observed underneath the bridge. Scour, 0.5 feet deeper than the average thalweg depth, also was observed along the upstream end of the left abutment during the Level I assessment. Scour protection at the site consisted of type-2 stone fill (less than 36 inches diameter) along the entire length of the right abutment and its wingwalls. 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 0.0 to 0.1 ft. The worst-case contraction scour occurred at the 500-year discharge. Abutment scour ranged from 15.9 to 21.2 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. 47). Usually, computed scour depths are evaluated in combination with other information including (but not limited to) historical performance during flood events, the geomorphic stability assessment, existing scour protection measures, and the results of the hydraulic analyses. Therefore, scour depths adopted by VTAOT may differ from the computed values documented herein.

Plymouth, VT. Quadrangle, 1:24,000, 1966
Photoinspected 1983

NORTH

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

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

LEVEL II SUMMARY

Structure Number FERRTH00260029 ***Stream*** Little Otter Creek

County Addison ***Road*** TH 26 ***District*** 5

Description of Bridge

Bridge length 33 ***ft*** ***Bridge width*** 15.3 ***ft*** ***Max span length*** 31 ***ft***

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

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

Stone fill on abutment? Yes ***Date of inspection*** 6/20/96

Description of stone fill Type-2 is located along the right abutment and its wingwalls. There also is type-1 stone fill located on the roadway embankments.

Brief description of piers/abutments Abutments and wingwalls are concrete. There are wingwalls on the right abutment only.

Is bridge skewed to flood flow according to Yes ***survey?*** Yes ***Angle*** 10

There is a mild channel bend in the upstream reach such that the flow impacts the right abutment. In the reach downstream of the site there is a severe channel bend.

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	6/20/96	0	0
Level II	6/20/96	0	0

Potential for debris Low. There is no vegetation debris in the channel upstream and the upstream channel is laterally stable with no cut-banks.

Describe any features near or at the bridge that may affect flow (include observation date) At the time of the assessment on 6/20/96, there was a large pile of type-2 stone fill in front of the right abutment with a scour hole along the edge of the stone fill.

Description of the Geomorphic Setting

General topography The channel is located in a moderate relief valley setting, with moderately sloping, irregular overbank areas and/or moderately sloping valley walls.

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

Date of inspection 6/20/96

DS left: Mildly sloping channel bank to a narrow overbank.

DS right: Mildly sloping channel bank and moderately sloping valley wall.

US left: Moderately sloping channel bank and a narrow overbank.

US right: Mildly sloping channel bank to the valley wall.

Description of the Channel

Average top width 64 ft ***Average depth*** 3 ft

Predominant bed material Cobbles ***Bank material*** Sand to Cobbles

Perennial and sinuous but stable with semi-alluvial channel boundaries and local anabranching.

6/20/96

Vegetative co Grass with a few shrubs and trees.

DS left: Grass with a few shrubs and trees.

DS right: Grass with a few shrubs and trees.

US left: Grass and trees.

US right:

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

None noted on 6/20/96.

Describe any obstructions in channel and date of observation.

Hydrology

Drainage area 37.9 ***mi²***

Percentage of drainage area in physiographic provinces: (approximate)

Physiographic province/section	***Percent of drainage area***
St. Lawrence Valley /Champlain	100

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

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

USGS gage description Little Otter Creek at Ferrisburg, VT

USGS gage number 04282650

Gage drainage area 57.1 ***mi²***

Is there a lake/p No

-

-

Calculated Discharges

Q100 3,430 ***ft³/s*** ***Q500*** 5,000 ***ft³/s***

The gage indicated above has less than 8 years of record. Therefore, its records were not considered for this analysis. The 100-year discharge was calculated by use of the Benson (1962) method. The resulting flood frequency curve was extrapolated to the 500-year event. The 100- and 500-year discharges from the Benson (1962) flood frequency curve were within a range of flood frequency curve estimates defined by use of several other empirical equations (FHWA, 1983; Johnson and Tasker, 1974; Potter, 1957; 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 downstream right wingwall (elev. 498.28 feet, arbitrary survey datum). RM2 is the head of a nail 5 ft above the ground in the first telephone pole left of the bridge (about 35 feet left of the left abutment) on the downstream side of the roadway (elev. 504.87 feet, arbitrary survey datum)

Cross-Sections Used in WSPRO Analysis

[1]*Cross-section*	*Section Reference Distance (SRD) in feet*	[2]*Cross-section development*	*Comments*
EXIT1	-46	1	Exit section
FULLV	0	5	Downstream Full-valley section (EXIT1 overbank and BRIDG channel)
BRIDG	0	1	Bridge section
RDWAY	10	1	Road Grade section
APPR1	47	2	Modelled Approach section (Templated from APTEM)
APTEM	55	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 0.050 to 0.055, and overbank "n" values ranged from 0.035 to 0.040.

Normal depth at the exit section (EXIT1) 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 0.000988 ft/ft, which was estimated from the appropriate topographic map (U.S. Geological Survey, 1963).

The surveyed approach section (APTEM) was moved along the approach channel slope (0.026 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 also provides a consistent method for determining scour variables.

Bridge Hydraulics Summary

Average bridge embankment elevation 499.4 *ft*
Average low steel elevation 498.0 *ft*

100-year discharge 3,430 *ft³/s*
Water-surface elevation in bridge opening 498.1 *ft*
Road overtopping? Yes *Discharge over road* 259 *ft³/s*
Area of flow in bridge opening 302 *ft²*
Average velocity in bridge opening 10.5 *ft/s*
Maximum WSPRO tube velocity at bridge 13.1 *ft/s*

Water-surface elevation at Approach section with bridge 500.7
Water-surface elevation at Approach section without bridge 497.3
Amount of backwater caused by bridge 3.4 *ft*

500-year discharge 5,000 *ft³/s*
Water-surface elevation in bridge opening 498.1 *ft*
Road overtopping? Yes *Discharge over road* 1,450 *ft³/s*
Area of flow in bridge opening 302 *ft²*
Average velocity in bridge opening 11.8 *ft/s*
Maximum WSPRO tube velocity at bridge 14.6 *ft/s*

Water-surface elevation at Approach section with bridge 502.6
Water-surface elevation at Approach section without bridge 499.3
Amount of backwater caused by bridge 3.3 *ft*

Incipient overtopping discharge 2,680 *ft³/s*
Water-surface elevation in bridge opening 495.5 *ft*
Area of flow in bridge opening 232 *ft²*
Average velocity in bridge opening 11.6 *ft/s*
Maximum WSPRO tube velocity at bridge 15.0 *ft/s*

Water-surface elevation at Approach section with bridge 498.1
Water-surface elevation at Approach section without bridge 496.2
Amount of backwater caused by bridge 1.9 *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 presented graphically in figure 8.

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

For comparison, estimates of contraction scour also were computed for the 100- and 500-year discharges by use of the Laursen clear-water contraction scour equation (Richardson and Davis, 1995, p. 32, equation 20) and the Umbrell pressure-flow equation (Richardson and Davis, 1995, p. 144). Results of these computations are presented in appendix F. Furthermore, for the 100-year discharge, which resulted in unsubmerged orifice flow, contraction scour was computed by substituting an estimate for the depth of flow at the downstream bridge face in the contraction scour equations. Results with respect to this substitution also are provided 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.

Scour Results

Contraction scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
	(Scour depths in feet)		
Main channel			
Live-bed scour	--	--	--
Clear-water scour	0.0	0.1	0.0
Depth to armoring	3.9	4.7	5.6
Left overbank	--	--	--
Right overbank	--	--	--

Local scour:	100-yr discharge	500-yr discharge	Incipient overtopping discharge
Abutment scour			
Left abutment	18.9	21.0	15.9
Right abutment	18.1	21.2	16.6
Pier scour			
Pier 1	--	--	--
Pier 2	--	--	--
Pier 3	--	--	--

Riprap Sizing

	100-yr discharge	500-yr discharge	Incipient overtopping discharge
		(D_{50} in feet)	
Abutments:			
Left abutment	2.4	2.7	2.9
Right abutment	2.4	2.7	2.9
Piers:			
Pier 1	--	--	--
Pier 2	--	--	--

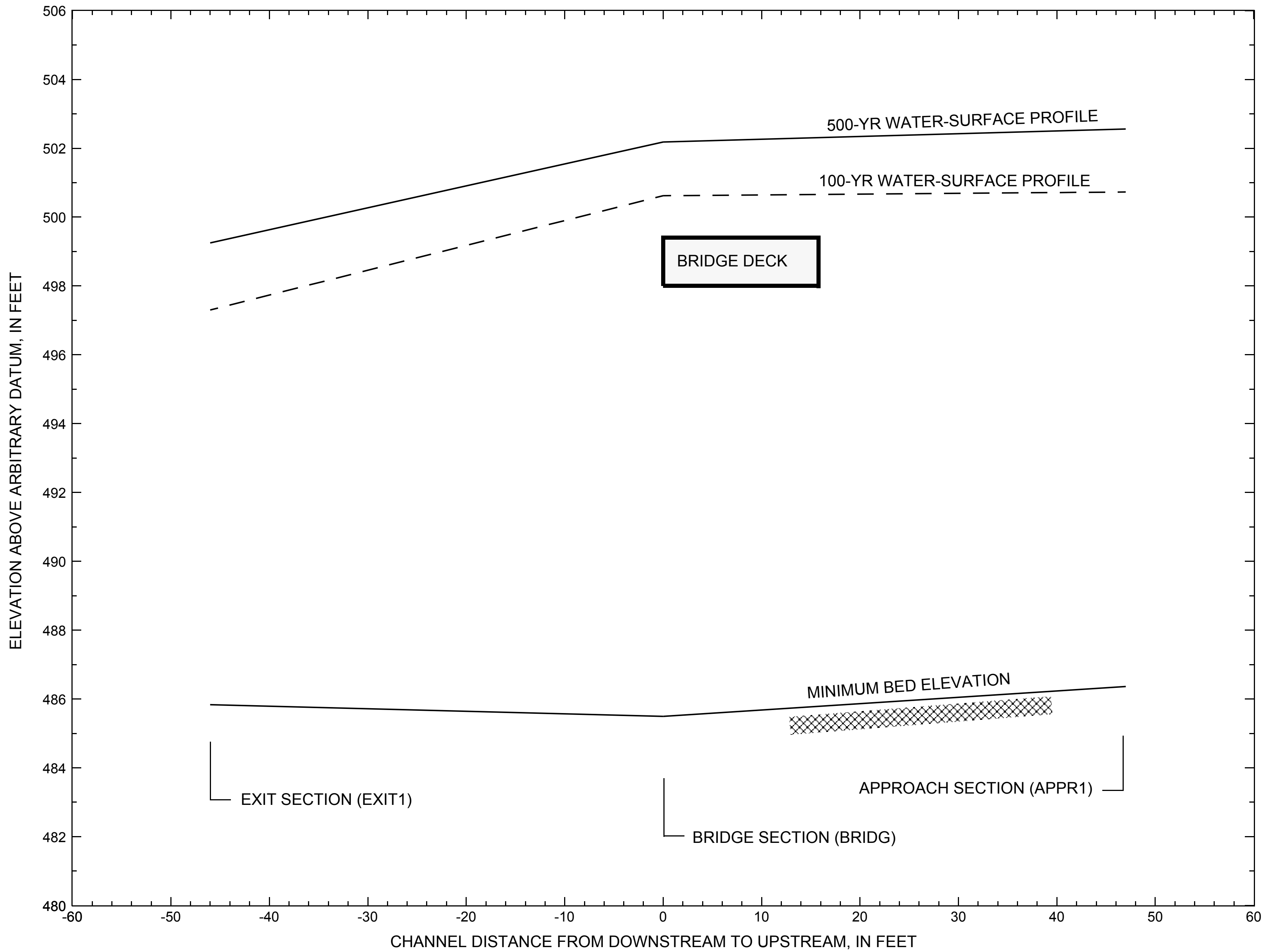


Figure 7. Water-surface profiles for the 100- and 500-yr discharges at structure FERRTH00260029 on Town Highway 26, crossing Little Otter Creek, Ferrisburg, Vermont.

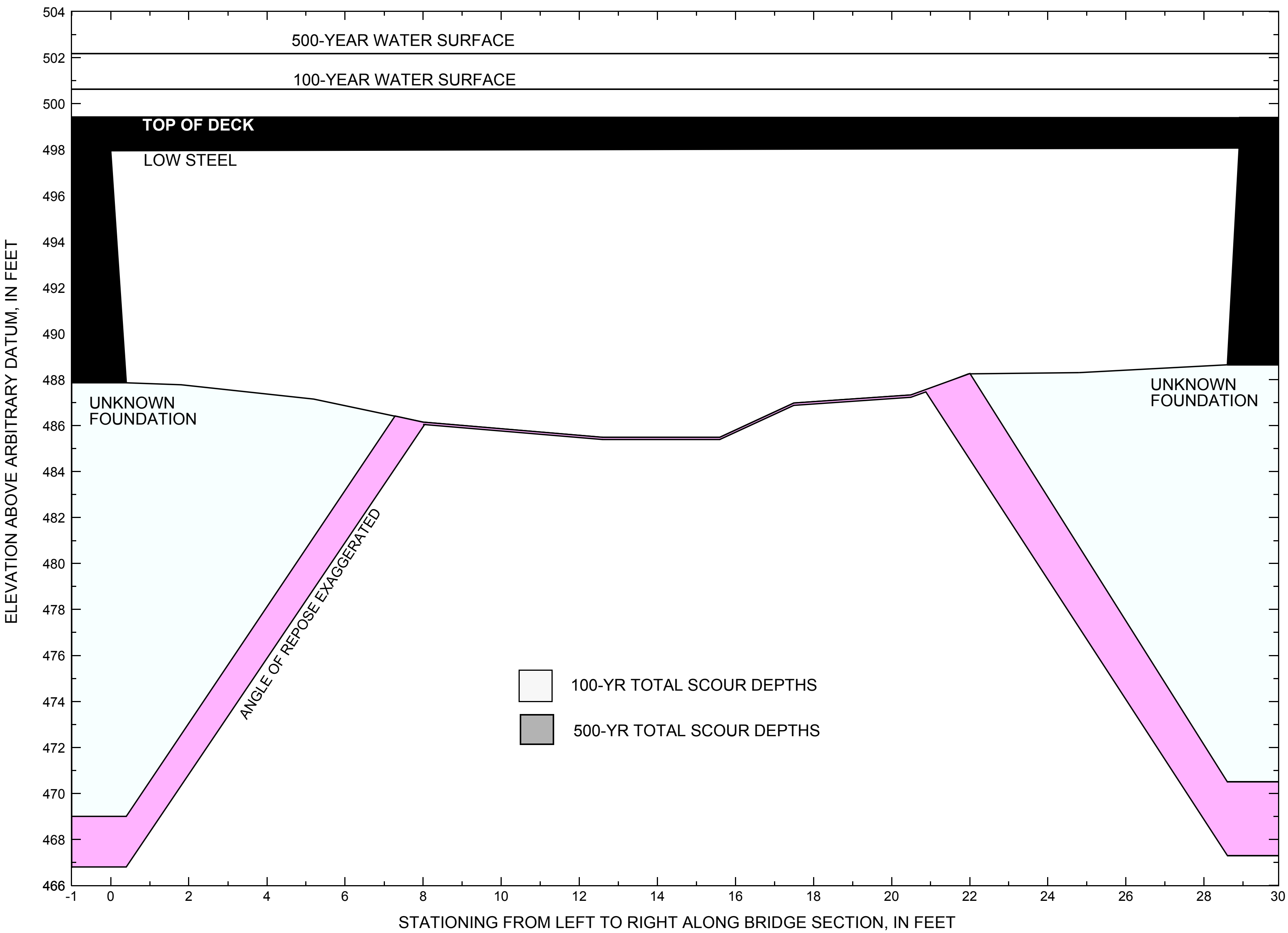


Figure 8. Scour elevations for the 100-yr and 500-yr discharges at structure FERRTH00260029 on Town Highway 26, crossing Little Otter Creek, Ferrisburg, Vermont.

Table 1. Remaining footing/pile depth at abutments for the 100-year discharge at structure FERRTH00260029 on Town Highway 26, crossing Little Otter Creek, Ferrisburg, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
100-yr. discharge is 3,430 cubic-feet per second											
Left abutment	0.0	--	498.0	--	487.9	0.0	18.9	--	18.9	469.0	--
Right abutment	28.9	--	498.1	--	488.6	0.0	18.1	--	18.1	470.5	--

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

Table 2. Remaining footing/pile depth at abutments for the 500-year discharge at structure FERRTH00260029 on Town Highway 26, crossing Little Otter Creek, Ferrisburg, Vermont.

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

Description	Station[1]	VTAOT minimum low-chord elevation (feet)	Surveyed minimum low-chord elevation[2] (feet)	Bottom of footing elevation[2] (feet)	Channel elevation at abutment/ pier[2] (feet)	Contraction scour depth (feet)	Abutment scour depth (feet)	Pier scour depth (feet)	Depth of total scour (feet)	Elevation of scour[2] (feet)	Remaining footing/pile depth (feet)
500-yr. discharge is 5,000 cubic-feet per second											
Left abutment	0.0	--	498.0	--	487.9	0.1	21.0	--	21.1	466.8	--
Right abutment	28.9	--	498.1	--	488.6	0.1	21.2	--	21.3	467.3	--

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.

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. Geological Survey, 1963, Monktonboro, Vermont 7.5 Minute Series quadrangle map: U.S. Geological Survey Topographic Maps; Photorevised 1972; Contour interval, 10 feet; Scale 1:24,000.

APPENDIX A:

WSPRO INPUT FILE

WSPRO INPUT FILE

```
T1        U.S. Geological Survey WSPRO Input File ferr029.wsp
T2        Hydraulic analysis for structure FERRTH00260029   Date: 29-MAY-97
T3        Town Highway 26 crossing of Little Otter Creek, Ferrisburg, VT    EMB
*
J1         * * 0.002
J3         6 29 30 552 553 551 5 16 17 13 3 * 15 14 23 21 11 12 4 7 3
*
Q           3430.0   5000.0   2680.0
SK          0.000988 0.000988 0.000988
*
XS   EXIT1    -46
GR          -81.0, 501.13    -60.7, 495.34    -30.3, 492.23    -16.0, 489.95
GR          -10.4, 489.55      0.0, 487.82      0.7, 486.78      7.4, 486.32
GR           17.8, 485.83     27.1, 485.89     37.2, 486.49     39.4, 487.80
GR           50.2, 489.11     57.9, 490.65     79.0, 505.57     97.0, 508.14
*
N           0.035        0.055
SA                 -10.4
*
XS   FULLV      0
GR          -81.0, 501.13    -60.7, 495.34    -30.3, 492.23    -16.0, 489.95
GR          -10.4, 489.55      0.4, 487.86      1.8, 487.77      5.2, 487.15
GR            8.0, 486.15     12.6, 485.49     15.6, 485.49     17.5, 486.98
GR           20.5, 487.33     39.4, 487.80     50.2, 489.11     57.9, 490.65
GR           79.0, 505.57     97.0, 508.14
*
N           0.035        0.055
SA                 -10.4
*
*             SRD     LSEL    XSSKEW
BR   BRIDG     0    498.01      15.0
GR            0.0, 497.95      0.4, 487.86      1.8, 487.77      5.2, 487.15
GR            8.0, 486.15     12.6, 485.49     15.6, 485.49     17.5, 486.98
GR           20.5, 487.33     21.3, 487.80     21.8, 488.26     24.8, 488.30
GR           28.6, 488.64     28.9, 498.07      0.0, 497.95
*
*         BRTYPE  BRWDTH       WWANGL    WWWID
CD           1      24.7
N           0.050
*
*             SRD    EMBWID   IPAVE
XR   RDWAY     10      15.3     2
GR         -130.4, 506.01    -50.4, 501.05      0.0, 499.42     28.7, 499.39
GR           74.1, 503.23    130.4, 509.15
*
XT   APTEM     55
GR         -105.1, 505.37    -50.9, 496.69    -18.6, 494.15    -12.2, 492.86
GR            0.0, 488.04      5.8, 487.04     11.2, 486.57     20.4, 486.66
GR           24.8, 486.70     32.6, 487.36     34.5, 487.87     49.0, 492.05
GR           71.8, 504.38     87.9, 509.93
*
AS   APPR1     47 * * * 0.026
GT
N           0.040        0.055
SA                 -12.2
*
HP 1 BRIDG 498.07 1 498.07
HP 2 BRIDG 498.07 * * 3177
HP 2 BRIDG 497.35 * * 3177
HP 2 RDWAY 500.62 * * 259
HP 1 APPR1 500.73 1 500.73
HP 2 APPR1 500.73 * * 3430
*
HP 1 BRIDG 498.07 1 498.07
HP 2 BRIDG 498.07 * * 3554
HP 2 RDWAY 502.18 * * 1447
HP 1 APPR1 502.56 1 502.56
HP 2 APPR1 502.56 * * 5000
```

APPENDIX B:

WSPRO OUTPUT FILE

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

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      302     22618      0     76                            0
  498.07           302     22618      0     76  1.00      0     29        0

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

        WSEL     LEW     REW    AREA         K        Q    VEL
      498.07     0.0    28.9   302.1    22618.    3177.  10.52

X STA.        0.0         3.0         4.6         6.1         7.3         8.5
 A(I)             27.2        17.2        15.0        13.8        13.4
 V(I)             5.85        9.23       10.60       11.47       11.83

X STA.        8.5         9.6        10.7        11.7        12.7        13.8
 A(I)             12.8        12.5        12.6        12.1        12.2
 V(I)            12.39       12.68       12.65       13.09       13.03

X STA.       13.8        14.8        15.8        16.9        18.2        19.5
 A(I)             12.1        12.5        13.2        13.4        13.6
 V(I)            13.09       12.70       12.06       11.88       11.64

X STA.       19.5        20.8        22.3        24.0        25.8        28.9
 A(I)             13.7        15.0        15.9        16.8        27.0
 V(I)            11.60       10.61        9.99        9.44        5.89

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

        WSEL     LEW     REW    AREA         K        Q    VEL
      497.35     0.0    28.9   283.7    28177.    3177.  11.20

X STA.        0.0         3.3         5.0         6.5         7.7         8.8
 A(I)             29.1        16.5        14.3        13.1        12.0
 V(I)             5.46        9.63       11.10       12.12       13.27

X STA.        8.8         9.9        10.9        11.9        12.8        13.7
 A(I)             11.6        11.1        11.1        10.7        10.8
 V(I)            13.69       14.34       14.32       14.83       14.78

X STA.       13.7        14.7        15.6        16.7        17.9        19.1
 A(I)             10.9        10.9        11.7        12.3        11.8
 V(I)            14.63       14.64       13.54       12.93       13.46

X STA.       19.1        20.4        21.9        23.5        25.4        28.9
 A(I)             12.7        13.9        14.4        16.8        28.1
 V(I)            12.52       11.44       11.01        9.46        5.65

   VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

        WSEL     LEW     REW    AREA         K        Q    VEL
      500.62   -37.1    43.2    66.1     1773.     259.   3.92

X STA.      -37.1       -19.7       -14.6       -10.9        -7.3        -4.1
 A(I)              4.9         3.3         2.9         3.3         3.3
 V(I)             2.63        3.96        4.45        3.93        3.98

X STA.       -4.1        -1.3         1.2         3.6         6.1         8.5
 A(I)              3.1         2.9         2.9         2.9         2.9
 V(I)             4.16        4.39        4.40        4.45        4.44

X STA.        8.5        10.9        13.3        15.8        18.2        20.7
 A(I)              2.9         2.9         3.0         3.0         3.0
 V(I)             4.41        4.40        4.34        4.37        4.28

X STA.       20.7        23.2        25.8        28.5        31.8        43.2
 A(I)              3.1         3.2         3.3         3.7         5.5
 V(I)             4.18        4.11        3.97        3.47        2.35

   CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      47.

    WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
            1      282     27742     65     66                         3330
            2      843    108227     78     82                        15749
  500.73          1125    135969    143    147  1.03    -76     65    17613

   VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      47.

        WSEL     LEW     REW    AREA         K        Q    VEL
      500.73   -77.4    65.4  1124.6  135969.    3430.   3.05

X STA.      -77.4       -42.5       -29.8       -20.4       -12.8        -6.3
 A(I)             94.6        68.9        59.3        54.5        59.9
 V(I)             1.81        2.49        2.89        3.15        2.86

X STA.       -6.3        -1.6         2.1         5.5         8.7        11.9
 A(I)             53.0        47.3        46.6        44.4        45.2
 V(I)             3.24        3.63        3.68        3.86        3.79

X STA.       11.9        14.9        18.1        21.3        24.6        28.0
 A(I)             44.2        45.5        45.3        46.7        47.9
 V(I)             3.88        3.77        3.79        3.67        3.58

X STA.       28.0        31.5        35.5        40.2        46.6        65.4
 A(I)             48.8        52.8        57.7        67.0        95.2
 V(I)             3.52        3.25        2.97        2.56        1.80
```

```
     U.S. Geological Survey WSPRO Input File ferr029.wsp
     Hydraulic analysis for structure FERRTH00260029   Date: 29-MAY-97
     Town Highway 26 crossing of Little Otter Creek, Ferrisburg, VT    EMB
        *** RUN DATE & TIME: 07-24-97  07:21

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

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      302     22618      0     76                            0
498.07           302     22618      0     76  1.00      0     29        0

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

      WSEL     LEW     REW    AREA        K        Q    VEL
    498.07     0.0    28.9   302.1   22618.    3554.  11.76

X STA.        0.0        3.0        4.6        6.1        7.3        8.5
  A(I)           27.2       17.2       15.0       13.8       13.4
  V(I)           6.54      10.32      11.85      12.83      13.23

X STA.        8.5        9.6       10.7       11.7       12.7       13.8
  A(I)           12.8       12.5       12.6       12.1       12.2
  V(I)          13.86      14.18      14.15      14.64      14.58

X STA.       13.8       14.8       15.8       16.9       18.2       19.5
  A(I)           12.1       12.5       13.2       13.4       13.6
  V(I)          14.64      14.21      13.49      13.29      13.02

X STA.       19.5       20.8       22.3       24.0       25.8       28.9
  A(I)           13.7       15.0       15.9       16.8       27.0
  V(I)          12.98      11.86      11.17      10.56       6.59

 VELOCITY DISTRIBUTION:  ISEQ =  4;  SECID = RDWAY;  SRD =      10.

      WSEL     LEW     REW    AREA        K        Q    VEL
    502.18   -68.6    61.7   234.0   11136.    1447.   6.18

X STA.      -68.6      -44.8      -36.6      -30.3      -25.0      -20.6
  A(I)           17.1       11.9       10.5        9.9        9.0
  V(I)           4.22       6.08       6.87       7.33       8.07

X STA.      -20.6      -16.6      -12.9       -9.4       -4.9       -0.9
  A(I)            8.6        8.3        8.6       11.2       10.8
  V(I)           8.37       8.76       8.41       6.43       6.70

X STA.       -0.9        3.0        6.9       10.9       14.9       18.9
  A(I)           10.8       10.8       10.9       11.1       11.2
  V(I)           6.72       6.70       6.62       6.52       6.49

X STA.       18.9       23.1       27.3       32.1       38.7       61.7
  A(I)           11.7       11.7       12.8       14.8       22.3
  V(I)           6.17       6.21       5.65       4.89       3.24

 CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      47.

  WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
          1      412     46794     77     77                         5419
          2      988    136794     81     85                        19568
502.56          1400    183588    158    163  1.02    -88     69    23408

 VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      47.

      WSEL     LEW     REW    AREA        K        Q    VEL
    502.56   -88.9    68.8  1399.6  183588.    5000.   3.57

X STA.      -88.9      -50.4      -37.7      -28.1      -19.8      -12.8
  A(I)          118.6       83.8       72.1       67.7       63.9
  V(I)           2.11       2.98       3.47       3.69       3.91

X STA.      -12.8       -6.3       -1.5        2.5        6.2        9.7
  A(I)           71.2       63.4       59.2       56.2       56.0
  V(I)           3.51       3.94       4.22       4.45       4.46

X STA.        9.7       13.2       16.6       20.1       23.7       27.4
  A(I)           56.0       56.0       56.5       57.2       59.8
  V(I)           4.46       4.46       4.42       4.37       4.18

X STA.       27.4       31.4       35.7       40.9       47.6       68.8
  A(I)           62.5       64.4       72.4       80.5      121.8
  V(I)           4.00       3.88       3.45       3.11       2.05
```

```
        U.S. Geological Survey WSPRO Input File ferr029.wsp
        Hydraulic analysis for structure FERRTH00260029   Date: 29-MAY-97
        Town Highway 26 crossing of Little Otter Creek, Ferrisburg, VT    EMB
           *** RUN DATE & TIME: 07-24-97  07:21

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

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      232     21260     28     43                          3799
   495.48           232     21260     28     43  1.00      0     29     3799

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

         WSEL     LEW     REW    AREA        K        Q    VEL
       495.48     0.1    28.8   231.7   21260.    2680.  11.57

X STA.         0.1         3.3         5.0         6.4         7.6         8.8
  A(I)            22.5        13.3        11.9        10.7        10.1
  V(I)            5.95       10.07       11.25       12.51       13.31

X STA.         8.8         9.8        10.8        11.7        12.7        13.6
  A(I)             9.4         9.5         8.9         8.9         9.0
  V(I)           14.30       14.18       15.05       15.02       14.93

X STA.        13.6        14.5        15.4        16.5        17.7        18.9
  A(I)             8.9         8.9         9.7        10.4        10.0
  V(I)           15.03       15.03       13.79       12.89       13.43

X STA.        18.9        20.2        21.8        23.5        25.4        28.8
  A(I)            10.3        11.8        11.8        13.5        22.1
  V(I)           12.98       11.31       11.31        9.95        6.06

    CROSS-SECTION PROPERTIES:  ISEQ =  5;  SECID = APPR1;  SRD =      47.

     WSEL  SA#     AREA         K   TOPW   WETP  ALPH    LEW    REW      QCR
             1      132      9522     49     49                          1235
             2      645     72607     73     76                         10889
   498.10           777     82130    122    125  1.06    -60     61    10839

    VELOCITY DISTRIBUTION:  ISEQ =  5;  SECID = APPR1;  SRD =      47.

         WSEL     LEW     REW    AREA        K        Q    VEL
       498.10   -61.0    60.6   776.9   82130.    2680.   3.45

X STA.       -61.0       -27.2       -14.7        -7.2        -2.6         1.0
  A(I)            68.5        50.5        45.1        38.8        35.1
  V(I)            1.96        2.65        2.97        3.46        3.82

X STA.         1.0         4.0         6.9         9.6        12.2        14.8
  A(I)            33.1        32.1        30.5        30.8        30.8
  V(I)            4.05        4.18        4.39        4.36        4.35

X STA.        14.8        17.5        20.2        22.9        25.6        28.5
  A(I)            31.1        31.1        31.4        32.3        33.0
  V(I)            4.30        4.31        4.27        4.14        4.06

X STA.        28.5        31.6        35.0        39.2        44.7        60.6
  A(I)            34.4        36.4        40.6        45.4        66.0
  V(I)            3.90        3.69        3.30        2.95        2.03
```

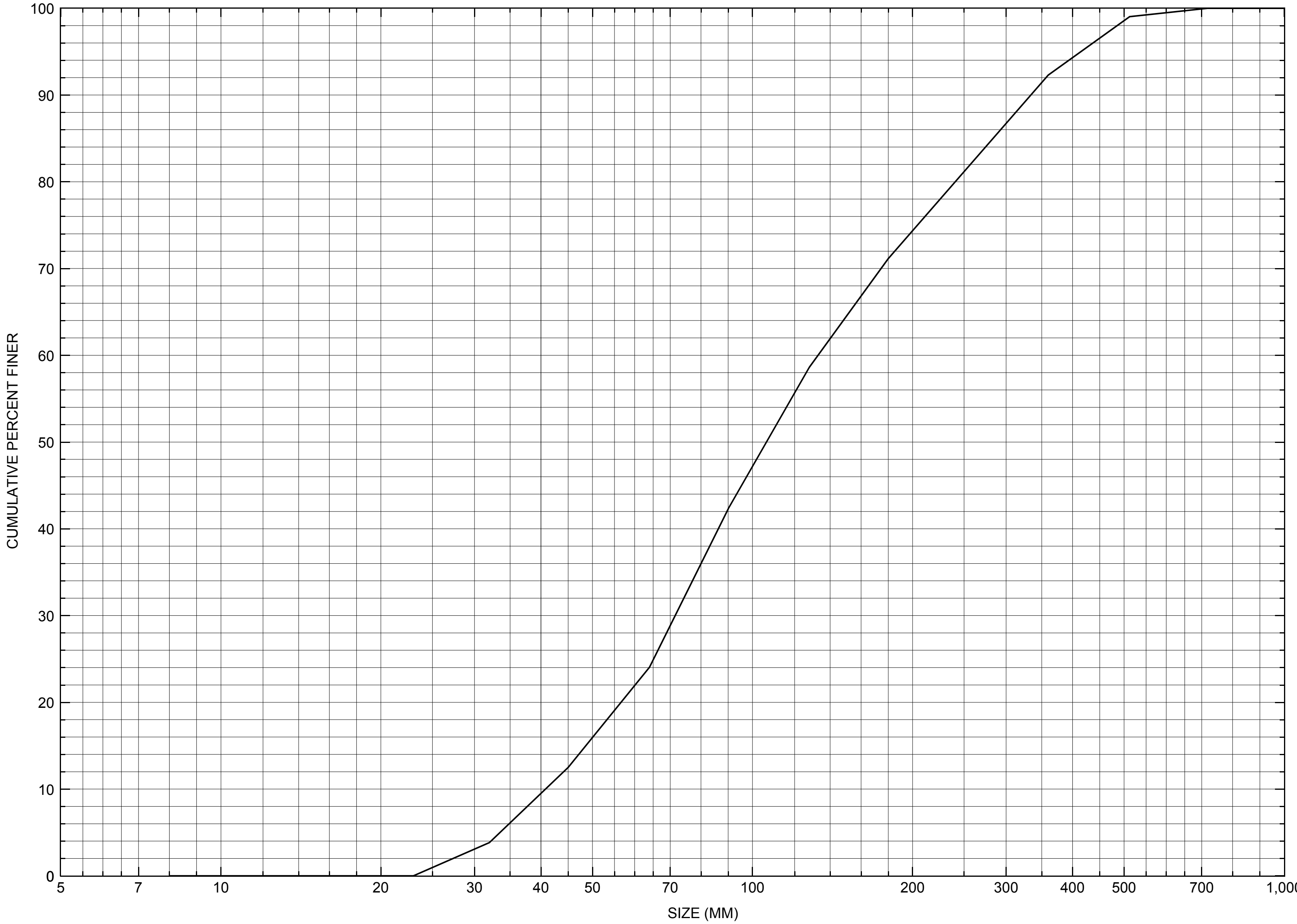
```
        U.S. Geological Survey WSPRO Input File ferr029.wsp
        Hydraulic analysis for structure FERRTH00260029   Date: 29-MAY-97
        Town Highway 26 crossing of Little Otter Creek, Ferrisburg, VT    EMB
           *** RUN DATE & TIME: 07-24-97  07:21

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

EXIT1:XS   ******    -67      955  0.20 *****  497.50  491.71    3430  497.30
       -45 ******     67   109055  1.00 ***** *******    0.24    3.59

FULLV:FV       46    -67      928  0.21  0.05  497.56 *******    3430  497.35
         0     46     67   103893  1.00  0.01    0.00    0.25    3.70
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                            "APPR1"     KRATIO =  0.67

APPR1:AS       47    -55      685  0.42  0.08  497.74 *******    3430  497.32
        47     47     59    69283  1.06  0.10    0.00    0.37    5.01
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===215 FLOW CLASS 1 SOLUTION INDICATES POSSIBLE ROAD OVERFLOW.
           WS1,WSSD,WS3,RGMIN =   499.82       0.00     496.34     499.39

 ===260 ATTEMPTING FLOW CLASS 4 SOLUTION.

 ===220 FLOW CLASS 1 (4) SOLUTION INDICATES POSSIBLE PRESSURE FLOW.
           WS3,WSIU,WS1,LSEL =   496.38     499.67     499.77     498.01

 ===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       46      0      302  1.72 *****  499.79  494.55    3177  498.07
         0 ******     29    22618  1.00 ***** *******    0.57   10.52

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   5.  0.463  0.000  498.01 ****** ****** ******

   XSID:CODE     SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    32.  0.02  0.15  500.86    0.00    259.  500.62

              Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    149.    51.   -37.    14.   1.2   0.8   4.4   3.9   1.0   2.9
   RT:    109.    29.    14.    43.   1.2   0.9   4.8   4.0   1.2   2.9

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

APPR1:AS       22    -76     1125  0.15  0.09  500.88  492.78    3430  500.73
        47     25     65   136019  1.03  0.47    0.00    0.19    3.05

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q         K     AREA     VEL    WSEL
   EXIT1:XS     -46.   -68.    67.   3430.  109055.     955.    3.59  497.30
   FULLV:FV       0.   -68.    67.   3430.  103893.     928.    3.70  497.35
   BRIDG:BR       0.     0.    29.   3177.   22618.     302.   10.52  498.07
   RDWAY:RG      10.*******   149.    259.******************    2.00  500.62
   APPR1:AS      47.   -77.    65.   3430.  136019.    1125.    3.05  500.73

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS  ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE     CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS     491.71    0.24  485.83  508.14************  0.20  497.50  497.30
   FULLV:FV   ********    0.25  485.49  508.14  0.05  0.01  0.21  497.56  497.35
   BRIDG:BR     494.55    0.57  485.49  498.07************  1.72  499.79  498.07
   RDWAY:RG   ***************  499.39  509.15  0.02******  0.15  500.86  500.62
   APPR1:AS     492.78    0.19  486.36  509.72  0.09  0.47  0.15  500.88  500.73
```

```
        U.S. Geological Survey WSPRO Input File ferr029.wsp
        Hydraulic analysis for structure FERRTH00260029   Date: 29-MAY-97
        Town Highway 26 crossing of Little Otter Creek, Ferrisburg, VT    EMB
           *** RUN DATE & TIME: 07-24-97  07:21

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

EXIT1:XS   ******    -73     1227  0.26 *****  499.51  492.88    5000  499.25
       -45 ******     70   159002  1.00 ***** *******    0.25    4.07

FULLV:FV       46    -74     1200  0.27  0.05  499.57 *******    5000  499.29
         0     46     70   153372  1.00  0.01    0.00    0.26    4.16
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPR1"     KRATIO =  0.68

APPR1:AS       47    -67      924  0.48  0.07  499.74 *******    5000  499.26
        47     47     63   103890  1.05  0.10    0.00    0.37    5.41
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===255 ATTEMPTING FLOW CLASS 3 (6) SOLUTION.
                        WS3N,LSEL =    499.29     498.01

            <<<<<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       46      0      302  2.15 *****  500.22  495.13    3554  498.07
         0 ******     29    22618  1.00 ***** *******    0.64   11.76

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   6.  0.800  0.000  498.01 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.    32.  0.02  0.20  502.74    0.00   1447.  502.18

            Q   WLEN    LEW    REW  DMAX  DAVG  VMAX  VAVG  HAVG  CAVG
   LT:    904.    82.   -69.    14.   2.8   1.8   7.0   6.2   2.3   3.1
   RT:    543.    48.    14.    62.   2.8   1.8   7.1   6.2   2.4   3.1

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

APPR1:AS       22    -88     1400  0.20  0.11  502.77  494.22    5000  502.56
        47     26     69   183683  1.02  0.47    0.00    0.21    3.57

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

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -46.   -74.    70.   5000.  159002.    1227.    4.07  499.25
   FULLV:FV       0.   -75.    70.   5000.  153372.    1200.    4.16  499.29
   BRIDG:BR       0.     0.    29.   3554.   22618.     302.   11.76  498.07
   RDWAY:RG      10.*******   904.   1447.******************    2.00  502.18
   APPR1:AS      47.   -89.    69.   5000.  183683.    1400.    3.57  502.56

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS   ***********************

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO   VHD     EGL    WSEL
   EXIT1:XS    492.88    0.25  485.83  508.14************  0.26  499.51  499.25
   FULLV:FV  ********    0.26  485.49  508.14  0.05  0.01  0.27  499.57  499.29
   BRIDG:BR    495.13    0.64  485.49  498.07************  2.15  500.22  498.07
   RDWAY:RG  ****************  499.39  509.15  0.02******  0.20  502.74  502.18
   APPR1:AS    494.22    0.21  486.36  509.72  0.11  0.47  0.20  502.77  502.56
```

```
        U.S. Geological Survey WSPRO Input File ferr029.wsp
        Hydraulic analysis for structure FERRTH00260029   Date: 29-MAY-97
        Town Highway 26 crossing of Little Otter Creek, Ferrisburg, VT    EMB
           *** RUN DATE & TIME: 07-24-97  07:21

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

EXIT1:XS   ******    -63      811  0.17 *****  496.38  491.08    2680  496.21
       -45 ******     66    85189  1.01 ***** *******    0.23    3.30

FULLV:FV       46    -63      784  0.18  0.05  496.44 *******    2680  496.26
         0     46     66    80322  1.00  0.01    0.00    0.25    3.42
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

 ===135 CONVEYANCE RATIO OUTSIDE OF RECOMMENDED LIMITS.
                           "APPR1"     KRATIO =  0.67

APPR1:AS       47    -47      565  0.37  0.08  496.61 *******    2680  496.24
        47     47     57    53781  1.06  0.10    0.00    0.37    4.75
         <<<<<THE ABOVE RESULTS REFLECT "NORMAL" (UNCONSTRICTED) FLOW>>>>>

            <<<<<RESULTS REFLECTING THE CONSTRICTED FLOW FOLLOW>>>>>

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

BRIDG:BR       46      0      232  2.32  0.18  497.80  493.74    2680  495.48
         0     46     29    21254  1.11  1.23    0.00    0.75   11.57

     TYPE PPCD FLOW      C    P/A    LSEL   BLEN   XLAB   XRAB
       1. ****   1.  0.947 ******  498.01 ****** ****** ******

    XSID:CODE    SRD   FLEN    HF   VHD     EGL     ERR       Q    WSEL
   RDWAY:RG      10.        <<<<<EMBANKMENT IS NOT OVERTOPPED>>>>>

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

APPR1:AS       22    -60      777  0.20  0.10  498.29  492.03    2680  498.10
        47     25     61    82083  1.06  0.39    0.01    0.25    3.45

       M(G)   M(K)       KQ   XLKQ   XRKQ    OTEL
      0.726  0.446   45392.     3.    32.   498.06

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

  FIRST USER DEFINED TABLE.

    XSID:CODE    SRD    LEW    REW       Q        K     AREA     VEL    WSEL
   EXIT1:XS     -46.   -64.    66.   2680.   85189.     811.    3.30  496.21
   FULLV:FV       0.   -64.    66.   2680.   80322.     784.    3.42  496.26
   BRIDG:BR       0.     0.    29.   2680.   21254.     232.   11.57  495.48
   RDWAY:RG      10.**************      0.******************    2.00********
   APPR1:AS      47.   -61.    61.   2680.   82083.     777.    3.45  498.10

    XSID:CODE   XLKQ   XRKQ       KQ
   APPR1:AS       3.    32.   45392.

 SECOND USER DEFINED TABLE.

    XSID:CODE    CRWS     FR#    YMIN    YMAX    HF    HO  VHD      EGL    WSEL
   EXIT1:XS    491.08    0.23  485.83  508.14************  0.17  496.38  496.21
   FULLV:FV  ********    0.25  485.49  508.14  0.05  0.01  0.18  496.44  496.26
   BRIDG:BR    493.74    0.75  485.49  498.07  0.18  1.23  2.32  497.80  495.48
   RDWAY:RG  ***************  499.39  509.15**********************************
   APPR1:AS    492.03    0.25  486.36  509.72  0.10  0.39  0.20  498.29  498.10
  ER

 NORMAL  END  OF  WSPRO  EXECUTION.
```

APPENDIX C:

BED-MATERIAL PARTICLE-SIZE DISTRIBUTION



Appendix C. Bed material particle-size distribution for a pebble count in the channel approach of structure FERRTH00260029, in Ferrisburg, Vermont.

APPENDIX D:

HISTORICAL DATA FORM

United States Geological Survey
Bridge Historical Data Collection and Processing Form

Structure Number FERRTH00260029

General Location Descriptive

Data collected by (First Initial, Full last name) R. BURNS

Date (MM/DD/YY) 06 / 14 / 96

Highway District Number (I - 2; nn) 05

County (FIPS county code; I - 3; nnn) 001

Town (FIPS place code; I - 4; nnnnn) 26275

Mile marker (I - 11; nnn.nnn) 0000

Waterway (I - 6) Little Otter Creek

Road Name (I - 7): -

Route Number TH 26

Vicinity (I - 9) 0.82 mi to jct w CL3 TH35

Topographic Map Monktonboro

Hydrologic Unit Code: 02010002

Latitude (I - 16; nnnn.n) 44121

Longitude (i - 17; nnnnn.n) 73115

Select Federal Inventory Codes

FHWA Structure Number (I - 8) 10010500290105

Maintenance responsibility (I - 21; nn) 03

Maximum span length (I - 48; nnnn) 0031

Year built (I - 27; YYYY) 1919

Structure length (I - 49; nnnnnn) 000033

Average daily traffic, ADT (I - 29; nnnnnn) 000020

Deck Width (I - 52; nn.n) 153

Year of ADT (I - 30; YY) 92

Channel & Protection (I - 61; n) 5

Opening skew to Roadway (I - 34; nn) 13

Waterway adequacy (I - 71; n) 5

Operational status (I - 41; X) P

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

Structure type (I - 43; nnn) 302

Year Reconstructed (I - 106) 0000

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

Clear span (nnn.n ft) 0290

Number of spans (I - 45; nnn) 001

Vertical clearance from streambed (nnn.n ft) 0123

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

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

Comments:

According to the structural inspection report dated 11/3/94, this is a steel stringer type bridge with a timber deck, concrete abutments, and short wingwalls parallel with the abutment walls. Both abutments and wingwalls have widespread concrete spalls and random cracks. The top of the left abutment wall has tipped toward the stream about 3 inches for every vertical 4 feet. The backwalls are laid-up stone. There is heavy stone fill at each end of the right abutment and small stone fill along the banks. There is some stone fill in front of the left abutment. Some bank erosion is noted on the downstream right bank.

Bridge Hydrologic Data

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

Terrain character: -

Stream character & type: -

Streambed material: -

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

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

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

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

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

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

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

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

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

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

Water Surface Elevation Estimates for Existing Structure:

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

Long term stream bed changes: -

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

Relief Elevation (*ft*): - Discharge over roadway at Q_{100} (*ft^3/ sec*): -

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

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

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

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

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

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

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

Comments:

-

USGS Watershed Data

Watershed Hydrographic Data

Drainage area *(DA)* **37.896** mi^2

Lake/pond/swamp area **1.35** mi^2

Watershed storage *(ST)* **3.56** %

Bridge site elevation **170** ft

Headwater elevation **900** ft

Main channel length **13.779** mi

10% channel length elevation **225** ft

85% channel length elevation **445** ft

Main channel slope *(S)* **21.29** 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 BENCKMARK 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:

There were no plans available for this site.

Cross-sectional Data

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

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

Comments: **This cross section is the upstream face. The low chord data is from the survey log done for this report on 6/20/96. The low chord to bed length data are from the sketch attached to the bridge inspection report dated 11/3/94. The sketch was done on 10/14/92.**

Station	0	7.1	15	24.3	29	-	-	-	-	-	-
Feature	LAB	-	-	-	RAB	-	-	-	-	-	-
Low chord elevation	498.0	498.0	498.0	498.0	498.0	-	-	-	-	-	-
Bed elevation	489.7	487.2	485.7	487.1	488.2	-	-	-	-	-	-
Low chord - bed length	8.3	10.8	12.3	10.9	9.8	-	-	-	-	-	-

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

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

Comments:

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

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

APPENDIX E:

LEVEL I DATA FORM

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

Qa/Qc Check by: MS Date: 07/03/97
Computerized by: MS Date: 07/07/97
Reviewd by: EMB Date: 12/15/97

Structure Number FERRTH00260029

A. General Location Descriptive

1. Data collected by *(First Initial, Full last name)* R. FLYNN Date *(MM/DD/YY)* 6 / 20 / 1996
2. Highway District Number 05 Mile marker 000000
County ADDISON (001) Town FERRISBURG (26275)
Waterway *(I - 6)* Little Otter Creek Road Name -
Route Number TH026 Hydrologic Unit Code: 02010002
3. Descriptive comments:
This structure is located 0.82 miles from the junction with Town Highway 35.

B. Bridge Deck Observations

4. Surface cover... LBUS 4 RBUS 6 LBDS 4 RBDS 4 Overall 4
*(2b us,ds,lb,rb: **1**- Urban; **2**- Suburban; **3**- Row crops; **4**- Pasture; **5**- Shrub- and brushland; **6**- Forest; **7**- Wetland)*
5. Ambient water surface... US 2 UB 1 DS 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 33 *(feet)* Span length 31 *(feet)* Bridge width 15.3 *(feet)*

Road approach to bridge:

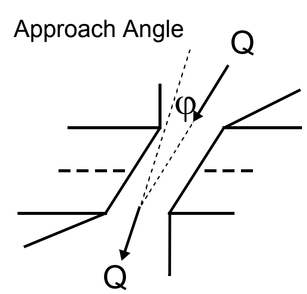
8. LB 2 RB 2 *(**0** even, **1**- lower, **2**- higher)*
9. LB 2 RB 2 *(**1**- Paved, **2**- Not paved)*
10. Embankment slope (*run / rise in feet / foot*):
US left - US right -

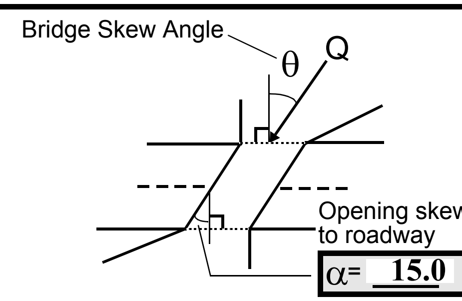
	Protection			
	11.Type	12.Cond.	13.Erosion	14.Severity
LBUS	1	3	2	1
RBUS	1	1	2	2
RBDS	1	1	2	1
LBDS	1	3	2	2

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

Channel approach to bridge (BF):

15. Angle of approach: 15 16. Bridge skew: 10





17. Channel impact zone 1: Exist? Y *(Y or N)*
Where? LB *(LB, RB)* Severity 1
Range? 28 feet US *(US, UB, DS)* to 55 feet US
Channel impact zone 2: Exist? Y *(Y or N)*
Where? RB *(LB, RB)* Severity 1
Range? 25 feet DS *(US, UB, DS)* to 150 feet DS

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

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

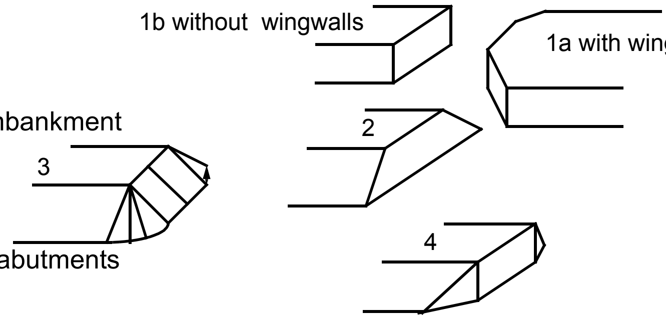
1a- Vertical abutments with wingwalls

1b- Vertical abutments without wingwalls

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

3- Spill through abutments

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



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

The bridge dimensions on the previous page are those available from the VTAOT database. Measurements made in this field assessment include a bridge length of 33 feet, a span length of 27.5 feet, and a bridge width of 15.3 feet.

The bridge opening is mixed as the right abutment has wingwalls (1a) and the left abutment does not have wingwalls (1b).

The left roadway embankments, upstream and downstream, have protection along the bank up to the roadway with large rocks (less than 36 inches) at the water's edge and along the abutment. The right roadway embankments have protection along the bank behind the wingwalls and larger rocks (<36 inches) along the face of the wingwalls and abutment.

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
39.5	**6.0**			**4.0**	**1**	**2**	**24**	**24**	**1**	**1**

23. Bank width **20.0** 24. Channel width **15.0** 25. Thalweg depth **67.5** 29. Bed Material **452**

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

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

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

-

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

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

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
34.5		1.5		2	7	7	-

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

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

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

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

452

The bed material is primarily cobbles, but along the right abutment the material is primarily placed boulders. There is scour evident under the bridge. The scour hole length is approximately 20 ft. while the width is approximately 10 ft. The hole is as much as 1.5 feet deeper than the average thalweg depth in the reach.

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 1____ *(1- Low; 2- Moderate; 3- High)*

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

70. Debris and Ice Comments:

1

-

Abutments	71. Attack ∠(BF)	72. Slope ∠ (Qmax)	73. Toe loc. (BF)	74. Scour Condition	75. Scour depth	76. Exposure depth	77. Material	78. Length
LABUT		-	90	0	1	0.5	-	90.0
RABUT	1	10	90			2	2	28.0

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

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

0

-

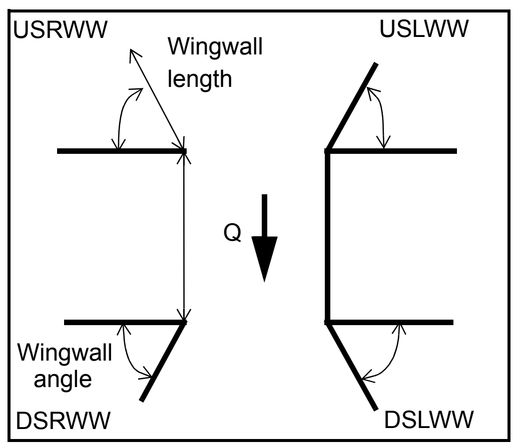
1

Scour is evident at the US corner of the left abutment. The abutment is undermined vertically about 0.5 feet for a distance of 2 feet along the abutment from the upstream end.

80. **Wingwalls**:

	Exist?	Material?	Scour Condition?	Scour depth?	Exposure depth?	81. Angle?	Length?
USLWW:						28.0	
USRWW:	N		-		-	2.5	
DSLWW:	-		-		Y	18.5	
DSRWW:	1		0		-	20.0	

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	-	-	Y	-	-	1	-	1
Condition	N	-	1	-	-	1	-	1
Extent	-	-	0	-	2	0	2	-

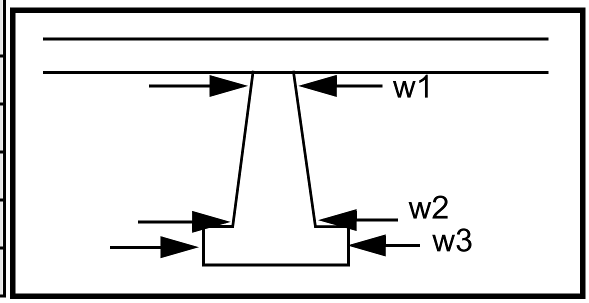
Bank / Bridge protection types: 0- absent; 1- < 12 inches; 2- < 36 inches; 3- < 48 inches; 4- < 60 inches; 5- wall / artificial levee
Bank / Bridge protection conditions: 1- good; 2- slumped; 3- eroded; 4- failed
Protection extent: 1- entire base length; 2- US end; 3- DS end; 4- other

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

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	-			-	75.0	12.0
Pier 2	-			-	55.0	13.0
Pier 3	-	-	-	-	-	-
Pier 4	-	-	-	-	-	-



Level 1 Pier Descr.	1	2	3	4	
86. Location (BF)	e left	the DS	inches	ply	*LFP, LTB, LB, MCL, MCM, MCR, RB, RTB, RFP*
87. Type	abut	end	in	ade-	***1**- Solid pier, **2**- column, **3**- bent*
88. Material	ment	of	diam	quat	***1**- Wood; **2**- concrete; **3**- metal; **4**- stone*
89. Shape	has	the	eter.	e	***1**- Round; **2**- Square; **3**- Pointed*
90. Inclined?	appr	abut	It	pro-	*Y- yes; N- no*
91. Attack ∠ (BF)	oxi-	ment	appe	tec-	
92. Pushed	mate	,	ars	tion	*LB or RB*
93. Length (feet)	-	-	-	-	
94. # of piles	ly 10	whic	that	agai	
95. Cross-members	rock	h are	they	nst	***0**- none; **1**- laterals; **2**- diagonals; **3**- both*
96. Scour Condition	s	less	woul	unde	***0**- not evident; **1**- evident (comment); **2**- footing exposed; **3**- piling exposed; **4**- undermined footing; **5**- settled; **6**- failed*
97. Scour depth	locat	than	d not	rmin	
98. Exposure depth	ed at	36	sup-	ing	

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

at the base of the abutment during a flood event.

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: 1

Scour dimensions: Length 1 Width 234 Depth: 234 Positioned 2 %LB to 2 %RB

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

452
0
0
-

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

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:	FERRTH00260029	Town:	Ferrisburg
Road Number:	TH 26	County:	Addison
Stream:	Little Otter Creek		

Initials EMB   Date: 7/24/97 Checked: RHF

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	3430	5000	2680
Main Channel Area, ft2	843	988	645
Left overbank area, ft2	282	412	132
Right overbank area, ft2	0	0	0
Top width main channel, ft	78	81	73
Top width L overbank, ft	65	77	49
Top width R overbank, ft	0	0	0
D50 of channel, ft	0.3485	0.3485	0.3485
D50 left overbank, ft	--	--	--
D50 right overbank, ft	--	--	--
y1, average depth, MC, ft	10.8	12.2	8.8
y1, average depth, LOB, ft	4.3	5.4	2.7
y1, average depth, ROB, ft	ERR	ERR	ERR
Total conveyance, approach	135969	183588	82130
Conveyance, main channel	108227	136794	72607
Conveyance, LOB	27742	46794	9522
Conveyance, ROB	0	0	0
Percent discrepancy, conveyance	0.0000	0.0000	0.0012
Qm, discharge, MC, cfs	2730.2	3725.6	2369.3
Ql, discharge, LOB, cfs	699.8	1274.4	310.7
Qr, discharge, ROB, cfs	0.0	0.0	0.0
Vm, mean velocity MC, ft/s	3.2	3.8	3.7
Vl, mean velocity, LOB, ft/s	2.5	3.1	2.4
Vr, mean velocity, ROB, ft/s	ERR	ERR	ERR
Vc-m, crit. velocity, MC, ft/s	11.7	12.0	11.3
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

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	3177	3554	2680
Main channel area (DS), ft2	284	302	232
Main channel width (normal), ft	27.9	27.9	27.7
Cum. width of piers, ft	0.0	0.0	0.0
Adj. main channel width, ft	27.9	27.9	27.7
D90, ft	1.0964	1.0964	1.0964
D95, ft	1.3598	1.3598	1.3598
Dc, critical grain size, ft	0.5640	0.6083	0.6542
Pc, Decimal percent coarser than Dc	0.305	0.280	0.258
Depth to armoring, ft	3.86	4.69	5.64

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	3430	5000	2680
(Q) discharge thru bridge, cfs	3177	3554	2680
Main channel conveyance	22618	22618	21260
Total conveyance	22618	22618	21260
Q2, bridge MC discharge,cfs	3177	3554	2680
Main channel area, ft2	302	302	232
Main channel width (normal), ft	27.9	27.9	27.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	27.9	27.9	27.7
y_bridge (avg. depth at br.), ft	10.82	10.82	8.38
Dm, median (1.25*D50), ft	0.435625	0.435625	0.435625
y2, depth in contraction,ft	9.09	10.00	7.90
ys, scour depth (y2-ybridge), ft	-1.74	-0.82	-0.47

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	3430	5000	2680
Q, thru bridge MC, cfs	3177	3554	2680
Vc, critical velocity, ft/s	11.73	11.97	11.34
Va, velocity MC approach, ft/s	3.24	3.77	3.67
Main channel width (normal), ft	27.9	27.9	27.7
Cum. width of piers in MC, ft	0.0	0.0	0.0
W, adjusted width, ft	27.9	27.9	27.7
qbr, unit discharge, ft2/s	113.9	127.4	96.8
Area of full opening, ft2	302.0	302.0	232.0
Hb, depth of full opening, ft	10.82	10.82	8.38
Fr, Froude number, bridge MC	0.57	0.64	0
Cf, Fr correction factor (<=1.0)	1.00	1.00	0.00
**Area at downstream face, ft2	284	N/A	N/A
**Hb, depth at downstream face, ft	10.18	N/A	N/A
**Fr, Froude number at DS face	0.62	ERR	ERR
**Cf, for downstream face (<=1.0)	1.00	N/A	N/A
Elevation of Low Steel, ft	498.01	498.01	0
Elevation of Bed, ft	487.19	487.19	-8.38
Elevation of Approach, ft	500.73	502.56	0
Friction loss, approach, ft	0.09	0.11	0
Elevation of WS immediately US, ft	500.64	502.45	0.00
ya, depth immediately US, ft	13.45	15.26	8.38
Mean elevation of deck, ft	499.4	499.4	0
w, depth of overflow, ft (>=0)	1.24	3.05	0.00
Cc, vert contrac correction (<=1.0)	0.97	0.97	1.00
**Cc, for downstream face (<=1.0)	0.955342	ERR	ERR
Ys, scour w/Chang equation, ft	-0.82	0.14	N/A
Ys, scour w/Umbrell equation, ft	-4.39	-3.50	N/A

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

**Ys, scour w/Chang equation, ft	-0.02	N/A	N/A
**Ys, scour w/Umbrell equation, ft	-3.74	N/A	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	9.09	10.00	7.90
WSEL at downstream face, ft	497.35	--	--
Depth at downstream face, ft	10.18	N/A	N/A
Ys, depth of scour (Laursen), ft	-1.09	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)

Characteristic	Left Abutment 100 yr Q	500 yr Q	Other Q	Right Abutment 100 yr Q	500 yr Q	Other Q
(Qt), total discharge, cfs	3430	5000	2680	3430	5000	2680
a', abut.length blocking flow, ft	77.9	89.4	61.6	37	40.4	32.3
Ae, area of blocked flow ft2	394.7	461.9	234.1	307.2	386	225.1
Qe, discharge blocked abut.,cfs	--	--	655.1	--	--	679.2
(If using Qtotal_overbank to obtain Ve, leave Qe blank and enter Ve and Fr manually)						
Ve, (Qe/Ae), ft/s	2.70	3.29	2.80	2.65	3.08	3.02
ya, depth of f/p flow, ft	5.07	5.17	3.80	8.30	9.55	6.97
--Coeff., K1, for abut. type (1.0, verti.; 0.82, verti. w/ wingwall; 0.55, spillthru)						
K1	1	1	1	0.82	0.82	0.82
--Angle (theta) of embankment (<90 if abut. points DS; >90 if abut. points US)						
theta	75	75	75	105	105	105
K2	0.98	0.98	0.98	1.02	1.02	1.02
Fr, froude number f/p flow	0.206	0.229	0.253	0.160	0.175	0.201
ys, scour depth, ft	18.94	21.05	15.87	18.11	21.20	16.60

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)	77.9	89.4	61.6	37	40.4	32.3
y1 (depth f/p flow, ft)	5.07	5.17	3.80	8.30	9.55	6.97
a'/y1	15.37	17.30	16.21	4.46	4.23	4.63
Skew correction (p. 49, fig. 16)	0.95	0.95	0.95	1.03	1.03	1.03
Froude no. f/p flow	0.21	0.23	0.25	0.16	0.18	0.20
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	0.62	0.64	0.75	0.62	0.64	0.75
y, depth of flow in bridge, ft	10.18	10.82	8.38	10.18	10.82	8.38
Median Stone Diameter for riprap at: left abutment				right abutment, ft		
Fr<=0.8 (vertical abut.)	2.42	2.74	2.91	2.42	2.74	2.91
Fr>0.8 (vertical abut.)	ERR	ERR	ERR	ERR	ERR	ERR